

AirWise: Collective Action for Clean Air

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University of Washington

Abstract

AirWise: Collective Action for Clean Air

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In the midst of contemporary global health challenges and the acknowledgment of the Anthropocene era, the intricate connection between human activities and planetary health is increasingly apparent (Schiff, 2022). The built environment plays a crucial role in shaping health outcomes, and this thesis focuses on the disparities exacerbated by air quality within urban settings. Utilizing Seattle, Washington as a case study, the research employs a place-conscious approach to unveil the unequal distribution of environmental risks and harms, particularly affecting marginalized communities. Applying a health equity framework, the study progresses through phases of exploration, localization, strategy development, and communication, with the aim of providing actionable design interventions to mitigate health inequities (Peterson et al., 2020). The thesis integrates methods of a comprehensive literature review, GIS mapping, field photography, and case study analysis to inform design typologies tailored to address specific determinants of air quality-related health impacts. The research not only illustrates disparities through the lens of air quality, but also serves as a practical guide for designers and communities, emphasizing the transformative potential of health equity-driven design interventions in fostering healthier and more equitable urban environments.



AirWise

COLLECTIVE ACTION FOR CLEAN AIR

DAQUAN PROCTOR

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CONTENTS

01 INTRODUCTION

FRAMING (8)

APPROACH (9)

METHODOLOGY (10)

02 DETERMINANTS OF HEALTH

HEALTH EQUITY (13)

ENVIRONMENTAL JUSTICE (14)

SOCIAL DETERMINANTS OF HEALTH (16)

NEIGHBORHOOD + BUILT ENVIRONMENT (17)

AIR QUALITY (18)

03 SEATTLE - A CASE STUDY

PERSISTING LEGACIES OF DISPARITY (25)

04 AIR QUALITY IN WASHINGTON

AIR QUALITY TRENDS OVER TIME (33)

AIR QUALITY ACROSS SCALES (35)

OVERBURDENED COMMUNITIES
HIGHLY IMPACTED BY AIR POLLUTION (39)

05 AIRWISE DESIGN GUIDE

HEALTH EQUITY DESIGN FRAMEWORK (54)

GROUNDING COMMUNITY INITIATIVES (56)

BUILT ENVIRONMENT CHALLENGES
TO OPPORTUNITIES (61)

PUBLIC OPEN SPACE -
INDUSTRIAL / CONSTRUCTION (63)

RESIDENTIAL - INDUSTRIAL (78)

RESIDENTIAL - CIVIC / COMMERCIAL (85)

RESIDENTIAL - TRANSPORTATION (100)

AIR QUALITY INTERVENTION
SUMMARY AND APPLICATIONS (115)

06 REFLECTIONS

REFLECTIONS AND CONCLUSIONS (117)

LIST OF FIGURES

FIG 1.1 Approach Diagram. (2024). Daquan Proctor

FIG 2.1 ETR's Health Equity Framework. (n.d.). ETR. <https://www.etr.org/about-us/health-equity-framework/>

FIG 2.2 Rev. Ben Chavis, right, raises his fist as fellow protesters are taken to jail at the Warren County PCB landfill near Afton, N.C. (1982). Greg Gibson/AP. <https://www.npr.org/2023/10/05/1198908047/climate-action-environmentalism-history>

FIG 2.3 Healthy People 2030 framework Social Determinants of Health Categories. (2024). Centers for Disease Control and Prevention. <https://www.cdc.gov/public-health-gateway/php/about/social-determinants-of-health.html>

FIG 2.4 Health Impacts of Air Pollution. (2023). European Environment Agency. <https://www.eea.europa.eu/en/topics/in-depth/air-pollution/eow-it-affects-our-health>

FIG 2.5 TRAP Health Outcomes. (2022). Boogarrrd et al. <https://www.sciencedirect.com/science/article/pii/S016041202200188X>

FIG 3.1 Early Duwamish Village. (n.d.). Duwamish Tribe. <https://www.duwamishtribe.org/history>

FIG 3.2 The results of the straightening and dredging of the Duwamish Rive. (1992). Duwamish Tribe. <https://www.duwamishtribe.org/history>

FIG 3.3 Redlining report. (1975). Seattle Municipal Archives. <https://www.seattle.gov/cityarchives/exhibits-and-education/online-exhibits/redlining-in-seattle>.

FIG 3.4 Seattle-Tacoma interurban streetcar, Kent. (1909). Photo by Asahel Curtis/MOHA. <https://www.historylink.org/File/9276>

FIG 3.5 Percent Below Poverty + No Health Insurance Maps. (2022). U.S. Census Bureau. <https://seattlecitygis.maps.arcgis.com/apps/MapSeries/index.html?appid=a447494df6e14dbba356963a9442834a>

FIG 4.1 Change in air quality by metro area, 2015 to 2021. (2023). Fitzpatrick et al. <https://www.axios.com/local/seattle/2023/04/27/seattle-air-pollution-rises>

FIG 4.2 Satellite image of wildfire smoke over the Salish Sea airshed in 2018. (2021). U.S. Environmental Protection Agency. <https://www.epa.gov/salish-sea/air-quality>

FIG 4.3 Sources of Greenhouse Gases In King, Kitsap, Pierce and Snohomish Counties (2015). (2022). Puget Sound Clean Air Agency. <https://pscleanair.gov/DocumentCenter/View/3328/PSCAA-GHG-Emissions-Inventory>

FIG 4.4 Washington Department of Ecology King County Air Emission Inventory. (2024). Adapted from the Washington State Department of Ecology. Daquan Proctor.

FIG 4.5 South Seattle / Duwamish Valley Emission Sources Conceptual Section. (2024). Daquan Proctor.

FIG 4.6 Flowchart of the process to identify overburdened communities highly impacted by air pollution. (2022). Washington State Department of Ecology. <https://storymaps.arcgis.com/stories/814b223ee0d14ff38e90feb90f8978d0>

FIG 4.7 Overburdened Communities Highly Impacted by Air Pollution. (2023). Washington State Department of Ecology. <https://storymaps.arcgis.com/stories/c10bdbfc69984a9d85346be1a23f6338>

FIG 4.8 Overburdened Communities Highly Impacted by Air Pollution Land Use Trends. (2024). Daquan Proctor.

FIG 4.9 South Seattle Land Use Trends. (2024). Daquan Proctor.

FIG 4.10 Identified Land Use Mix Conditions. (2024). Daquan Proctor.

FIG 4.11 Public Open Space - Industrial Transportation Site Map. (2024). Daquan Proctor.

FIG 4.12 Public Open Space - Industrial Transportation Field Observations. (2024). Daquan Proctor.

FIG 4.13 Residential - Industrial Site Map. (2024). Daquan Proctor.

FIG 4.14 Residential - Industrial Field Observations. (2024). Daquan Proctor

FIG 4.15 Residential - Civic / Commercial Site Map. (2024). Daquan Proctor.

FIG 4.16 Residential - Civic / Commercial Field Observations. (2024). Daquan Proctor.

FIG 4.17 Residential - Transportation Site Map. (2024). Daquan Proctor.

FIG 4.18 Residential - Transportation Field Observations. (2024). Daquan Proctor.

FIG 4.19 Documented Built Environment Challenges to Achieving Clean Air. (2024). Daquan Proctor.

FIG 5.1 In a Glimpse: Duwamish Valley Clean Air Action Plan. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/clean-air-program>.

FIG 5.2 Clean Air Action Plan Progress. (n.d.). Duwamish River Community Coalition <https://www.drcc.org/clean-air-program>.

FIG 5.3 DVYC Members Collecting Moss Sample. (2021). Duwamish River Community Coalition. <https://www.drcc.org/moss-study>.

FIG 5.4 DVYC Members Preparing Moss Samples for Analysis. (2021). Duwamish River Community Coalition. <https://www.drcc.org/moss-study>.

FIG 5.5 DVYC Advertising Neighborhood Tree Giveaway. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/duwamish-valley-youth-corps>

FIG 5.6 DVYC Members During Tree Planting Initiative. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/duwamish-valley-youth-corps>

FIG 5.7 Box Fan Filter Community Education Event. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/clean-air-program>.

FIG 5.8 DAISY Community Advocacy Team Members. (n.d.). Duwamish River Community Coalition. <https://deohs.washington.edu/edge/>

FIG 5.9 DVYC Engagement Event at the Georgetown Steamplant. (n.d.). Reconnect South Park. <https://reconnectsouthpark.org/rsp-media>.

FIG 5.10 Reconnect South Park Community Engagement Event. (n.d.). Reconnect South Park. <https://reconnectsouthpark.org/rsp-media>.

FIG 5.11 Air Quality Built Environment Challenges to Opportunities. (2024). Daquan Proctor

FIG 5.12 Publix Open Space - Industrial / Transportation Existing Condition. (2024). Daquan Proctor.

FIG 5.13 Public Open Space - Industrial / Transportation Proposed Interventions. (2024). Daquan Proctor.

FIG 5.14 Open Road Context Responsive Planting Intervention Diagram. (2024). Daquan Proctor

FIG 5.15 Air Filtration Plant Selection Intervention Diagram. (2024). Daquan Proctor

FIG 5.16 Topographic Buffer Intervention Diagram. (2024). Daquan Proctor.

FIG 5.17 Continuous Planting Buffer Intervention Diagram. (2024). Daquan Proctor.

FIG 5.18 Air Filtration Tower Intervention Diagram. (2024). Daquan Proctor.

FIG 5.19 Depaving + Revegetation Intervention Diagram. (2024). Daquan Proctor.

FIG 5.20 Permeable Paving Intervention Diagram. (2024). Daquan Proctor.

FIG 5.21 Residential - Industrial Existing Conditions. (2024). Daquan Proctor.

FIG 5.22 Residential - Industrial Proposed Interventions. (2024). Daquan Proctor.

FIG 5.23 Shallow Canyon Context Responsive Planting Intervention Diagram. (2024). Daquan Proctor.

FIG 5.24 Separated Transportation Lanes Intervention Diagram. (2024). Daquan Proctor.

- FIG 5.25** Urban Canopy Expansion Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.26** Residential - Civic / Commercial Existing Conditions. (2024). Daquan Proctor
- FIG 5.27** Residential - Civic / Commercial Proposed Interventions. (2024). Daquan Proctor.
- FIG 5.28** Climate Adaptive Planting Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.29** Superblock Streets Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.30** Green Screen Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.31** Avenue Canyon Context Responsive Roadside Planting Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.32** Multimodal Connectivity Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.33** Traffic Management Optimization Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.34** Mixed Use / Complete Communities Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.35** Residential - Transportation Existing Conditions. (2024). Daquan Proctor.
- FIG 5.36** Residential - Transportation Proposed Interventions. (2024). Daquan Proctor.
- FIG 5.37** Filtered Natural Ventilation Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.38** Envelope Airtightness / Weatherization Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.39** Healthy Materials Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.40** Air Purifier / Air Filter Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.41** Photocatalytic Paving Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.42** Median Context Responsive Roadside Planting Intervention Diagram. (2024). Daquan Proctor.
- FIG 5.43** Physical Barrier Intervention Diagram. (2024). Daquan Proctor.
- FIG 6.1** AirWise Community Exhibit Opening Event. (2024). Daquan Proctor.
- FIG 6.2** Daquan Proctor posing with AirWise Exhibit. (2024). Daquan Proctor.

LIST OF TABLES

- TABLE 2.1** International Freight Emissions by Freight Type. (2021). Data from the International Transport Forum.
- TABLE 4.1** Washington Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants. (2024). Data from the U.S, Environmental Protection Agency.

01 INTRODUCTION

FRAMING

In the context of contemporary global health challenges, climate crises, and the declaration of the Anthropocene as the sixth mass extinction, an undeniable entanglement of human actions and planetary health emerges (Schiff, 2022). The built environment serves as the medium through which humans experience and interact with the world and each other. Beyond buildings and infrastructure, the built environment encompasses the managed, altered, and constructed landscapes and natural systems that surround us (Moffatt & Kohler, 2008, p. 249-250). Moreover, even areas traditionally perceived as wild and untouched are imprinted with human influence (Schiff, 2022). Indigenous peoples, stewards of these landscapes since time immemorial, have played a crucial role in shaping and preserving their ecological integrity. Yet, the interconnected nature of our world means that even these seemingly remote and pristine areas are impacted by activities emanating from distant development.

Recognizing the feedback loop between human actions, the built environment, and health underscores the need for conscientious and deliberate interventions in urban development that alter the existing relationships with land and wellbeing.

Grounded in theoretical frameworks such as Environmental Justice (Mohai et al., 2009), Social Determinants of Health (CDC, n.d.), and Healthy Cities (World Health Organization, 2020), this thesis sets out to comprehend the intricate forces influencing health disparities both globally and locally. In developing a comprehensive understanding of health disparities through a range of determinants explored in the literature review, this thesis hones in on air quality as the primary focus for further development of design strategies. The World Green Building Council (WGBC) reported that “91% of the world’s population, urban and rural, breathe air that exceeds WHO guidelines for key pollutants” and that “Air pollution is the largest environmental killer, with approximately 8 million deaths annually” (WGBC, n.d.).

The reality is that risk, exposure, and harms from the built environment are not equitably distributed spatially or demographically (Mohai et al., 2009, 411-415). The interplay of power differentials and intentional socioeconomic marginalization results in uneven exposure to environmental risks and harm.

Consequently, minority and low-income communities face higher levels of vulnerability, and are disproportionately burdened by the adverse impacts of the built environment. In order to engage with and comprehend these global issues and overarching concepts in a place-conscious approach (Turner & O’Brien, 2021), this thesis is grounded in Seattle, Washington as a local case study, facilitating an in-depth exploration of the intersections between health equity (Peterson et al., 2020) and the role of design in fostering well-being (Markovich et al., 2018). By analyzing the specific dynamics of Seattle, this research aims to unearth valuable insights and applicable strategies that can span geographies, contributing to a broader discourse of creating healthier, more equitable environments.

In the Emerald City, a narrative unfolds revealing the stark health disparities shaped by the city’s urban fabric, notably Seattle’s poorest and most diverse communities co-located with the city’s most harmful infrastructure and outputs (Abel & White, 2011). This thesis aims to tackle these disparities by presenting evidence-based design strategies selected to improve targeted environmental conditions and health outcomes (Pati, 2011). The thesis document, accompanied by a supporting air quality design guide, serves as a practical resource for designers, stewards, and residents of the built environment. The guide advocates for targeted design interventions, deployable at a community scale, to promote accessible and actionable strategies for fostering healthier environments.

The literature review and GIS mapping reveal a robust correlation between air quality and respiratory disease, accentuated by the intricate dynamics of South Seattle where a mix of diverse and layered sources contribute to compromised air quality. This targeted exploration aims to identify region-specific factors, shaping and shaped by air quality, and develop responsive design typologies for healthier air. I envision a broader initiative of developing strategies targeting the entire spectrum of built environment determinants of health; however, for the purpose of this thesis, the scope is narrowed to local sources of air pollution with the greatest impact on air quality and potential for community-led design interventions.

APPROACH

This research employs a health equity framework, integrating Environmental Justice (Mohai et al., 2009), Social Determinants of Health (CDC, n.d.), and Healthy Cities (World Health Organization, 2020) theories to examine the relationships between the built environment and health outcomes in marginalized communities in Seattle. This theoretical framework serves as the guiding force throughout the research, from influencing source selection in the literature review, to criteria for mapping, to the design framework for proposed health equity design strategies. This thesis unfolds across four fluid phases as illustrated in Figure 1.1: Phase 1 engages in an in-depth exploration of built environment factors impacting health equity; Phase 2 involves the localization and spatialization of findings specifically tailored to the context of Seattle; Phase 3 is dedicated to developing strategies and recommendations that support health equity; and Phase 4 revolves around the effective communication of findings in a visually compelling and accessible manner.

The mission of this thesis extends beyond academia, as it is distilled into the Air Quality Design Guide. Integrated into Chapter 5. Air Quality Design Strategies, the design guide adopts a graphically focused approach and utilizes accessible language to effectively communicate with a broader community audience. By providing this dual-layered presentation, the research aims to bridge the gap between academic discourse and practical community applications, fostering a broader understanding of health equity in the built environment.

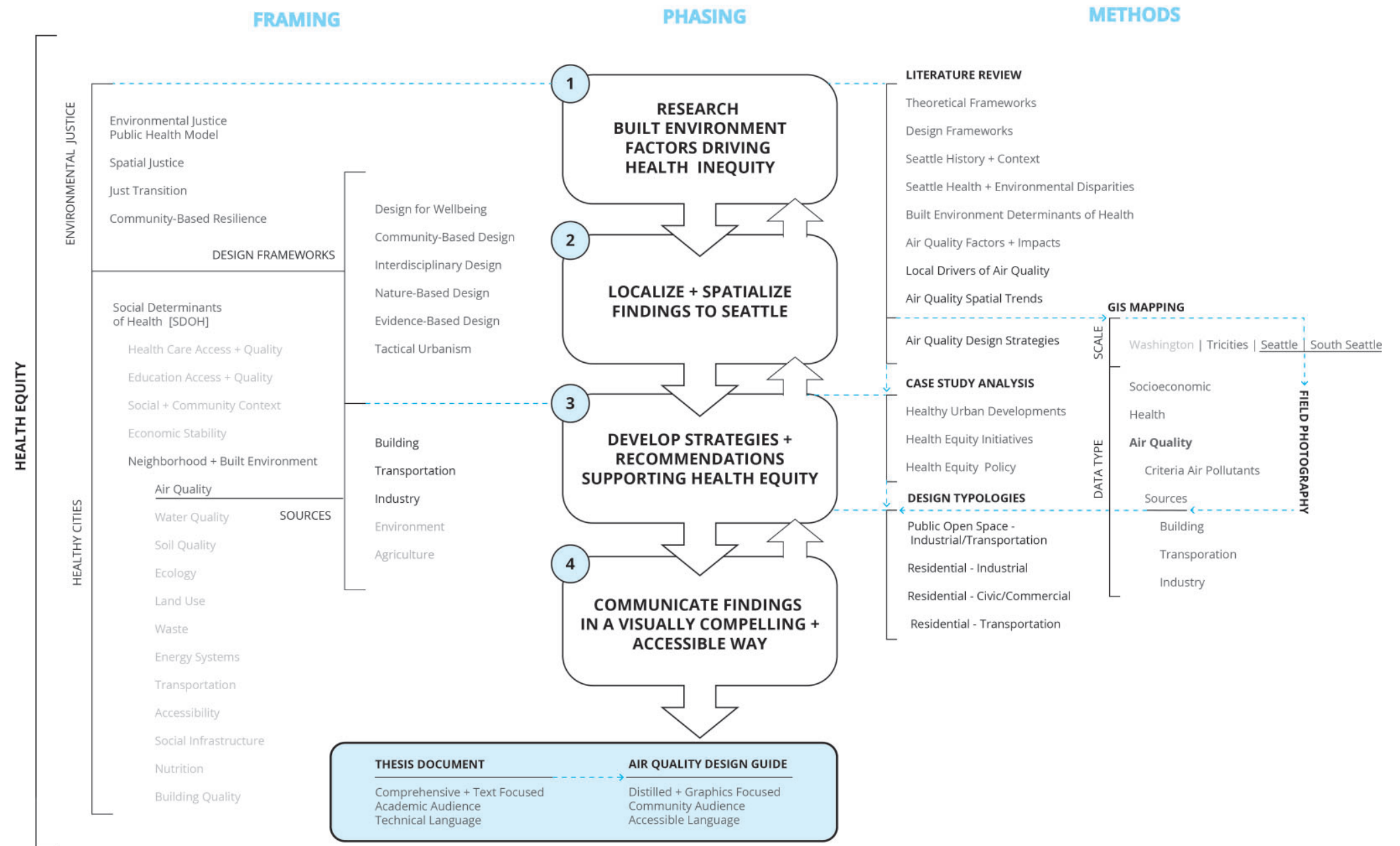


FIG 1.1 Approach Diagram. (2024). Daquan Proctor
This graphic illustrates the guiding framework, phasing, proposed methods and deliverables of "AirWise: Collective Action for Clean Air"

METHODOLOGY

The methodology employed for this exploration embraces a multifaceted approach. A thorough literature review dives into theoretical frameworks, air quality factors, and potential intervention strategies. GIS mapping is utilized to contextualize data and identify spatial trends. Field photography adds an experiential and qualitative dimension to the research, while case study analysis summarizes best practices and identifies potential intervention opportunities. Design typologies serve as a pivotal link, translating the research findings into implementable design strategies that are actionable at a community scale.

Literature Review

The literature review, integrated throughout the upcoming chapters, begins by exploring determinants of health with a specific focus on the built environment and its impact on health outcomes. The research employs a network of theoretical frameworks, starting with broad public health frameworks of health equity and narrowing down to specific theories that highlight the interconnected relationship between the built environment, air quality, and health outcomes.

The research utilizes Seattle as a place-based case study, examining historical and contemporary factors that contribute to health disparities. Factors such as settler colonialism, industrialization, racially predatory practices, transportation policies, and disinvestment are analyzed for their enduring impact on health outcomes and differences in longevity. The chapter highlights how these factors have resulted in persistent spatial inequalities, environmental degradation, and social fragmentation, disproportionately affecting communities of color and low-income neighborhoods.

Additionally, the literature review investigates air quality trends in Washington state, with a particular emphasis on Seattle. The study explores how proximity to major transportation corridors and industrial facilities disproportionately impacts overburdened communities, especially communities of color and low-income neighborhoods.

By examining local dynamics and the specific factors driving air quality trends, the research aims to shed light on the significant health disparities faced by these communities and the need for targeted interventions to address these environmental injustices. The literature review concludes with an analysis of relevant case studies and research articles related to air quality interventions. Through this comprehensive literature analysis, the study aims to establish a robust health equity design framework and inform a toolkit of evidence-based design strategies. This framework examines the relationship between the built environment and health outcomes, providing a structured approach to integrating health equity considerations into the planning, design, and implementation of built environment interventions.

GIS Mapping

Geographic Information System (GIS) Mapping facilitates the translation of insights from the literature review into the specific context of Seattle. GIS has the ability to reveal relationships not apparent from analyzing numerical data alone. For example, the study “Assessing Evidence of Environmental Inequities: A Meta-Analysis” found that research utilizing GIS distance-based methods reveal more significant racial and socioeconomic inequalities in how environmental hazards are distributed compared to studies relying solely on census tracts or zip code areas (Ringquist, 2005). Specifically, distance-based approaches demonstrate stronger associations between race and the location of environmental hazards than income.

GIS is employed in this thesis through mapping datasets sourced from state, county, and city geospatial open data portals, aligning them with the identified relationships and trends between built environment factors and health outcomes identified in the literature. For example, “Race, Class and Environmental Health: A Review and Systematization of the Literature” a synthesis of data on race and class disparities in air pollution found that “there was a clear race difference. Class differences were smaller” (Brown, 1995, p. 20). By overlaying local datasets of factors such as the percentage of people of color, annual income, or percentage below the poverty line with indicators of air quality such as the air quality index or specific criteria air pollutants like PM2.5, the GIS mapping process allows for an examination of how these variables intersect spatially and potentially corroborate or challenge existing research findings.

Furthermore, GIS mapping enables the visualization of spatial patterns and disparities, providing a comprehensive understanding of how built environment factors contribute to health outcomes across different neighborhoods and demographic groups within Seattle. This spatial analysis empowers researchers to identify areas of concentrated environmental burdens and health disparities, guiding the development of targeted interventions and policy recommendations. By integrating GIS mapping into the methodology, this research seeks to bridge the gap between theoretical insights and practical applications, ultimately fostering evidence-based decision-making for promoting health equity in Seattle's built environment.

Field Photography

Field photography is complementary to the predominantly quantitative data and literature analysis, offering qualitative and experiential insights that enrich the narrative on built environment health disparities in Seattle. By capturing images of built environment factors, identified through literature review and GIS mapping as significant for impacting local air quality, field photography provides a firsthand visual and experiential understanding of the environmental context. These photographs not only add depth to the narrative but also offer nuanced details about spatial conditions that cannot be derived from data alone, such as the condition of neighborhood infrastructure, and the presence of undocumented environmental stressors. Moreover, field photography contributes to the development of design typologies by providing a tangible reference point for understanding existing conditions and informing the creation of interventions aimed at improving health equity. This interdisciplinary approach ensures that urban design and planning initiatives are rooted in the lived experiences of communities, promoting more effective and contextually sensitive interventions to address built environment health disparities.

Case Study Analysis

As the project progresses into subsequent phases, its focus undergoes a transformative shift toward developing strategic interventions within the built environment to address prevailing health disparities. This transition is marked by an analysis of case studies sourced from a diverse range of global and local contexts.

Through examination of these case studies, the project endeavors to identify valuable insights, lessons, and best practices that can guide the development and implementation of targeted interventions tailored to the unique challenges faced by the Seattle region.

These case studies serve as more than just illustrative examples; they act as dynamic narratives that showcase to community members and designers alike how interventions can be implemented and the impact they can have on community well-being and health outcomes. Through the lens of these case studies, stakeholders are empowered to envision and enact contextually appropriate solutions that address the complex factors contributing to health disparities.

Design Typologies

At the core of this thesis is a design exploration aimed at translating research findings into tangible, actionable design solutions within the built environment. This exploration is a conscientious effort to address entrenched health disparities and environmental injustices, particularly within the Duwamish Valley and South Seattle communities.

The objective of this design exploration seeks to catalyze real-world change by proposing innovative and adaptable design typologies. By leveraging insights from the overarching theoretical framework and the more specific health equity design framework outlined in Chapter 5, these typologies are crafted to address the multifaceted complexities and scales of built environment health disparities.

Grounded in principles of health equity and environmental justice, they represent a fusion of theoretical understanding and practical applicability, to transform the urban landscape in impactful ways. By integrating these typologies into the fabric of urban planning and development, the project aspires to pave the way for transformative change, not only within the Duwamish Valley and South Seattle but in cities around the world grappling with similar challenges.



02

DETERMINANTS OF HEALTH

This chapter reviews existing literature on built environment determinants of health, offering insights into various factors that contribute to health outcomes. It specifically focuses on air quality as a predominant built environment determinant of health

“AirWise: Collective Action for Clean Air” employs a network of theoretical frameworks, initially drawing from broad public health frameworks of health equity and progressively narrowing its focus to specific theories and research that reveal the interconnected relationship between the built environment and health outcomes. This synthesis establishes a crucial link between health equity discourse and the built environment. Through outlining these theoretical frameworks, the research aims to lay a robust foundation that not only comprehensively explores the complexities of health disparities but also sheds light on the intricate ways in which the built environment acts as a determinant of health outcomes. This theoretical framework, therefore, forms an essential lens through which subsequent phases of the study will unravel and address the layered forces contributing to health disparities within the context of Seattle.

HEALTH EQUITY

Public health non-profit Education, Training and Research (ETR) is dedicated to advancing health equity and developed a health equity model, outlined in the article “The Health Equity Framework: A Science- and Justice-Based Model for Public Health Researchers and Practitioners”. This article defines health equity as “having the personal agency and fair access to resources and opportunities needed to achieve the best possible physical, emotional, and social well-being” (Peterson et al., 2020). Health inequities arise from an inability to attain health, stemming from unequal access to resources and opportunities shaped by social, economic, and environmental conditions. This model was developed in response to criticism that existing public health approaches are ineffective at reducing health inequities because they ignore the systemic forces driving disparity. The article contends that conventional public health models, which emphasize individual-level strategies for increasing health-promoting behaviors, fail to address upstream determinants preventing individuals and communities from achieving optimal health. ETR’s Health Equity Framework centers population-level health outcomes to intentionally shift the scale of forces being investigated and targeted for intervention. This model, illustrated in Figure 2.1, identifies four factors influencing health equity: physiological pathways, systems of power, relationships and networks, and individual factors.

ETR’s Health Equity Framework.

Health and education outcomes are influenced by complex interactions between people and their environment.



FIG 2.1 ETR’s Health Equity Framework. [n.d.]. ETR. <https://www.etr.org/about-us/health-equity-framework/>
This graphic illustrates the four “spheres of influence” influencing health and education outcomes

While all four factors exert influence over health outcomes, this thesis centers on investigating the built environment’s impact on health, placing physiological pathways at the forefront. The author defines physiological pathways as a “person’s biological, physical, cognitive, and psychological abilities” which when impaired by environmental and experiential factors can increase health inequities (Peterson et al., 2020). Physiological pathways also consider how the timing and intensity of other health determinants impact developmental, biological, and cognitive outcomes. ETR provided guidance for applying physiological pathways in practice, one recommendation that resonated with this thesis was to consider “how interventions can maximize and support the resilience of physiological functions and abilities after exposure”.

This recommendation could be refined into the following guiding research question:

How can interventions maximize and support the resilience of physiological functions and abilities before, during, and after exposure to environmental stressors?

Nevertheless, the examination of the other factors gains relevance when viewed through the lens of physiological pathways. Systems of power can illuminate a history of disenfranchisement and the unequal distribution of harmful and beneficial stressors. Relationships and networks may relate to concepts of community resilience and advocacy around shifting existing dynamics affecting physiological health. Individual factors may align with strategies at the personal or household level to mitigate exposure to harmful conditions and increase access to beneficial factors.

ENVIRONMENTAL JUSTICE

Expanding upon the established theoretical foundation, the integration of environmental justice theory serves to further contextualize concepts of systems of power and structural inequity in reference to environmental disparities. The Annual Review of Environment and Resources journal published the article “Environmental Justice” that synthesizes two decades of Environmental Justice discourse, featuring notable scholars including Paul Mohai, David Pellow, and J. Timmons Roberts (Mohai et al., 2009).

Through the lens of environmental justice theory, historical disenfranchisement and unequal distribution of detrimental and beneficial health determinants can be examined within marginalized communities, specifically concerning the built environment’s impact on health. Environmental justice was born out of the environmental racism political and academic movement, which gained national attention during the 1982 civil rights protest (Figure 2.2) to stop the state of North Carolina from dumping 120 million pounds of PCB-contaminated soil in a landfill in Warren County, which had the highest percentage of Black residents in the state. This movement reshaped national perceptions around the equity of environmental risks, resulting in environmental justice emerging as a movement with “hundreds of studies concluding that, in general, ethnic minorities, indigenous persons, people of color, and low-income communities confront a higher burden of environmental exposure from air, water, and soil pollution resulting from industrialization, militarization, and consumer practices” (Mohai et al., 2009, 406).



FIG 2.2 Rev. Ben Chavis, right, raises his fist as fellow protesters are taken to jail at the Warren County PCB landfill near Afton, N.C. (1982). Greg Gibson/AP. <https://www.npr.org/2023/10/05/1198908047/climate-action-environmentalism-history>

The first national-level study of community demographics adjacent to hazardous waste sites, “Toxic Wastes and Race in the United States,” revealed that the racial composition of a community emerged as the predominant factor influencing the location of toxic waste sites (United Church of Christ Commission for Racial Justice, 1987). The findings showed that, in comparison to zip codes without toxic waste sites, communities with one or two waste sites had an average percentage of people of color that was two to three times higher respectively. Subsequent studies and meta-analyses consistently supported these findings; “Race, Class and Environmental Health: A Review and Systematization of the Literature,” synthesized 54 separate studies, concluding that race and class were the primary determinants of proximity to environmental hazards, alongside considerations of the timing and extent of remediation efforts (Brown, 1995).

More recent studies include “Assessing Evidence of Environmental Inequities: A Meta-Analysis” reviewing 49 quantitative studies to validate claims that environmental hazards are inequitably distributed based on race and socioeconomic factors, concluding “there is ubiquitous evidence of environmental inequities based upon race” (Ringquist, 2005, 223). However, this review found that evidence for the claim of class-based disparities is weaker stating “while some environmental risks in some places may be concentrated in low-income areas, this result is not generalizable across areas and risk vectors” (Ringquist, 2005, 241). The findings from these seminal studies emphasize the significant influence of race and class on the distribution of environmental hazards, with well-documented disparities based on race and less conclusive evidence for class-based disparities.

With an extensive body of literature supporting the inequitable siting of environmental hazards, the “Chicken and the Egg” debate arose, questioning whether the hazardous facilities or marginalized communities were established first. The study “Which Came First? Toxic Facilities, Minority Move-In, and Environmental Justice” examined the relationship between minority residential communities and polluting facilities over thirty years in the Los Angeles Basin, identifying a pattern of polluting facilities being sited in existing communities of color rather than the inverse (Pastor et al., 2016). Another study “Historical Context and Hazardous Waste Facility Siting: Understanding Temporal Patterns in Michigan” examined fifty years of hazardous waste Treatment, Disposal, Storage Facility (TDSF) siting trends in Michigan, finding a pattern of locating hazardous waste facilities in minority and low income communities (Saha & Mohai, 2005). Interestingly this study found little evidence indicating disparities in hazardous facility siting prior to 1970, noting that these spatial disparities significantly increased in the 1970s and 1980s which coincides with rising public concerns surrounding environmental harms and hazardous waste. The study attributed the increase in disparities during this period to the greater ability of white communities to prevent hazardous land uses from being located in their neighborhoods, leading to a disproportionate diversion of such facilities to politically vulnerable minority and low-income communities. These works deepen the understanding of the inequitable distribution of environmental harms, revealing that such distributions result from deliberate siting of hazardous facilities in disenfranchised minority neighborhoods.

With the evolution of the Environmental Justice movement, its definition has changed with it; however, the Environmental Protection Agency (EPA) defines it in official policy as:

“The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate share of the negative human health or environmental impacts of pollution or environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local and tribal programs and policies” (Mohai et al., 2009, p. 407)

Despite the considerable efforts of the EPA, and various other governmental agencies and community organizations in advancing environmental justice and mitigating environmental harms, disparities persist and are further exacerbated by the impacts of climate change. “Climate change reflects and increases social inequality in a series of ways, including who suffers most its consequences, who caused the problem, who is expected to act, and who has the resources to do so” (Mohai et al., 2009). Climate change disproportionately affects marginalized communities who often lack the resources to mitigate its impacts or adapt to changing conditions. Historical social divisions perpetuate unequal access to adaptive and resilience resources, as seen in disparities in the aftermath of disasters such as Hurricane Katrina. This ongoing inequity emphasizes the need for concerted efforts to address both environmental justice and climate change simultaneously, recognizing their interconnectedness and the need for inclusive solutions.

SOCIAL DETERMINANTS OF HEALTH

Incorporating insights from the health equity framework and an awareness of the sociopolitical dynamics shaping environmental disparities, the Social Determinants of Health (SDOH) framework aims to dive deeper into the interplay of social, economic, and environmental factors influencing health outcomes (CDC, n.d.). SDOH captures a broad spectrum of “non-medical determinants” that significantly impact individuals and community health outcomes. These factors are connected with larger societal dynamics and systems, including economic policies, cultural norms, political structures, and development practices. Recognizing the importance of addressing SDOH, initiatives such as Healthy People 2030 have integrated them into their health indicators, emphasizing the urgency of creating social, physical, and economic environments conducive to achieving optimal health and well-being for all individuals. This entails ensuring that everyone has an equitable opportunity to attain their highest level of health by removing barriers such as poverty and discrimination, including power imbalances and inadequate access to essential resources like education, employment, housing, and healthcare.



FIG 2.3 Healthy People 2030 framework Social Determinants of Health Categories. (2024). Centers for Disease Control and Prevention. <https://www.cdc.gov/public-health-gateway/php/about/social-determinants-of-health.html>

SDOH includes a range of factors grouped into five categories within the Healthy People 2030 framework (Figure 2.3):

Economic Stability: The link between financial resources and health, including income, cost of living, and socioeconomic status, impacting poverty, employment, food security, and housing stability.

Education Access and Quality: The link between education and health and well-being, including factors like high school graduation rates, enrollment in higher education, educational achievements, language skills, literacy levels, and early childhood education and development.

Social and Community Context: How community characteristics affect health, including community cohesion, civic participation, discrimination, cultural norms, interpersonal violence, workplace conditions, immigration status, and incarceration.

Healthcare and Quality: The connection between healthcare access and understanding, including access to healthcare services, primary care, health insurance, and health literacy.

Neighborhood and Built Environment: How living conditions impact health, such as housing quality, transportation access, availability of healthy foods, water and air quality.

Contextualizing social determinants of health, neighborhood and built environment emerges as particularly relevant to this thesis. The neighborhood and built environment exert a large influence on health outcomes, encompassing a spectrum of factors that extend far beyond physical infrastructure. Housing quality, for instance, encompasses not just the structural integrity of buildings but also considers factors like exposure to environmental hazards such as lead or mold, which can significantly impact respiratory health and overall well-being. Accessibility and transportation is another critical aspect, as it determines individuals' ability to reach essential services like healthcare facilities or grocery stores, thereby shaping their access to resources necessary for maintaining good health. Additionally, the availability of and proximity to healthy foods within neighborhoods plays a pivotal role in shaping nutritional intake and influencing rates of diet-related diseases such as obesity and diabetes.

Environmental integrity directly impacts human health, as evidenced by the significant influence of water and air quality on physical well-being. Poor-quality water sources present contamination risks, while air pollution contributes to respiratory ailments and cardiovascular diseases. This understanding of the neighborhood and built environment as determinants of health underscores the interconnectedness of environmental factors in shaping individual and community well-being. Importantly, it emphasizes that health outcomes are not solely determined by individual choices but are profoundly influenced by the contexts in which individuals live and operate. Recognizing this, interventions and policies aimed at improving health equity must extend beyond addressing individual behaviors to tackle the structural determinants embedded within the built environment. By intentionally designing neighborhoods and built environments to prioritize health equity and foster supportive, inclusive communities, it becomes possible to intervene and create environments that promote optimal health and well-being for all individuals.

NEIGHBORHOOD + BUILT ENVIRONMENT

Neighborhoods play a critical role in shaping individual and community health and well-being, influenced by various localized social and built environment factors. Studies, such as “Poverty Area Residence and Changes in Physical Activity Level: Evidence From the Alameda County Study”, have underscored the independent impact of neighborhood characteristics on mortality rates, with residence in a poverty area being associated with an approximately 50% increased risk of premature mortality emphasizing the necessity of considering these factors alongside individual health characteristics (Yen & Kaplan, 1998, 1709). The social environment within neighborhoods include a diverse array of socioeconomic factors, community support networks, and levels of disorder, all of which contribute to residents’ health outcomes (Gomez et al., 2015). Additionally, the built environment encompasses structural attributes like walkability, access to health-promoting resources, and the prevalence of undesirable amenities such as fast food restaurants, which further define individuals’ opportunities for health promotion and well-being. Concerns surrounding public health inequities necessitate assessing how neighborhood environments, including both social and built aspects, are addressed in research and improvement initiatives.

The influence of neighborhoods on health extends beyond their social and physical structure, encompassing a broader spectrum of health and safety risks confronted by residents. Issues such as environmental conditions like polluted air, extreme heat, contaminated water, and challenges related to access to healthy foods and quality housing all contribute significantly to health disparities within communities (Child Welfare League of America, n.d.). Racial minorities and individuals with low incomes disproportionately bear the burden of these risks, exacerbating systemic inequalities and perpetuating cycles of ill health. For instance, housing quality is affected by characteristics like a home’s design and age with factors including air quality, space per individual, and the presence of mold, asbestos, or lead having a direct impact on mental and physical health. Low-income families are more likely to live in substandard housing, facing challenges such as increased risk of water leaks associated with mold growth, which has been shown to affect respiratory health and increase the likelihood of asthma. Interventions and policy changes at various levels of scale are imperative to address these health risks and promote health equity across diverse communities. Collaborative approaches that engage community members, designers, planners, public health professionals, policymakers, and other stakeholders are essential in developing and implementing interventions that are contextually relevant and responsive to the unique needs of diverse neighborhoods.

In an effort to identify the primary determinants of health within the built environment, the following list aims to compile and categorize the main factors influencing health as documented in the literature. While not exhaustive, this list serves as a starting point to identify potential areas for intervention.

Air Quality: Poor air quality, characterized by high levels of pollutants such as particulate matter and nitrogen dioxide, can lead to respiratory diseases, cardiovascular issues, and exacerbation of existing health conditions (World Health Organization, n.d.).

Water Quality: Contaminated water sources can pose significant health risks, increasing the likelihood of gastrointestinal illnesses, waterborne infections, and long-term health effects from exposure to toxins and pollutants (Centers for Disease Control and Prevention, 2023).

Soil Quality: Soil contaminated with heavy metals, pesticides, or industrial chemicals can negatively impact human health through direct contact, ingestion, or inhalation, potentially leading to adverse effects on reproductive health, neurological development, and overall well-being (Agency for Toxic Substances and Disease Registry, 2015).

Ecology: Disruption of ecosystems and loss of biodiversity can have cascading effects on human health, including increased risk of infectious diseases, reduced access to clean water and food sources, and heightened vulnerability to natural disasters (United Nations, n.d.).

Land Use: Poorly planned land use, such as urban sprawl or industrial development near residential areas, can contribute to environmental hazards, compromised mental health due to lack of green spaces, and increased exposure to noise pollution and traffic-related accidents (Lindberg & Narayan, 2021).

Waste Systems: Inadequate waste management systems can lead to environmental pollution, contamination of air and water sources, and public health hazards from exposure to hazardous waste materials and pathogens (World Bank, 2019).

Energy Systems: Dependency on fossil fuels and inefficient energy systems contribute to air pollution, respiratory illnesses, and climate change-related health impacts such as heat-related illnesses and extreme weather events (Seddighi et al., 2023).

Transportation: Transportation infrastructure affects health through air pollution emissions, traffic accidents, physical inactivity due to car-dependent environments, and disparities in access to essential services for individuals with limited mobility or transportation options. (Centers for Disease Control and Prevention, 2014)

Accessibility: Neighborhood walkability and accessibility are crucial for promoting physical activity and social engagement for everyone, including individuals with disabilities. Inadequate infrastructure, such as a lack of sidewalks and accessible public transportation, can limit mobility, exacerbate social isolation, and lead to health disparities (Centers for Disease Control and Prevention, 2020).

Social Infrastructure: Strong social infrastructure, including community centers, social services, and support networks, fosters social cohesion, mental well-being, and resilience to stressors, while inadequate social infrastructure can lead to social isolation, poor mental health, and limited access to resources (Hutcheon & Steiner, 2022).

Nutrition: Access to nutritious food options influences overall health and well-being, with inadequate nutrition contributing to malnutrition, chronic diseases such as obesity and diabetes (World Health Organization, 2020).

Building Quality: Poor building quality, characterized by issues such as inadequate ventilation, moisture intrusion, and structural deficiencies, can lead to indoor air pollution, mold-related respiratory illnesses, and injuries from building collapses or accidents (US Department of Health and Human Services, n.d.).

AIR QUALITY

91% of the global population lives in areas where air pollution surpasses WHO guidelines for key pollutants (WGBC, n.d.). “Air pollution is the largest environmental killer”, claiming approximately 8 million lives each year. Out of these fatalities, 4.2 million are linked to outdoor air pollution, while 3.8 million result from indoor exposure to compromised air quality. The sources of air pollution are diverse, including both human-made and natural factors. Human activities such as vehicle emissions, industrial processes, and power generation contribute significantly to air pollution, alongside natural events like wildfires, dust storms, and volcanic eruptions. While the sources of air pollution are multifaceted and varied, several key indicators called criteria air pollutants are commonly employed to evaluate air quality more broadly (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2016) :

Carbon Monoxide (CO): Carbon monoxide is a colorless, odorless gas produced primarily by the incomplete combustion of fossil fuels in vehicles and industrial processes. Exposure to elevated levels of CO can lead to headaches, dizziness, nausea, and even death in severe cases due to its ability to interfere with the oxygen-carrying capacity of the blood .

Nitrogen Oxides (NOx): Nitrogen oxides are a group of gasses primarily emitted from vehicles, power plants, and industrial activities. They contribute to the formation of ground-level ozone and particulate matter, leading to respiratory issues such as asthma exacerbation, bronchitis, and cardiovascular problems.

Particulate Matter (PM10 and PM2.5): Particulate matter refers to tiny airborne particles of varying sizes, with PM10 and PM2.5 denoting particles smaller than 10 and 2.5 micrometers, respectively. Sources include vehicle emissions, industrial processes, and natural sources like dust and wildfires. PM exposure is associated with respiratory and cardiovascular diseases, lung cancer, and premature death.

Sulfur Dioxide (SO2): Sulfur dioxide is a gas primarily emitted from burning fossil fuels containing sulfur, such as coal and oil in power plants and industrial facilities. Inhalation of SO2 can cause respiratory issues like asthma exacerbation, bronchitis, and irritation of the eyes and throat.

Volatile Organic Compounds (VOCs): VOCs are a diverse group of organic compounds emitted from sources like vehicle exhaust, industrial processes, and chemical solvents. They can react with other pollutants to form ground-level ozone and contribute to the formation of particulate matter. VOC exposure is associated with respiratory irritation, headaches, nausea, and long-term exposure can lead to liver, kidney, or central nervous system damage.

Ammonia (NH3): Ammonia is a colorless gas emitted from agricultural activities, livestock operations, and vehicle emissions. It contributes to the formation of particulate matter and can lead to respiratory irritation, particularly in areas with intensive agricultural activities.

The health consequences of air pollution affect a variety of organ systems and contribute to numerous chronic diseases (Figure 2.4). Exposure to air pollution has been linked to respiratory stress, inflammation, and an increased risk of mortality (National Institute of Environmental Health Sciences, 2024). due to long-term exposure to air pollution. Moreover, disparities in air pollution exposure based on socioeconomic status and race highlight the need for targeted interventions to address environmental concerns.

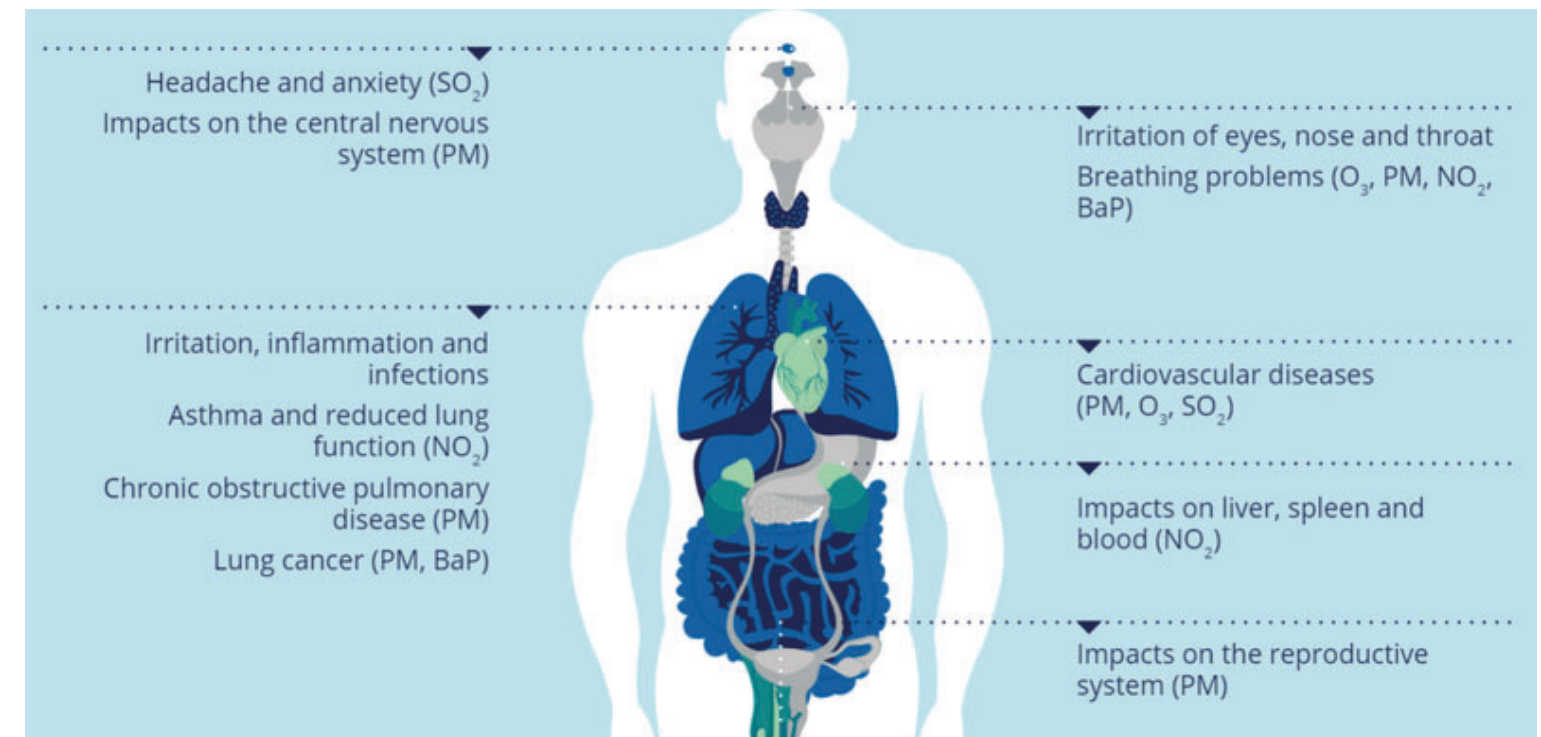


FIG 2.4 Health Impacts of Air Pollution. (2023).European Environment Agency. <https://www.eea.europa.eu/en/topics/in-depth/air-pollution/eow-it-affects-our-health>

The relationship between air pollution and climate change is complex, with both issues originating from similar sources such as fossil fuel combustion. This interconnectedness underscores the importance of addressing air pollution not only for human health but also for environmental sustainability. Efforts to improve air quality and reduce air pollution are essential for safeguarding public health and promoting overall well-being. Strategies such as implementing regulations on emissions, transitioning to cleaner energy sources, and investing in public transportation and green infrastructure can help mitigate the health impacts of air pollution. Community involvement and collaborative research approaches are also crucial for identifying local sources of pollution and implementing effective interventions to protect vulnerable populations and improve air quality for all.

Transportation Sources

Traffic-related air pollution (TRAP) exerts a significant impact on health and well-being. Unlike industrial or agricultural pollution, our transportation networks are intricately connected with residential neighborhoods, resulting in high concentrations of pollutants in close proximity to where people live, work, and recreate.

Our society's heavy reliance on personal vehicles and design of urban developments and infrastructure further worsen this problem and reinforce the interconnected relationship. Traffic-related air pollution poses major health risks to humans due to the emission of harmful pollutants such as nitrogen oxides, particulate matter, and volatile organic compounds from vehicles (Boggaard et al., 2022). These pollutants can penetrate deep into the respiratory system, leading to various health issues such as respiratory infections, exacerbation of asthma, cardiovascular diseases, and even lung cancer. Prolonged exposure to traffic-related air pollution has been linked to reduced lung function, increased susceptibility to respiratory illnesses, and higher mortality rates, particularly in vulnerable populations. Figure 2.5 provides an overview of the primary health effects linked to prolonged exposure to traffic-related air pollution, as evidenced by a meta-analysis examining 353 studies on "Long-term exposure to traffic-related air pollution and selected health outcomes".

The global economy heavily relies on freight transportation, which facilitates the movement of billions of tons of cargo annually via trucks, planes, ships, and trains (Greene, 2023). This sector accounts for 8% of worldwide greenhouse gas emissions, up to 11% when accounting for warehouses and ports. The vast majority of freight transportation still depends on oil and gas. If current trends persist, freight is projected to become the top emitting sector by 2050.

While ships carry nearly three-quarters of the world's cargo, road vehicles such as trucks and vans contribute to 65% of freight emissions. Ships, despite burning fossil fuels and emitting carbon, are highly efficient in moving large volumes of cargo, making them the most efficient mode of transportation. Conversely, road freight can emit over 100 times more CO2 than ships to transport the same amount of cargo over the same distance. The road transportation sector is rapidly expanding, with 80% of the global increase in diesel consumption attributed to trucks, driven in part by the rise of e-commerce and home delivery services. In addition to greenhouse gasses, freight transportation poses other climate concerns, notably the emission of over 20% of the world's black carbon by transportation equipment. Black carbon, a potent short-lived climate pollutant, is visible as black smoke emitted from truck tailpipes and can lead to severe health issues, particularly in communities near ports or affected by home delivery services.

Locomotives, predominantly running on diesel engines, emit harmful nitrogen oxides and particulate matter (Lazare, 2023). Despite EPA regulations categorizing locomotives into tiers based on emission standards, loopholes allow older dirtier locomotives to continue operating, with only gradual shifts toward cleaner technologies. Advocates push for stricter regulations and the adoption of zero-emission technologies to mitigate health risks and environmental impacts associated with rail transportation. Studies link diesel emissions to negative health outcomes, especially affecting communities near rail yards, which are often minority and low-income. The transition to electric locomotives is advocated to address these concerns despite persisting industry opposition.

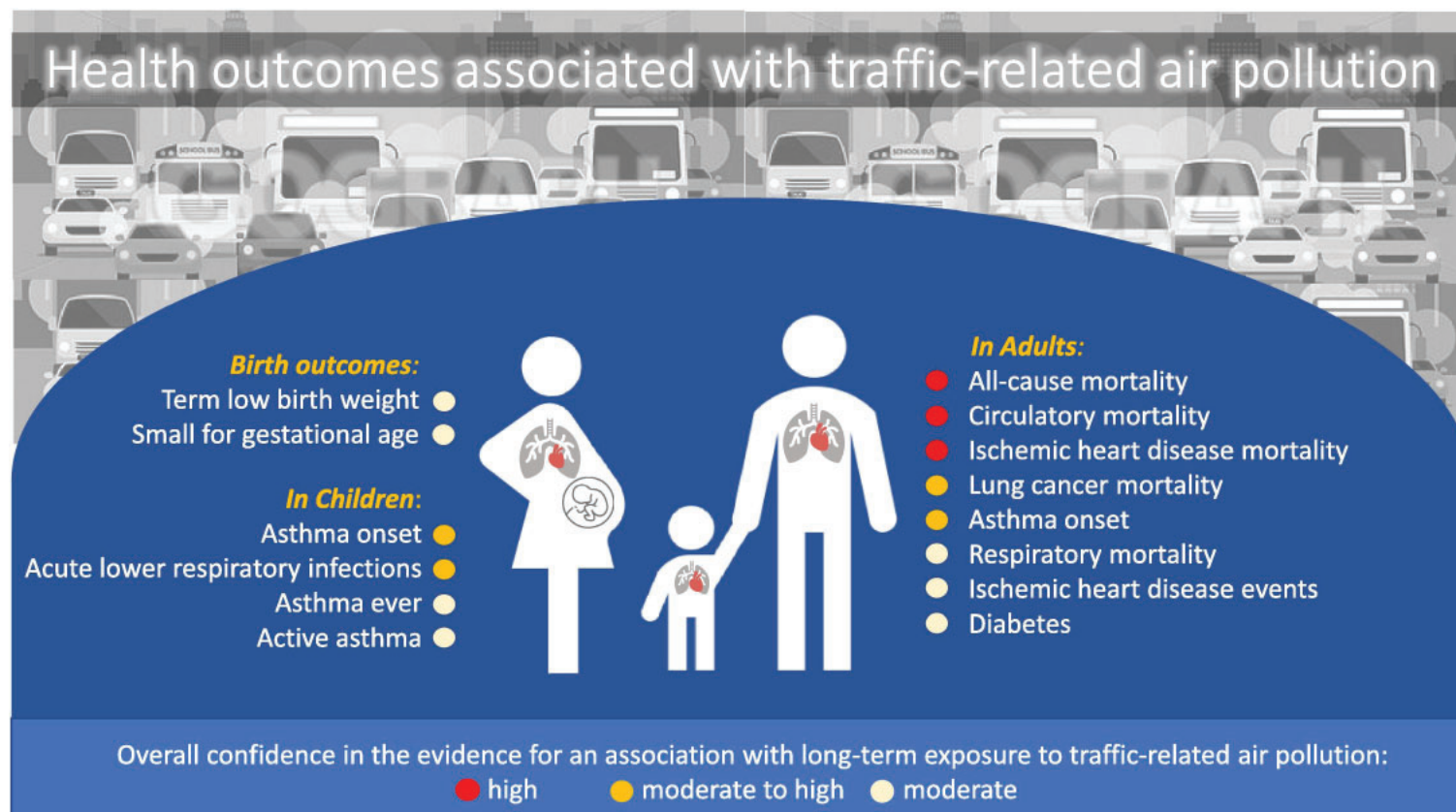


FIG 2.5 TRAP Health Outcomes. [2022]. Boogarrd et al. <https://www.sciencedirect.com/science/article/pii/S016041202200188X>
 This graphic illustrates the key health outcomes of long-term exposure to traffic-related air pollution documented in literature

Advancements in aircraft technology and operational efficiency led to a 77% reduction in the energy intensity of air travel in the United States (Overton, 2022). However, despite this progress, global carbon dioxide (CO2) emissions from commercial aviation have been steadily increasing, reaching 920 million tons in 2019, with the U.S. accounting for 23% of this total. While aviation's 2.4% share of total CO2 emissions may seem minor, its impact extends beyond CO2. Aircrafts emit ultrafine particulate matter small enough to reach the deepest parts of the lungs and even enter the bloodstream upon inhalation. These particles have been linked to respiratory diseases, cardiovascular problems, and other adverse health effects. Looking ahead, both passenger travel and air freight are expected to continue growing, potentially tripling commercial aircraft emissions by 2050. To mitigate these impacts, strategies such as sustainable biofuels and optimized flight planning are being explored, while acknowledging the significant contribution of ground operations to emissions and local air quality degradation. Table 2.1 summarizes and compares the annual amount of freight transported and CO2 emissions released for each freight transportation type.

FREIGHT TRANSPORT TYPE	AMOUNT OF FREIGHT MOVED (billions of tonne-kilometers)	CO2 EMISSIONS (millions of tonnes)
AIR	303	155
RAIL	10,842	170
ROAD	26,807	2,230
BOAT	101,486	657

TABLE 2.1 International Freight Emissions by Freight Type. (2021). Data from the International Transport Forum.

Construction + Building Sources

Buildings play a substantial role in outdoor air pollution, contributing to approximately 40% of global energy-related carbon emissions (WGBC, n.d.). Additionally, buildings emit other greenhouse gasses known as short-lived climate pollutants (SLCPs), including methane, hydrofluorocarbons, and black carbon which contribute to approximately 45% of current global warming. The construction process itself emits carbon and other pollutants, with brick production alone contributing to 20% of global black carbon emissions. Dust particles from construction, like hardwood or silica dust, are linked to serious health issues such as silicosis, asthma, and heart disease. The operational phase of buildings emits fine particles (PM2.5/PM10) from fuel combustion for heating, cooling, and lighting. Furthermore, the global supply chain involved in building construction, from excavation to transportation, adds to embodied emissions, emphasizing the need for sustainable practices throughout a building's life cycle.

Indoor air pollution is another major concern, with nearly 4 million deaths per year attributed to exposure to household air pollutants (WGBC, n.d.). Indoor air pollution stems from various sources, including poor ventilation leading to pollutant accumulation, release of gasses and chemicals from furnishings and household items, and the presence of toxic building materials like asbestos. Activities such as cooking, heating with solid fuels, smoking, and using VOC-releasing products for cleaning or decorating can further contribute to indoor pollutant levels. The use of traditional cookstoves, open fires or kerosene lamps for heating, cooking and lighting in homes, is responsible for up to 58% of black carbon emissions worldwide. Biological contaminants like mold and fungi, volatile organic compounds (VOCs) emitted from household products, and poor ventilation exacerbate indoor air quality issues. VOCs are emitted as gasses from various solids or liquids, posing potential health risks ranging from headaches and nausea to organ damage and suspected links to cancer. Indoor concentrations of many VOCs are consistently higher than outdoor levels, ranging from ten to a thousand times higher. These compounds originate from everyday products such as paints, sprays, cleaning supplies, and building materials.

The relationship between outdoor and indoor pollution is intertwined, as outdoor pollutants can infiltrate indoor environments through openings and cracks in buildings. Given that people spend 90% of their time indoors, exposure to outdoor air pollution often occurs within buildings (WGBC, n.d.). In polluted outdoor environments, natural ventilation methods are often ineffective due to the intake of contaminated outdoor air. As an alternative, energy-intensive air filtration systems are commonly utilized, potentially exacerbating energy consumption unless powered by renewable sources or efficient mechanical ventilation systems such as heat recovery ventilators. Additionally, increased reliance on air conditioning systems contributes to local warming effects, worsening the urban heat island phenomenon. This heightened demand for indoor cooling amplifies the impracticality of natural ventilation, with global energy demands from air conditioners projected to triple by 2050, further deteriorating global air quality. This interconnectedness underscores the importance of addressing both indoor and outdoor sources of pollution to safeguard human health.

Industrial Sources

Numerous studies highlight the detrimental impacts of industrial air pollution on human health. Every year, industrial facilities across every state and territory in the U.S. release millions of pounds of carcinogenic substances (Rahman et al., 2021). Particulate matter (PM) emissions from industries, including PM2.5 and PM10, along with pollutants like carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and volatile organic compounds (VOCs), contribute to respiratory disorders, cardiovascular diseases, and premature mortality. Notably, industrial areas often experience higher levels of PM pollution, exacerbating health risks for nearby communities. Research indicates a strong correlation between industrial pollution and adverse health outcomes. For instance, studies have found that exposure to industrial PM10 is positively associated with mortality from non-accidental causes, cancers, and cardiac diseases. Similarly, air pollutants like NO₂ and PM have been linked to increased mortality rates.

A study published in the *Journal of the National Cancer Institute*, highlights disparities in the distribution of carcinogenic emissions from U.S. industrial facilities (Costello, 2024). Researchers analyzed data from the U.S. EPA and the U.S. Census, finding that approximately 11 million pounds of carcinogens were emitted by 2,196 industrial facilities in 1,763 census tracts, potentially exposing around 7 million people.

Importantly, certain populations, including African Americans, Hispanics, individuals experiencing poverty, and those with less than a high school education, were more likely to live in areas with higher emissions of carcinogens. Specifically, the odds of residing in areas with the highest emissions of benzene, 1,3-butadiene, ethylene oxide, formaldehyde, trichloroethylene, and nickel were elevated for African American and Hispanic/Latino populations, while White populations were less likely to live in such areas. Moreover, individuals experiencing poverty or with lower educational attainment faced a higher burden of exposure, irrespective of race or ethnicity.

Industrialized nations, which contribute significantly to global pollution emissions, bear a substantial responsibility for addressing these health risks. Efforts to address industrial pollution require a multi-faceted approach, incorporating strict emission regulations, technological advancements in pollution control, and investment in cleaner energy sources. Additionally, promoting public awareness and community engagement is crucial for fostering support for pollution mitigation initiatives and advocating for healthier environments.

Agricultural Sources

Agriculture and air quality exhibit a complex, interrelated dynamic with far-reaching consequences for environmental sustainability, public health, and global food security. Agricultural activities are significant contributors to global air pollution with food production accounting for an estimated quarter of the world's greenhouse gas emissions (Agricultural Outlook: How Limiting Air Pollution Will Protect Farms, 2019). A major culprit is ammonia, primarily emitted from livestock manure and fertilizer application. These emissions account for 95% of all atmospheric ammonia and significantly contribute to particulate matter pollution in urban areas. Studies in European cities reveal that ammonia emissions are responsible for up to 58% of their particulate matter problem. Furthermore, the issue extends beyond localized impacts with chemical drift from pesticides, herbicides, and fertilizers affecting neighboring areas and amplifying air quality concerns across diverse geographical contexts.

Air pollution and climate change have a synergistic relationship. Short-lived air pollutants are responsible for 30-40 percent of global warming. Agricultural activities exacerbate air pollution, which in turn intensifies climate change impacts. The most visible consequence of this intertwined relationship is on agricultural productivity itself.

Rising temperatures and altered weather patterns negatively affect crop yields. Studies indicate that staple crops like rice, corn, and wheat could see yield reductions of up to 10% per degree Celsius of global warming, with some regions facing even steeper declines. However, reductions in air pollution metrics have been documented to increase crop yields. A study by Lobell and Burney found that improvements in air quality between 1999 and 2019, specifically reductions in ozone, particulate matter, nitrogen dioxide, and sulfur dioxide, were responsible for roughly 20% of the increase in U.S. corn and soybean yields during that period (Bishop, 2022). This translates to an annual economic benefit of approximately \$5 billion. Further evidence comes from research utilizing satellite data demonstrating potential crop yield increases of 25% for winter crops in China and 10% for crops in western Europe following a 50% reduction in nitrous oxide pollution. These findings underscore the importance of addressing agricultural air pollution alongside emissions from other sources in order to safeguard environmental resilience, human well-being, and global food security.

Environmental Sources

Despite the progress made in curbing anthropogenic air emissions, particularly those contributing to fine particulate matter, achieving clean air remains a global challenge. This challenge is heightened by the substantial contribution of natural emission sources to air pollution. Environmental phenomena like dust storms in arid regions, sea salt spray from oceans, and organic compounds released by vegetation all contribute to air pollution levels (Martinovich, 2022). Recent research by MIT highlights the limitations of solely focusing on reducing anthropogenic emissions, finding that even with complete elimination of human-caused emission sources, over half the global population would still be exposed to unhealthy levels of air pollution. This underscores the need for a multifaceted approach to air quality management, one that considers the unique challenges posed by natural sources in different regions.

Natural sources contribute to various forms of air pollution. Volcanic eruptions release sulfur dioxide, ash, and other harmful gasses into the atmosphere, impacting air quality regionally and sometimes globally. Forest fires, both natural and human-caused, release a mixture of pollutants including ozone, volatile organic compounds (VOCs), and particulate matter, degrading air quality over vast areas.

Even natural phenomena like lightning strikes can generate nitrogen oxides, contributing to ozone formation. These natural events, particularly wildfires, can dramatically worsen air quality even in regions that typically enjoy good or moderate annual levels. These events can trigger periods of extremely compromised air quality, pushing normally clean areas into the ranks of the world's most polluted regions.

Understanding the specific chemical makeup of air pollution in a particular region is crucial for effective mitigation strategies. Speciation, as it is called, allows researchers to pinpoint the dominant natural and anthropogenic sources. This information empowers development of targeted solutions. For instance, regions with high dust levels might require stricter land management practices to minimize dust generation. Addressing air pollution requires a holistic approach that acknowledges the significant

03

SEATTLE - A CASE STUDY

This chapter explores the historical and contemporary factors contributing to health disparities in Seattle, including settler colonialism, industrialization, racially predatory practices, transportation policies, and disinvestment. These factors have resulted in enduring health disparities and differences in longevity.

PERSISTING LEGACIES OF DISPARITY

Seattle, like many cities across the United States, grapples with persistent disparities rooted in historical and contemporary factors. Settler colonialism laid the foundation for the displacement and marginalization of Indigenous communities, shaping land use patterns and power dynamics that continue to influence health outcomes today. Industrialization brought economic prosperity to the region but also brought contamination and environmental degradation, disproportionately impacting communities of color and low-income neighborhoods. Racially predatory practices, such as redlining and discriminatory zoning policies, further exacerbated spatial inequalities, confining marginalized populations to areas with higher levels of pollution and fewer resources. Transportation and urban renewal initiatives, while aimed at modernization and growth, often resulted in the displacement of communities and the destruction of social networks, contributing to social fragmentation and disinvestment in impacted neighborhoods. The burdens of these historical injustices continue to manifest in health disparities and differences in longevity among Seattle's residents, highlighting the enduring impact of structural inequities on community health.

Settler Colonialism

The historical relationship between white settlers, Indigenous peoples, and the native landscapes of Seattle is a complex narrative that unfolds through centuries of colonization, displacement, and environmental transformation. In 1851, European settlers arrived in the region, establishing the first permanent non-Indigenous settlement in what would become Seattle. However, this arrival overlooks the deep-rooted history of the Duwamish and other Indigenous communities who had inhabited and stewarded the land since time immemorial (McNamee, n.d.).

The naming of the city after Chief Seattle (Sealth) is often portrayed as a gesture of hospitality, yet it also symbolizes the power imbalances inherent in the encounter between European settlers and Indigenous peoples (McNamee, n.d.). The naming reflects a colonial narrative that downplays the displacement, dispossession, and violence experienced by Indigenous communities as a result of settler colonialism. This encounter was marked by contrasting perspectives on the environment and relationships with land.



FIG 3.1 Early Duwamish Village. (n.d.). Duwamish Tribe. <https://www.duwamishtribe.org/history>

The Indigenous peoples view their surroundings as dynamic and integral to their way of life, shaping their practices around the land's rhythms. In contrast, white settlers saw economic opportunities in exploiting the natural resources of the region, leading to significant alterations in the landscape (Klinge, 2007).

Colonial practices manifested through land claims and treaties which disrupted traditional Indigenous practices and resulted in the displacement of Native peoples from their villages (Figure 3.1) and ancestral lands (Updegrave, 2016). The signing of treaties not only ceded land but also introduced uncertainty and fear among Native communities regarding their future and cultural survival (Cummings, 2020). Early epidemics introduced by Europeans, including diseases like smallpox, measles, tuberculosis, and syphilis, had devastating impacts that reduced Native populations by 60% to 90% (Crowley, 2000). These diseases caused population declines that weakened Indigenous communities' ability to resist settler encroachment and negotiate favorable terms. Displacement from traditional lands meant the loss of crucial resources for survival, such as hunting grounds and fishing areas, further exacerbating the challenges faced by Native peoples. The loss of livelihood, cultural disruption, and environmental changes due to colonization significantly shaped the trajectory of Indigenous communities and Seattle.

This historical context of colonization, disease, displacement, and environmental transformation forms the backdrop for understanding the enduring health disparities and environmental disparities experienced by Indigenous and other marginalized communities in Seattle today. The legacy of settler colonialism continues to influence land use patterns, power dynamics, and health outcomes, highlighting the ongoing impact of historical injustices on community well-being.

Industrialization + Contamination

The establishment of the first steam-powered sawmill in 1852 marked the early signs of industrial growth, signaling a shift towards intensive resource extraction and production that would shape Seattle's development trajectory (Crowley, 2000). The onset of industrialization in Seattle marked a significant shift in the region's landscape and ecological balance, leading to environmental degradation and long-term health consequences.

Seattle's early economy was dependent on logging, fishing, and mining industries, emphasizing the exploitation of natural resources for economic gain. Engineering projects, such as hill regrading and canal building, reshaped Seattle's physical geography, altering natural landscapes and ecologies (Klinge, 2007). The development of the logging, fishing, and mining industries was accompanied by significant environmental impacts. The exploitation of timber resources led to large scale deforestation, altering ecosystems and habitats. Similarly, the expansion of Seattle's fishing industry resulted in overfishing and the disruption of aquatic ecosystems, particularly affecting salmon populations. Seattle's historical significance as the biggest coal port in the Pacific Northwest and the largest coal supplier on the West Coast reflects the mining industry's role in fostering a reliance on fossil fuels for powering the city and industry, contributing to significant air quality degradation (Berger & Hegg, 2019). Industrial growth along the Duwamish Waterway further intensified these environmental changes. The construction of harbors and infrastructure for shipping facilitated resource transport but also led to pollution and habitat destruction. Discharge of sewage and industrial waste into the river, coupled with filling and dredging of wetlands, significantly degraded water quality and disrupted natural habitats (Updegrave, 2016).

The channeling of the Duwamish River specifically for industrial purposes further transformed the natural flow of waterways, disrupting ecosystems and exacerbating pollution issues (Figure 3.2). This industrial development along the waterway, although driving economic growth, also brought about health impacts from varied sources of pollution. Moreover, the loss of farmland and agricultural livelihood due to industrial expansion underscored the environmental and social impacts of industrialization (Wilma, 2001). The rapid growth of industries and the associated environmental changes laid the groundwork for ongoing environmental challenges and health disparities linked to industrial pollution and land use changes in Seattle.



FIG 3.2 The results of the straightening and dredging of the Duwamish Rive. (1992). Duwamish Tribe. <https://www.duwamishtribe.org/history>

In 2001 the EPA designated the Duwamish River as a Superfund Site due to extensive toxic contamination, marking it as one of the nation's most toxic hazardous waste sites (DRCC, n.d.). This designation mandated cleanup efforts, with 5.5 miles of the river and 412 acres identified for remediation. This process has involved the formation of groups like the Lower Duwamish Waterway Group (LDWG) and the Duwamish River Cleanup Coalition/ Technical Advisory Group (DRCC/TAG), representing responsible parties and the community, respectively. Collaborative efforts with these groups, agencies, and communities have culminated in the EPA's Final Cleanup Plan, released in 2014, detailing strategies and technologies to address the river's pollution. Hazardous substances like PCBs, dioxins, and arsenic that have contaminated the river sediments make seafood from the Duwamish unsafe for consumption and necessitate ongoing monitoring and remediation.

Racially Predatory Practices + Disinvestment

Seattle's history is marked by racially exclusionary practices that targeted a spectrum of communities, including African Americans, Asian Americans, Pacific Islanders, Latinx people, Native Americans, and Jews (The Civil Rights and Labor History Consortium, n.d.). These practices were pervasive, infiltrating various spheres of life such as housing, employment, education, and public accommodations, perpetuating systemic inequalities and reinforcing social segregation.

In the late 19th century, Seattle witnessed a surge of racial tensions culminating in violent outbreaks, notably seen in the anti-Chinese riots of the 1880s (McNamee, n.d.). These riots resulted in the expulsion and land dispossession of nearly 200 Chinese residents. Moving into the 20th century, discriminatory practices continued to shape Seattle's landscape, exemplified by the internment of Japanese Americans during World War II. Thousands of Japanese Americans were forcibly relocated and confined, representing a violation of civil liberties and a manifestation of systemic prejudice prevalent not only in Seattle but across the nation (Crowley, 2006). Post-war debates over the resettlement of Japanese Americans further revealed the racial tensions and challenges faced by minority communities in Seattle.

One of the mechanisms that perpetuated segregation and inequality was redlining, a discriminatory housing policy implemented through the Home Owners' Loan Act (HOLC) of the 1930s. Under this system, neighborhoods were graded based on perceived desirability, which was often linked to racial demographics (Weinberger, 2022). Areas with predominantly white populations received higher grades (A and B), indicating more favorable lending conditions and investment opportunities. Conversely, areas with large minority populations, particularly African American, Asian American, Latinx, and Native American communities, were often graded lower (C and D), making it challenging for residents to secure mortgages and hindering investment in these neighborhoods.

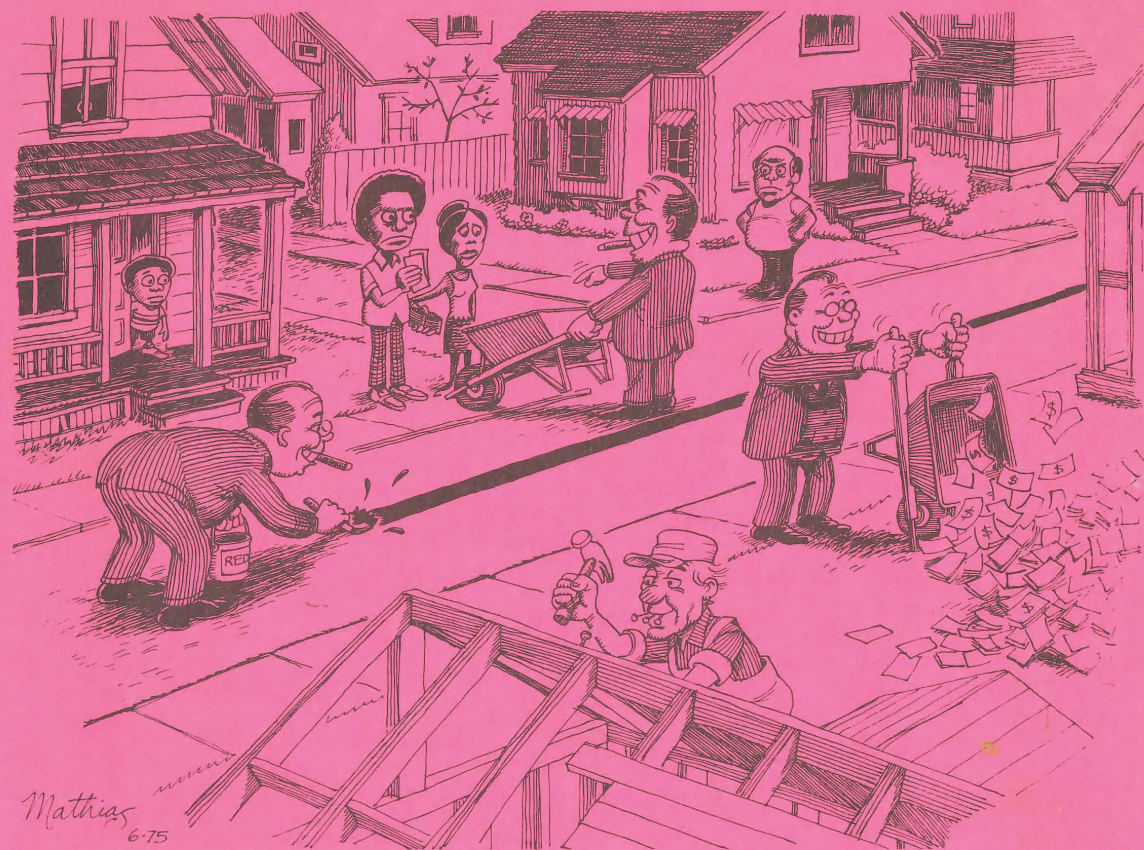
Racially restrictive covenants were another tool used to enforce segregation, explicitly excluding people of color from purchasing homes in certain areas of the city. specific racial or ethnic backgrounds (The Civil Rights and Labor History Consortium, n.d.).

These covenants were prevalent in many cities across the United States, including Seattle, during the early to mid-20th century, and were used by white property owners and developers to enforce racial segregation and maintain homogeneity within neighborhoods. Racially restrictive covenants effectively reinforced the discriminatory practices of redlining, where minority communities were systematically excluded from accessing the same housing opportunities and resources as their white counterparts. They restricted where minorities could purchase homes, effectively confining them to areas of the city that were often considered undesirable or poorly graded according to the Home Owners' Loan Act (HOLC) grading system. These covenants not only limited where minorities could live but also perpetuated housing segregation and wealth disparities, as properties in areas with higher HOLC grades appreciated in value, while those in lower-graded areas stagnated or declined.

The Central District in Seattle is a prime example of the impact of racial segregation and redlining practices. Racial restrictive covenants confined Black families to this area, establishing it as a predominantly Black neighborhood while barring access to white areas (Jagana, 2021). Redlining maps classified Black neighborhoods as "high-risk" and "no-investment zones," hindering Black residents' opportunities for homeownership and wealth accumulation. This disinvestment led to eroded wealth and economic instability within Black communities. Major banks systematically denied loans to Black applicants in the Central District, channeling funds away from these neighborhoods to predominantly white suburban areas. A 1975 report, pictured in Figure 3.3, revealed that Black residents received less than a quarter of loan reinvestment compared to white suburban areas, exacerbating economic disparities and weakening community stability. The consequences of disinvestment were compounded by gentrification, fueled by declining Black homeownership rates and increased vulnerability to displacement, paving the way for white homebuyers to enter and reshape the Central District. Black homeownership rates in King County plummeted by nearly 43% from 1970 to 2017, ranking among the lowest nationally (Jagana, 2021). Presently, only 25% of Black residents in Seattle own homes, well below the national average, contributing to lower median household incomes and net worth among Black communities.

REDLINING AND DISINVESTMENT IN CENTRAL SEATTLE:

HOW THE BANKS ARE DESTROYING OUR NEIGHBORHOODS



A REPORT TO THE COMMUNITY BY THE
CENTRAL SEATTLE COMMUNITY COUNCIL FEDERATION

JULY, 1975

The Fair Housing Act of 1968 marked a significant turning point by prohibiting discrimination in housing based on race, color, religion, sex, or national origin, effectively invalidating racially restrictive covenants (The Civil Rights and Labor History Consortium, n.d.). However, their legacy persisted, as the effects of decades of segregation and limited access to resources continued to impact minority communities in terms of housing affordability, quality, and access to opportunities. Although these discriminatory practices are no longer legal, their impacts remain visible in the present-day racial spatial distribution patterns and property value disparities that continue to echo the historic patterns established by these practices.

Racial and socioeconomic spatial stratification, shaped by historic redlining and restrictive covenants, enabled minority communities to be disproportionately selected for the siting of undesirable industrial and transportation infrastructure. This decision-making was influenced by the perception that these communities have lower capacity for political resistance compared to Seattle's predominantly white and affluent neighborhoods (Berger, 2021). Moreover, these marginalized communities face disparities in access to desirable amenities such as parks and open spaces, public transportation, and nutritious food. These discrepancies contribute to existing environmental inequalities in Seattle, with neighborhoods experiencing racial and economic disadvantages often having significant walkability gaps and limited access to green space (Fesler, 2016). Furthermore, the unequal distribution of Seattle's tree canopy decline exacerbates these issues, particularly affecting the same underserved communities already lacking in tree cover which are experiencing greater losses in canopy than the citywide average (City of Seattle, n.d). These contrasts in access to desirable and undesirable resources underscores systemic inequities resulting from discrimination and disinvestment, emphasizing the need for equitable strategies to address these longstanding challenges.

Transportation + Urban Renewal

Seattle's transportation evolution began with the arrival of the Northern Pacific Railway in 1873 (McNamee, n.d.). This event marked a transformative period, turning Seattle into a major transportation hub and fueling its economic growth. This growth extended to the comprehensive development of Seattle's transportation network, encompassing railroads, streetcars, highways, bridges, and canals (Crowley, 2006).

FIG 3.3 Redlining report. (1975). Seattle Municipal Archives. <https://www.seattle.gov/cityarchives/exhibits-and-education/online-exhibits/redlining-in-seattle>.

Early streetcar lines played a crucial role in suburban development, particularly in areas like Ballard and West Seattle, shaping land-use patterns with broad avenues, dense housing, and compact business districts (Crowley, 2000). However, despite initial successes, Seattle faced challenges in sustaining public transit systems. A lack of investment in public transit compared to private automobiles, led to the decline of streetcars and their eventual demise. This trend was reinforced by federal funding favoring car travel over public transportation.



FIG 3.4 Seattle-Tacoma interurban streetcar, Kent. (1909). Photo by Asahel Curtis/MOHAI. <https://www.historylink.org/File/9276>

The landscape of transportation policy underwent significant changes, as seen between 1940 and 1950 with King County’s suburban population doubling to reach a quarter million residents, eventually surpassing the City of Seattle’s population by 1970 (Crowley, 2000). This surge in suburban growth raised concerns about environmental and traffic issues, prompting advocacy for a regional transit system with a rail component in the County Charter. Efforts to establish a regional transit system faced repeated defeats between 1952 and 1970 due to cost concerns and automobile industry opposition, with rail transit initiatives only gaining traction by the 1980s, leading to the creation of Sound Transit in 1996.

The signing of the National Defense Highways Act in 1956 marked a shift towards heavily subsidized transportation infrastructure, prioritizing interstate highways over rail projects (Crowley, 2000). Freeway construction projects, like the Eastside Expressway, disrupted established neighborhoods by slicing through residential and commercial areas, impacting traffic flow patterns and local street grid connectivity (Becker, 2003). The South Park neighborhood in the Duwamish Valley exemplifies the impacts of highway infrastructure, as State Route 99 bisects the community entirely, offering only two crossing points for pedestrians and a sole crossing point for vehicles. The construction’s fallout included displacement of residents and businesses, neighborhood disruption, and increased noise and air pollution.

Highway expansions frequently reinforced racial and economic inequalities, as they were often employed to eliminate “blighted” areas by displacing impoverished and racially diverse communities, and reinforcing segregation between predominantly white neighborhoods and those of nonwhite residents.(Berger, 2021). Wealthier and whiter communities like Mercer Island received preferential treatment during highway expansion, while historically Black neighborhoods like the Central District had to fight for similar mitigation considerations, reflecting systemic inequalities in transportation planning. Displacement of marginalized communities due to highway construction has been a recurring issue, leading to instability, loss of community ties, and economic hardship. Cultural disruption, such as the physical division of the Chinatown-International District by Interstate 5, posed threats to community identity and well-being, emphasizing the complex social and cultural ramifications of transportation infrastructure.

Limited transportation options in communities of color have exacerbated reliance on cars, contributing to environmental pollution and limiting access to essential resources and opportunities (Berger, 2021). These challenges underscore the ongoing struggle to create inclusive and sustainable urban environments in Seattle, where transportation planning must address historical injustices and prioritize equity and community well-being.

Burdens of Harm

The burden of environmental harm and disparity in Seattle is deeply rooted in historical injustices, particularly evident in the enduring impact of redlining on air quality. The study titled “Skewed Risksapes and Gentrified Inequities: Environmental Exposure Disparities in Seattle, Washington” revealed stark disparities despite a two-thirds reduction in industrial footprint and a 99% decrease in pollution volume from 1990 to 2007 (Abel & White, 2011). These reductions obscure concerning findings, as neighborhoods with high minority populations and low socioeconomic status face the highest air pollution risks, with 70% of hazardous facilities located in these vulnerable areas since 1990. Gentrification complicates matters, prompting industrial facilities to relocate to lower-income neighborhoods, resulting in a situation where the remaining high-risk facilities were disproportionately located near vulnerable communities. Notably, the study found that the most significant health risks may be concentrated in specific areas due to the presence of a single high-polluting facility which accounted for 95% of Seattle’s air toxic exposure risk in 2007.

The University of Washington and the University of California at Berkeley study titled “Historical Redlining Is Associated with Present-Day Air Pollution Disparities in U.S. Cities” reveals alarming statistics about historically redlined neighborhoods disproportionately exposed to harmful air pollutants like nitrogen dioxide (NO₂) and fine particulate matter (PM_{2.5}) (Weinberger, 2022). This exposure contributes to respiratory problems, heart disease, and cancer, with areas receiving D grades being exposed to 56% higher pollution levels nationally than their A-rated counterparts. The research also highlights racial disparities in exposure within redlined neighborhoods, suggesting factors beyond redlining, such as gentrification patterns, may further disadvantage minority communities. Another recent study “Exposure Disparities by Income, Race and Ethnicity, and Historic Redlining Grade in the Greater Seattle Area for Ultrafine Particles and Other Air Pollutants” builds upon the correlation between historical redlining and present-day air quality, revealing that neighborhoods labeled “hazardous” under redlining practices face disproportionately higher concentrations of air pollutants, especially ultrafine particles (Breda, 2023).

The unequal distribution of pollutants extends to areas with lower average household income and higher Black populations, where the concentration of harmful pollutants like soot, fine particles, nitrogen dioxide, and ultrafine particles is significantly higher than the citywide average. Census blocks with lower average household income (under \$20,000) and higher Black populations had the highest levels of all four pollutants measured in the study, with an average ultrafine particle concentration 40% higher than the study’s overall average. Conversely, blocks with higher median income (over \$110,000) had ultrafine particle concentrations 16% lower than the city average. Black residents across the study area had the highest exposures to all four pollutants measured, indicating a disparity in pollution exposure based on race and income. Industrial areas not graded by the Home Owners’ Loan Corporation (HOLC) due to their zoning also exhibit alarmingly high pollution levels, surpassing some redlined neighborhoods in ultrafine particle concentration, indicating a combined impact of redlining and industrial land use practices on environmental burdens.

Burdens of harm faced by low-income communities and communities of color from pollution are compounded by disproportionate impacts of climate change. The lack of affordable housing forces many low-income residents to live in neighborhoods with poor air quality due to higher industrial and traffic pollution levels. The 2020 wildfires in Washington and Oregon significantly worsened Seattle’s air quality, pushing the Air Quality Index (AQI) to hazardous levels, particularly in low-income and minority neighborhoods near highways with higher traffic pollution (Powell, 2020). Rising temperatures create heat islands in urban areas, with low-income neighborhoods having less access to air conditioning and tree cover, further amplifying negative health impacts. Climate change impacts are felt across the entire city, but its effects are magnified in vulnerable communities that already experience layered environmental burdens, placing these communities on the front lines of the climate crisis. These disparities underscore systemic inequalities in environmental planning and the need for equitable policies and interventions to address environmental justice and protect the health of marginalized communities.

Health Disparity + Longevity

Seattle's deep-rooted history of discriminatory practices and policies has led to prolonged exposure to environmental disparities, particularly affecting marginalized communities with high concentrations of minority residents and lower socioeconomic status. These communities bear disproportionate burdens of harm, experiencing poor air quality, limited access to green spaces, and heightened exposure to pollutants, resulting in elevated rates of health disparities compared to Seattle's whiter and wealthier neighborhoods. The Duwamish Valley serves as an exemplary case study of the impacts of these layered injustices, highlighting the intersection of historical discrimination, environmental hazards, and health disparities. The Duwamish Valley Cumulative Health Impacts Analysis (CHIA) offers an exploration into the health and longevity disparities prevalent in much of South Seattle. This analysis delves into various dimensions of health inequities, shedding light on the complex interplay between social determinants, environmental exposures, and health outcomes.

ZIP code 98108, comprising Beacon Hill, Georgetown, and South Park, emerges as a focal point in understanding the pronounced health challenges faced by residents of the Duwamish Valley. This area exhibits the highest cumulative health impact score of 106 out of 120, indicating a significantly heavier burden compared to other regions within the study (Cummings & Gould, 2013). Social vulnerability indicators within this ZIP code, including socioeconomic factors and sensitive populations, rank notably high. Indicators such as poverty levels, minority population percentages, and the presence of vulnerable groups like children under 5 and the elderly received the highest rankings possible. Furthermore, the environmental vulnerability of residents in this area is underscored by the highest exposure to air pollution, potential proximity to contaminated waste sites, and a limited built environment that lacks essential green spaces and tree canopy cover, contributing to poorer air quality and overall well-being.

A comparative analysis between the Duwamish Valley and King County reveals disparities in key socioeconomic and health metrics. Residents in the Duwamish Valley grapple with higher poverty rates (17.6% compared to 9.7% in King County), lower rates of health insurance coverage (20% versus 13%), and a substantial educational attainment gap, with a higher percentage of individuals lacking a high school diploma (20.1% compared to 8.2% in King County) (Cummings & Gould, 2013).

(20.1% compared to 8.2% in King County) (Cummings & Gould, 2013). These socioeconomic factors intertwine with health outcomes, as evidenced by higher rates of low birth weight, a marker for future health issues, and significantly elevated mortality rates in the Duwamish Valley compared to the county averages. For instance, the Valley reports higher rates of lung cancer (52.3 per 100,000 residents versus 41.4 in King County) and unintentional injuries (41.3 per 100,000 residents versus 32.7). Lower life expectancies in the Duwamish Valley (79.4 years) compared to King County's average (81.5 years) further underscores the longevity disparities faced by residents.

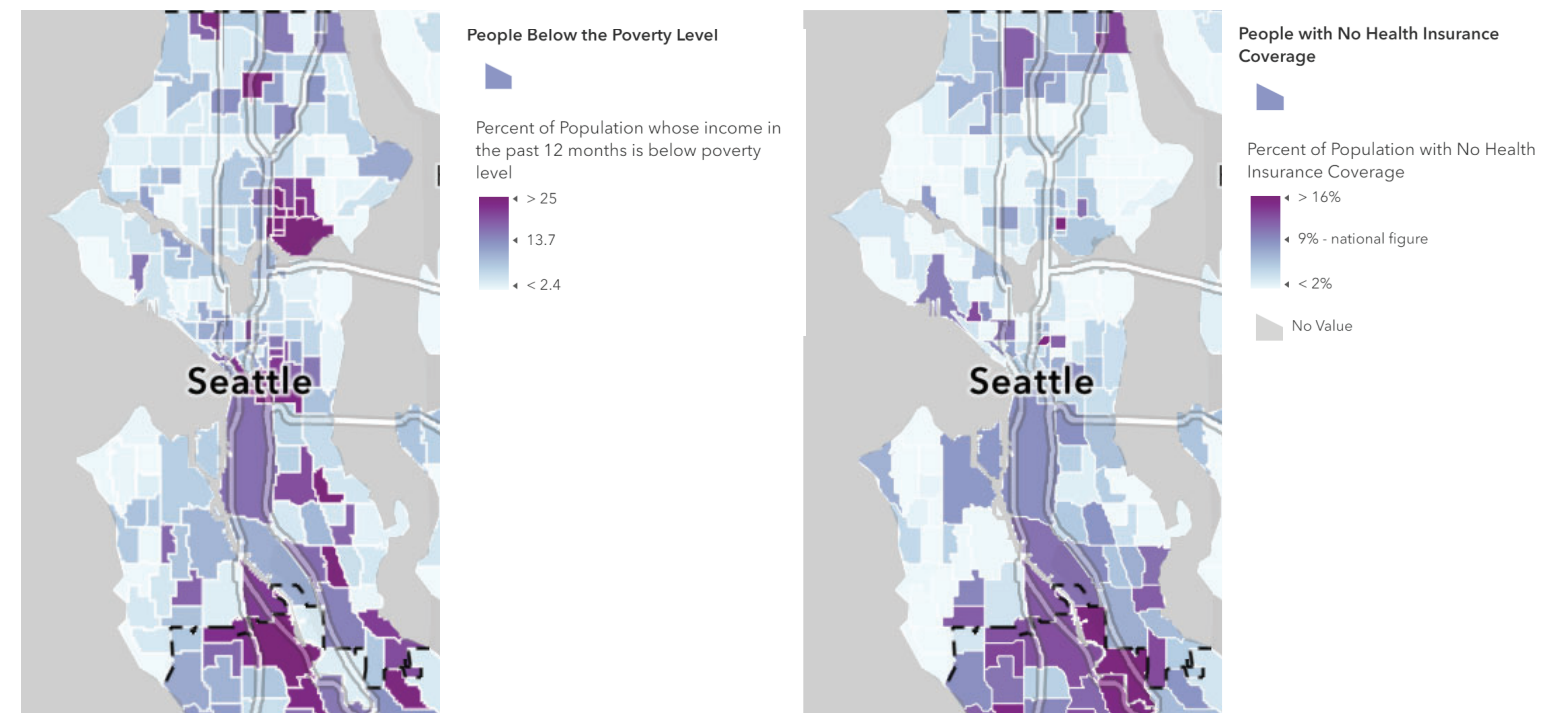


FIG 3.5 Percent Below Poverty + No Health Insurance Maps. (2022). U.S. Census Bureau. <https://seattlecitygis.maps.arcgis.com/apps/MapSeries/index.html?appid=a447494df6e14dbba356963a9442834a>

A granular examination of specific neighborhoods within the Duwamish Valley, such as South Park and Georgetown, reveals even more concerning findings. Despite moderate heart disease death rates at the ZIP code level, these neighborhoods exhibit substantially higher rates (202.9 per 100,000) compared to the broader CHIA range, indicative of localized health crises (Cummings & Gould, 2013). The life expectancy in these neighborhoods stands at 73.3 years, a 13-year difference from wealthier areas like Laurelhurst, highlighting the contrasts in health outcomes within Seattle's urban landscape. These disparities in health outcomes and environmental burdens highlighted in Seattle's Duwamish Valley illustrate the need for intentional interventions in the built environment to address systemic inequities.



04

AIR QUALITY IN WASHINGTON

Overburdened communities in Washington, particularly communities of color and low-income neighborhoods, experience disproportionate impacts from air pollution due to their proximity to major transportation corridors and industrial facilities. This chapter investigates the specific factors driving air quality trends in Washington state, with a focus on the City of Seattle, exploring the local dynamics and impacts of air pollution within these communities.

AIR QUALITY TRENDS OVER TIME

Historic Air Quality Trends

Air quality is a dynamic metric influenced by various factors, fluctuating over daily, weekly, seasonal, and even long-term timescales. Examining the historical trajectory of air quality in Washington state and the city of Seattle reveals temporal trends shaped by developmental activities, natural occurrences, and environmental conditions. To comprehend the present air quality status in Washington, it's important to contextualize air quality measurements within historical trends. While historical data is somewhat limited, one way to understand trends over time is by looking at the EPA's nonattainment/maintenance status for certain pollutants. Nonattainment areas are places where the levels of these pollutants exceed the EPA's standards indicating unhealthy concentrations of the respective pollutant. Since 1992, the EPA has maintained a comprehensive table detailing attainment status by county (United States Environmental Protection Agency, 2024). This table delineates years designated as nonattainment, when the area transitioned to attainment and maintenance status, and the current classification of severity for each criteria pollutant, providing valuable insights into the evolution of air quality and the ongoing challenges .

Washington State's air quality trends reflect a mix of progress and persistent challenges in improving air quality. While there have been notable improvements across the state, some areas continue to grapple with air pollution. While Table 4.1 on the begins in 1992, it is important to note that many areas were nonattainment for measured pollutants prior to 1992 with air quality likely beginning to degrade alongside an increase in industrialization. 1-hour ozone, documented only in Washington's western counties, including Clark, King, Pierce, and Snohomish, reached attainment with EPA standards around 1996. Washington's western counties also reached Carbon Monoxide attainment by 1996, transitioning to a maintenance designation. However, a visible regional disparity emerges as eastern counties like Yakima and Spokane lagged behind, reaching attainment for carbon monoxide approximately 5-10 years later between 2002-2005. This trend of eastern counties attaining compliance with EPA standards later than western counties holds true for most documented criteria pollutants.

Particulate matter including PM10 and PM2.5 took longer to address across all counties. Particulate matter (PM10) followed a similar trend as carbon monoxide, with western counties achieving attainment by 2001 and eastern counties reaching it by 2005. PM2.5, documented only for Pierce County's Tacoma area, showed non-attainment as recently as 2014. While PM2.5 attainment is not documented for other counties, trends for Carbon Monoxide, Ozone, and PM10 would imply that other western counties would have a similar attainment date and the eastern counties would reach attainment about 5-10 years later. Sulfur dioxide (SO2), documented only in Whatcom County, remains non-attainment in 2024 due to point source industrial emissions from the now-closed Intalco aluminum smelter.

As a whole, most of Washington was designated nonattainment for key criteria pollutants up until the late 1990s and early 2000s. Criteria pollutants such as PM2.5 and SO2 pose more difficulties, with some counties still struggling to meet air quality standards. Additionally, a clear regional pattern exists, with western counties generally attaining compliance 5-10 years earlier than eastern counties. This indicates spatial patterns between western and eastern Washington that may be related to regional airsheds and geography or environmental practices and policies. While most of western Washington, including King County, is in attainment with EPA levels for air pollutants, this does not necessarily mean that the current air quality is healthy. Even areas with air quality in attainment with EPA standards can have detrimental impacts on human health, especially in areas where county trends don't reflect concentrated hotspots of air pollution, such as the Duwamish Valley where residents live in close proximity to high concentrations of emissions. Additionally, while King County may currently be in attainment with EPA standards, current trends of declining air quality challenge the county's ability to meet compliance in future years.

Current Air Quality Trends

While long-term monitoring by the Washington State Department of Ecology reveals significant reductions in traditional air pollutants over past decades, recent years have seen concerning trends of declining air quality, with a 7% increase in the average concentration of fine particle pollution across the Seattle metropolitan area (Fitzpatrick et al., 2023). This indicates that past efforts to improve air quality have yielded positive results. However, the rise of PM2.5 and persistent struggles with ozone paint a more nuanced picture. Factors such as increased vehicular and industrial emissions associated with urban growth and climate change forces including increasing wildfire events and summer heat waves have contributed to recent trends of declining air quality. Figure 4.1 illustrates the average annual change in PM2.5 pollution in select metropolitan areas between 2015 and 2021.

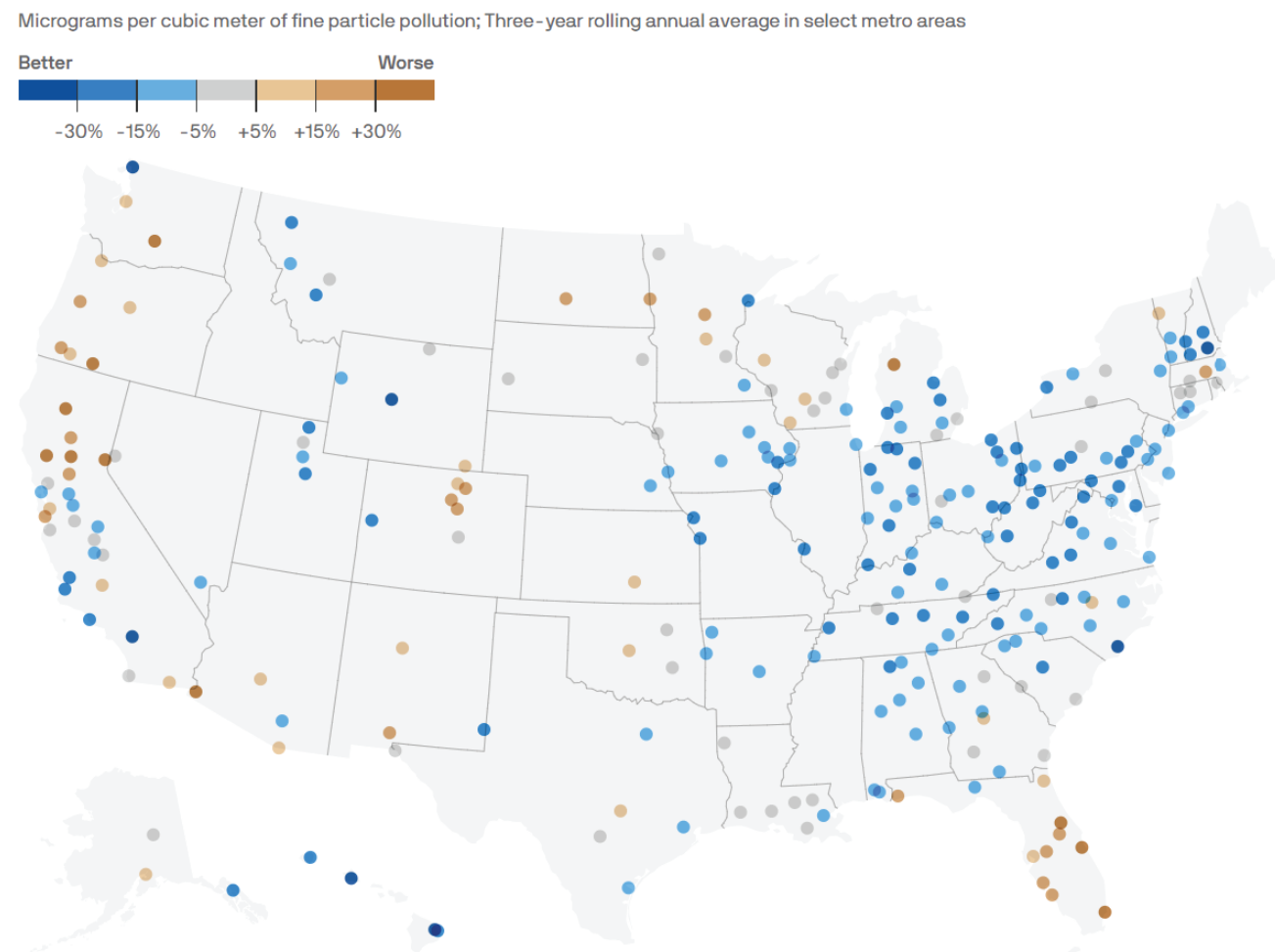


FIG 4.1 Change in air quality by metro area, 2015 to 2021. (2023). Fitzpatrick et al. <https://www.axios.com/local/seattle/2023/04/27/seattle-air-pollution-rises>

Seattle is represented as a light tan, indicating an increase in particulate matter pollution between 5-15%, with an increase of 7%. When comparing Seattle to other adjacent metropolitan areas on the map, a regional trend becomes apparent, with cities along the West Coast from Seattle to Northern California all experiencing worsening PM2.5 pollution with the highest increases observed around the Bay Area. This trend aligns with the spatial extent of regions highly impacted by increasing summer wildfire events, which contribute significantly to the rise in particulate matter.

Washington's air quality exhibits seasonal variations. Winter wood burning is a significant contributor to PM2.5 levels, with concentrations typically 40% higher during colder months compared to summer (IQAir, 2024). This seasonal increase highlights the need for alternative heating sources and pollution control measures for wood-burning fireplaces and stoves to minimize their impact on air quality, particularly during winter. However, summer brings its own set of challenges. Wildfire events can cause significant spikes in PM2.5 levels, compromising air quality and posing health risks, especially for those with respiratory issues.

Wildfires are a major driver of PM2.5 increase across the state. The past decade has seen a significant rise in the average number of moderate or worse air quality days during summers due to wildfire smoke (Saldanha, 2022). Data analysis by National Public Radio and Stanford University highlights a concerning trend - wildfire smoke exposure on the West Coast, including Washington, has nearly doubled in the last decade. This surge in wildfires overshadows past air quality gains and poses a growing health concern, particularly for those with respiratory issues. Beyond PM2.5, statewide trends exceeding the EPA's recommended limit for unhealthy ozone days is another challenge for Washington.

Despite generally "good" air quality ratings based on the US Air Quality Index and long-term improvements in traditional pollutants, Seattle faces its own challenges with PM2.5 and ozone. The city experiences fluctuations in PM2.5 levels, with a slight rise observed since 2017, likely due to increased wildfire smoke (IQAir, 2024). Similarly, Seattle struggles to meet federal ozone standards experiencing an average of 14.2 unhealthy ozone days per year, exceeding the EPA's recommended limit. The threat of climate change projects declining trends in air quality, with predictions of increased wildfire frequency and severity.

AIR QUALITY ACROSS SCALES

Air quality in Washington varies across different spatial scales, influenced by factors such as weather patterns, geographic features, and human activities. Understanding these dynamics requires a multidimensional approach that considers both local sources of pollution and regional factors that contribute to air quality degradation. The Georgia Basin/Puget Sound (Salish Sea) Airshed encompasses a vast and diverse region stretching from British Columbia's Lower Mainland through Washington State's Puget Sound area (Environment Canada & U.S. Environmental Protection Agency, 2014). This airshed experiences a dynamic mix of urban, industrial, and natural influences on air quality. Urban centers like Vancouver and Seattle contribute to emissions from transportation, residential heating, and commercial activities, while industrial zones along the coast compound pollutant levels. Moreover, the region is prone to seasonal variations, with wildfires in surrounding areas impacting air quality during summer months.

Airsheds emphasize the interconnectedness of air quality across geographic regions, transcending political boundaries like state lines. In Washington State, the distinction between Eastern and Western Washington is not just geographical but also significant in terms of air quality characteristics. As visible in Figure 4.2, the well-defined boundaries created by the Cascades and other mountain ranges play a crucial role in dividing the state into distinct airsheds. The mountain ranges act as natural barriers, affecting airflow patterns, pollutant dispersion, and atmospheric conditions (Ranney, 2022). Eastern Washington, characterized by semi-arid terrain and agricultural landscapes, experiences different air quality challenges compared to the more urbanized and industrialized Western Washington. The Eastern region is influenced by agricultural activities, dust storms, and wildfires, which contribute to particulate matter and other pollutants in the air. Wildfire smoke from Central and Eastern Washington can travel westward, impacting air quality in Western Washington. This smoke, combined with urban emissions, industrial sources, and transportation-related pollutants, exacerbates air quality concerns in the Puget Sound region and other urban areas. The Washington State Department of Ecology monitors air quality through various pollutants, such as nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and carbon monoxide (CO), whose concentrations vary depending on factors like population density, industrial activities, and topography.



FIG 4.2 Satellite image of wildfire smoke over the Salish Sea airshed in 2018. (2021). U.S. Environmental Protection Agency. <https://www.epa.gov/salish-sea/air-quality>

Within the Puget Sound region, air quality is primarily driven by human activity and can vary based on proximity to urban centers, industrial zones and traffic corridors. In the Puget Sound region, transportation is the primary contributor (35%) to greenhouse gas emissions as illustrated in Figure 4.3 (Puget Sound Clean Air Agency, 2022). The reliance on automobiles for commuting, freight transportation, and recreational travel contributes significantly to the region’s greenhouse gas emissions. Efforts to reduce these emissions include promoting public transit, encouraging alternative modes of transportation such as cycling and walking, and advocating for the adoption of electric vehicles. Transportation is followed by the residential built environment (21%), commercial built environment (19%), and industrial built environment (17%) as top contributing sources. Initiatives aimed at enhancing energy efficiency in buildings, promoting renewable energy sources, and implementing sustainable urban planning strategies play a crucial role in mitigating emissions from the residential, commercial, and industrial sectors.

During wildfire season, Seattle faces some of the world’s worst air quality due to significant emissions from natural sources, despite their minor impact on annual Puget Sound air quality data trends. The Puget Sound Clean Air Agency provides real-time data on air quality metrics, indicating fluctuations in pollutant levels and advising precautions during periods of poor air quality. King County, home to urban centers like Seattle, experiences localized air quality challenges related to vehicular, residential, industrial, and commercial activities. Seattle faces unique air quality concerns driven by high population density, traffic volume, and concentration of industrial zones. Fine particulate matter and nitrogen oxides are prominent pollutants here, affecting respiratory health and visibility.

SOURCES OF GREENHOUSE GASES IN KING, KITSAP, PIERCE, AND SNOHOMISH COUNTIES (2015).

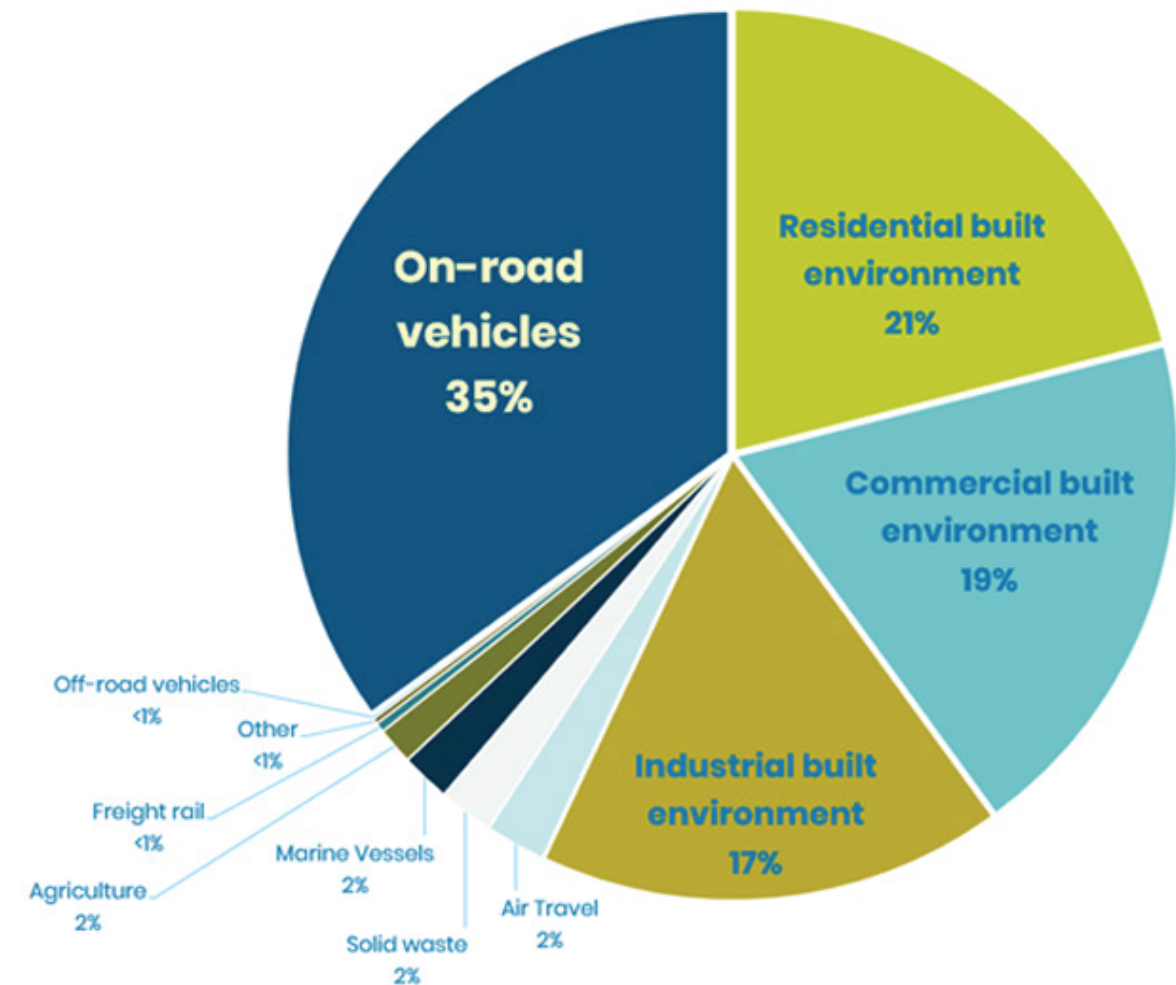


FIG 4.3 Sources of Greenhouse Gases In King, Kitsap, Pierce and Snohomish Counties (2015). (2022). Puget Sound Clean Air Agency. <https://pscleanair.gov/DocumentCenter/View/3328/PSCAA-GHG-Emissions-Inventory>

Figure 4.4 features the Washington Department of Ecology’s Air Emission Inventory for King County that outlines the diverse source of emissions and their respective contribution to key measured air pollutants (Washington State Department of Ecology, 2020). This table affirms the trends found at the Puget Sound scale, with transportation, industry and residential sources being the primary contributors.

Air quality is not uniform across the city, with certain areas within Seattle facing challenges due to concentrated sources of pollution, especially in South Seattle and the Duwamish Valley. This area hosts a mix of heavy industry, busy transportation corridors, and diverse residential communities, leading to a disproportionate impact on air quality for vulnerable populations. Industrial emissions, including particulate matter, nitrogen oxides, and volatile organic compounds, combine with traffic-related pollutants to create localized air pollution hotspots.

























	CO	NO x	PM 10	PM 2.5	SO 2	VOC	NH 3
TRANSPORTATION							
ONROAD MOBILE VEHICLES 	37%	45%	4%	4%	8%	12%	20%
NONROAD EQUIPMENT + VEHICLES 	42%	12%	2%	5%	1%	10%	<1%
DUST [ROADS] 			21%	9%			
AIRCRAFTS 	2%	4%	<1%	1%	21%	<1%	
COMMERCIAL MARINE VESSELS 	<1%	9%	<1%	1%	7%	<1%	<1%
BOATS 	3%	2%	<1%	<1%	<1%	2%	<1%
LOCOMOTIVES 	<1%	3%	<1%	<1%	<1%	<1%	<1%
INDUSTRY							
INDUSTRIAL/COMMERCIAL/INSTITUTIONAL FUEL COMBUSTION 	1%	11%	3%	8%	27%	<1%	2%
NONPOINT SOLVENT USE 						39%	
LARGE POINT SOURCES 	1%	6%	<1%	1%	22%	1%	<1%
COMMERCIAL COOKING 	<1%		8%	22%		<1%	
NONPOINT GASOLINE [STATIONS/STORAGE/MARKETING] 						5%	
RESIDENTIAL							
RESIDENTIAL WOOD COMBUSTION 	10%	1%	10%	28%	9%	7%	6%
RESIDENTIAL FUEL [NON-WOOD] 	<1%	6%	<1%	<1%	2%	<1%	15%
RESIDENTIAL OUTDOOR BURNING [YARD WASTE+TRASH] 	1%	<1%	2%	5%	1%	1%	2%
CONSTRUCTION							
DUST [CONSTRUCTION] 			47%	14%			
AGRICULTURE							
LIVESTOCK 			1%	1%		1%	34%
FERTILIZER APPLICATION 							14%
AGRICULTURE BURNING 	<1%	<1%	<1%	<1%	<1%	1%	1%
DUST [AGRICULTURAL TILLING + HARVESTING] 			<1%	<1%			
SILVICULTURAL BURINING 	<1%	<1%	<1%	<1%	<1%	<1%	<1%
ENVIRONMENT							
NATURAL EMISSIONS [SOIL+VEGETATION] 	1%	<1%				17%	
WILDFIRES 	1%	<1%	<1%	1%	1%	1%	1%
MISCELLANEOUS 	<1%	<1%	<1%	1%	<1%	<1%	6%

FIG 4.4 Washington Department of Ecology King County Air Emission Inventory. (2024). Adapted from the Washington State Department of Ecology. Daquan Proctor.

The topographic conditions of the Duwamish Valley intensify air quality impacts in several ways. The valley's natural bowl-like shape traps air leading to the concentration of pollutants within its boundaries due to limited dispersion (The Globe Program, n.d.). Temperature inversions, common in valleys, further exacerbate this issue by trapping pollutants beneath warm air layers. Limited airflow and ventilation in valleys hinder the dispersion of pollutants, prolonging their presence and contributing to worse air quality. Industrial activities and transportation corridors in the area release pollutants directly into the air, with the valley's topographical features trapping these pollutants and amplifying their effects as illustrated in Figure 4.5.

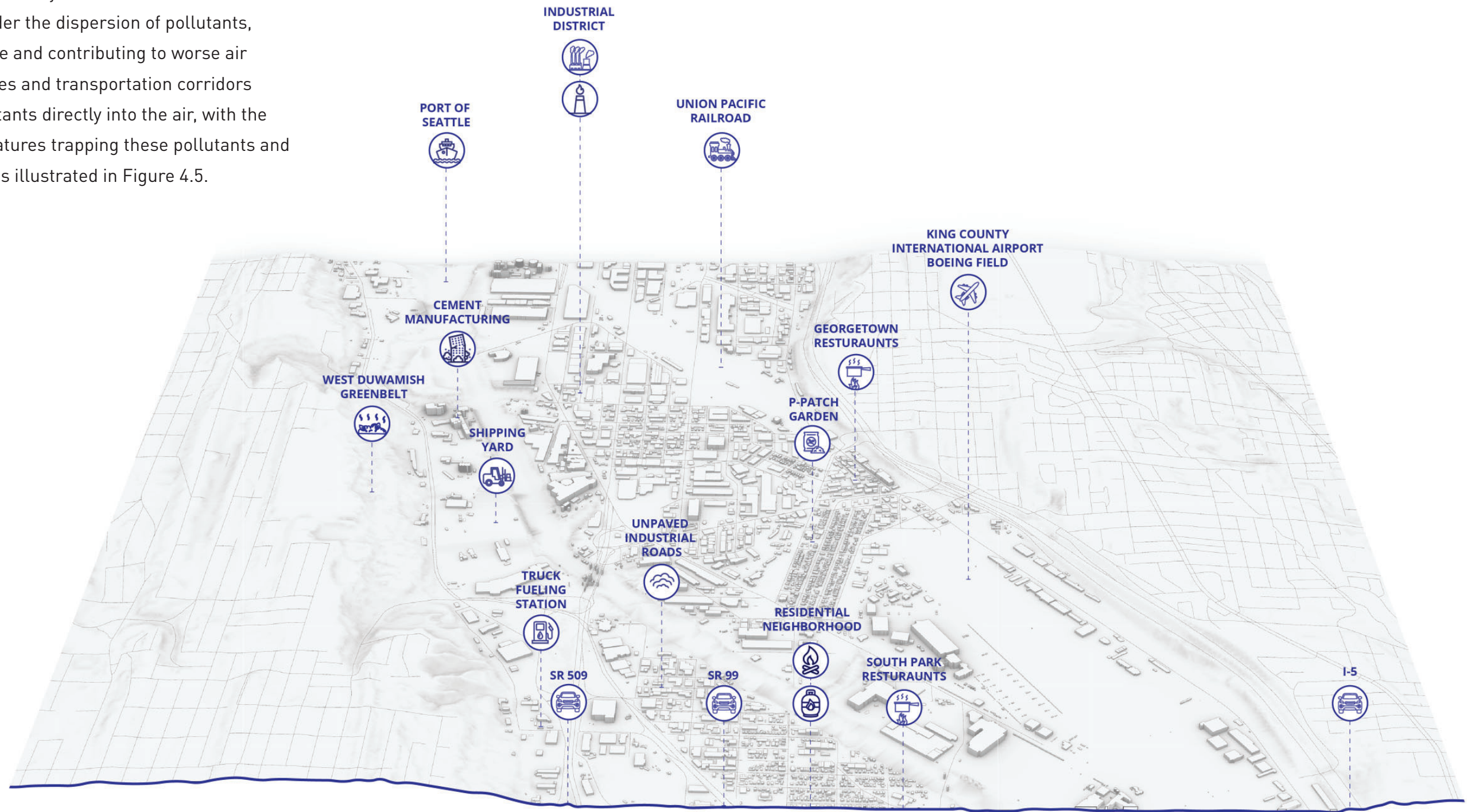


FIG 4.5 South Seattle / Duwamish Valley Emission Sources Conceptual Section. (2024). Daquan Proctor.

These challenges are exacerbated by socioeconomic factors, with communities in South Seattle facing higher levels of exposure to environmental hazards, leading to environmental justice concerns (Duwamish River Community Coalition, n.d.). These communities often experience a disproportionate burden of environmental hazards and pollution due to historical discriminatory practices in zoning, land use, and industrial development. This heightened exposure is compounded by factors such as limited access to healthcare and substandard housing, which can increase vulnerability to health issues associated with poor air quality.

OVERBURDENED COMMUNITIES HIGHLY IMPACTED BY AIR POLLUTION

The Washington State Department of Ecology’s “Improving Air Quality in Overburdened Communities” initiative tackles environmental justice concerns by focusing on disadvantaged communities disproportionately impacted by air pollution (Washington State Department of Ecology, 2023). Established under the Climate Commitment Act (CCA), this initiative targets reducing criteria air pollutants like PM2.5 and nitrogen dioxide in overburdened communities. The initiative defines “overburdened communities” as those facing a triple threat: environmental burdens (like polluted air), vulnerability to health risks from air pollution exposure (due to factors like age, income, or pre-existing conditions), and limited ability to mitigate air pollution effects (such as living near industrial areas or lacking resources for air filtration).

The Department of Ecology identifies these communities using a data-driven approach that considers multiple factors. This includes the Washington Environmental Health Disparities Map, which highlights areas with existing environmental burdens and health disparities. They also utilize EJScreen demographics, which pinpoint areas with high concentrations of environmental hazards and vulnerable populations. Additionally, air quality monitoring data plays a crucial role, supplemented by public input to ensure a holistic understanding of community experiences. The identification process prioritizes areas with a high potential for elevated pollution levels. This is achieved by combining existing air quality monitoring data with sophisticated computer modeling that factors in emissions, meteorology, and topography. However, the department acknowledges that models and data may not capture the full picture of on-the-ground experiences and real-time air quality fluctuations and they commit to reevaluating boundaries every six years.

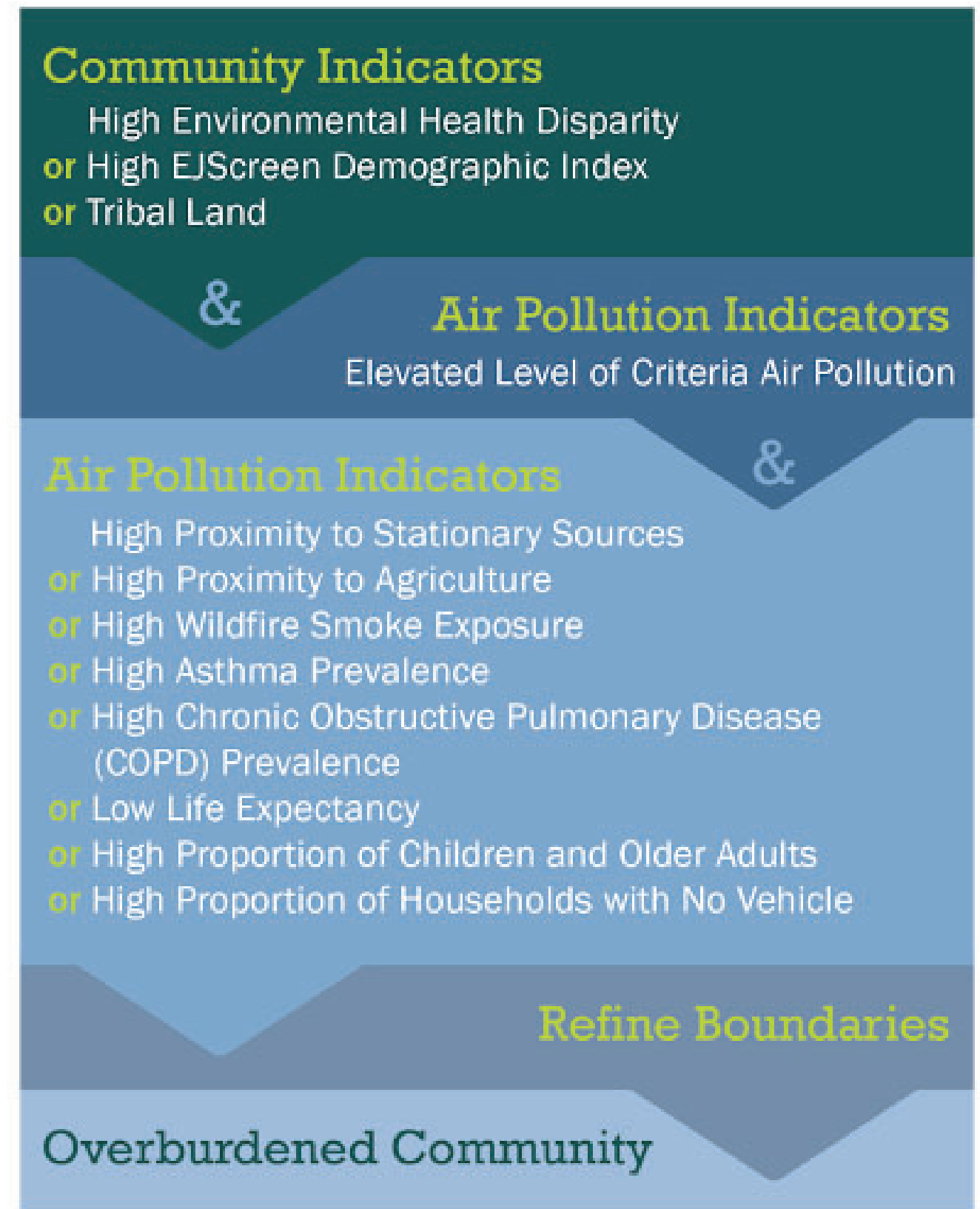


FIG 4.6 Flowchart of the process to identify overburdened communities highly impacted by air pollution. [2022]. Washington State Department of Ecology. <https://storymaps.arcgis.com/stories/814b223ee0d14ff38e90feb90f8978d0>

Currently, 16 communities across Washington are designated as overburdened, impacting over 1.2 million residents, or roughly 15.5% of the state's population (Washington State Department of Ecology, 2023). These communities encompass a diverse mix of urban, suburban, and rural settings, ranging from small towns of 1,500 residents to bustling cities exceeding 200,000. Geographical extents also vary significantly, spanning from a few square miles to vast areas exceeding 170 square miles. The "Improving Air Quality in Overburdened Communities" initiative has identified several relevant communities within the Seattle metropolitan area that are highly impacted by air pollution that should be included in local air quality trend analyses including: Everett, North Seattle and Shoreline, South Seattle, South King County, and South and East Tacoma.

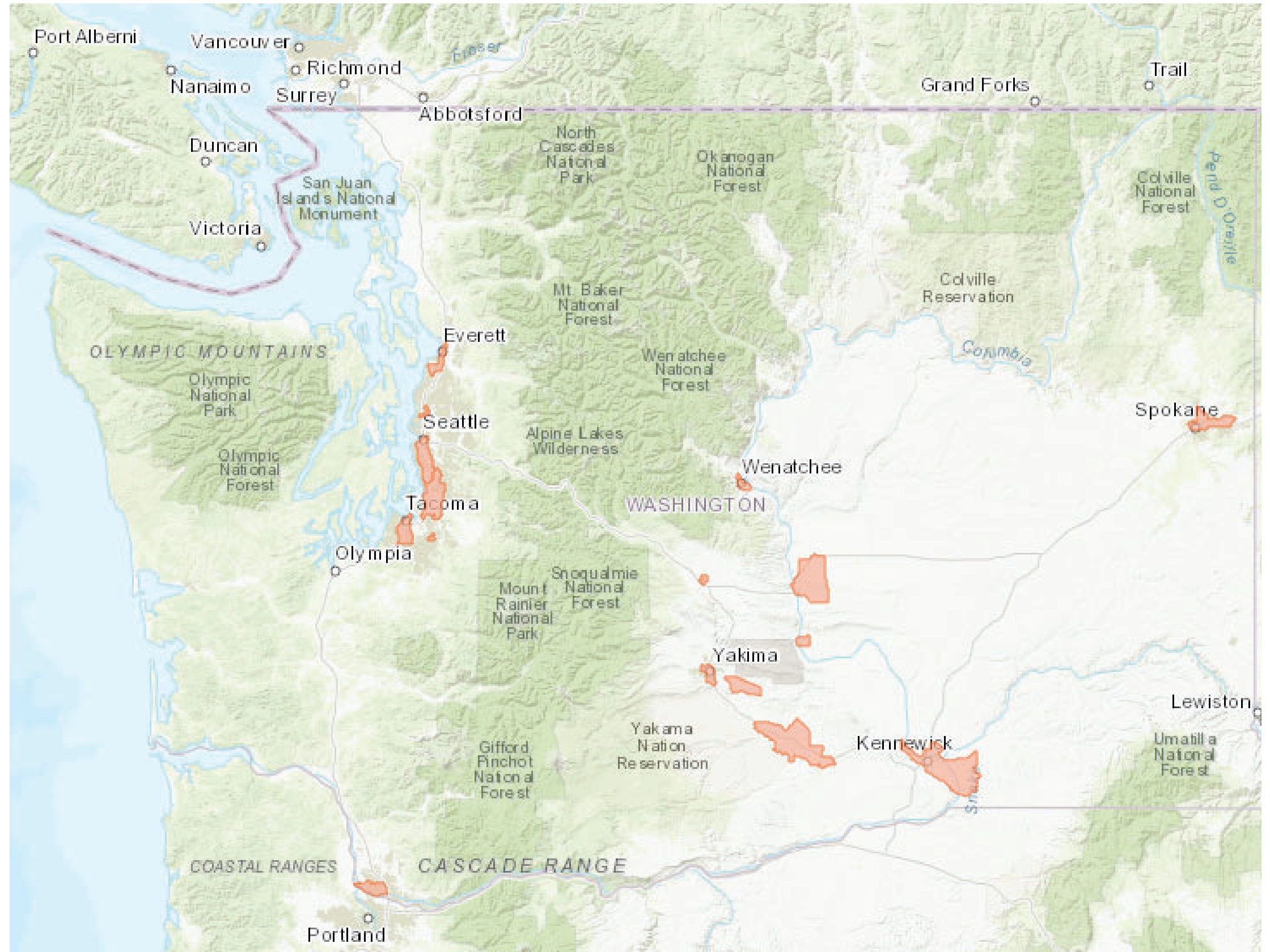
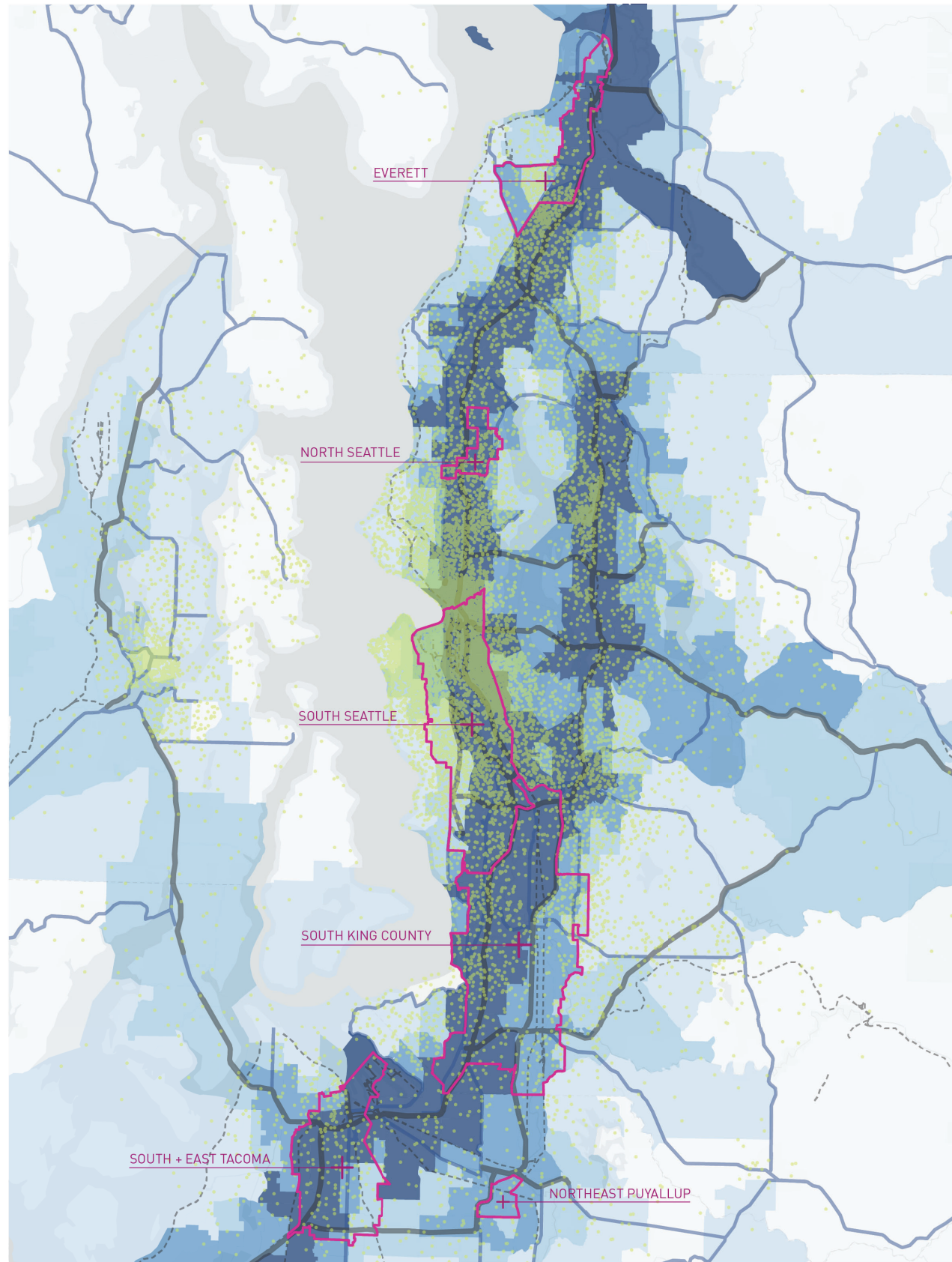


FIG 4.7 Overburdened Communities Highly Impacted by Air Pollution. (2023). Washington State Department of Ecology. <https://storymaps.arcgis.com/stories/c10bdbfc69984a9d85346be1a23f6338>

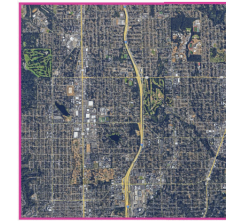
- LEGEND**
- Communities Highly Impacted by Air Pollution
 - Concentration Of Toxic Emissions From Facilities
 - High # of Residents
 - Population In Close Proximity To Heavy Traffic Roadways
 - Low # of Residents
 - Interstate
 - Highway
 - Railroad



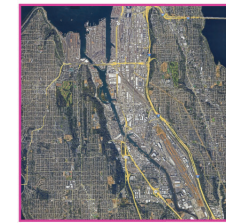
City of Seattle, King County, WA State Parks GIS, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USFWS



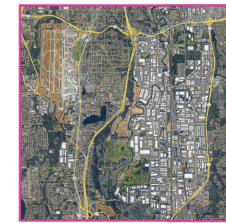
EVERETT
POPULATION | 86,400



NORTH SEATTLE
POPULATION | 41,081



SOUTH SEATTLE
POPULATION | 200,000



SOUTH KING COUNTY
POPULATION | 207,973



SOUTH + EAST TACOMA
POPULATION | 133,700



NORTHEAST PUYALLUP
POPULATION | 9,629

Figure 4.8 maps the identified communities within the Seattle metropolitan area against land use data, revealing a recurring trend of vulnerable populations residing in close proximity to heavy industrial and transportation land uses. These communities are predominantly situated along Western Washington’s north-south transportation corridor, primarily along Interstate 5 (I-5). This corridor not only serves as a major transportation artery, but also exposes these communities to high concentrations of toxic emissions from colocated industrial facilities, shipping ports, and vehicular traffic. The spatial analysis of these communities underscores the complex interplay between land use patterns and social vulnerability. Moving forward, the initiative emphasizes collaboration with the identified communities and environmental justice organizations. This collaborative approach aims to empower residents and leverage their unique understanding of local challenges. Additionally, Ecology plans to expand air quality monitoring within these communities to gain a more precise understanding of pollution levels and their impact. Ultimately, the initiative seeks to develop targeted strategies to reduce exposure to criteria air pollutants and create a cleaner, healthier environment for these overburdened communities.

FIG 4.8 Overburdened Communities Highly Impacted by Air Pollution Land Use Trends. (2024). Daquan Proctor.

South Seattle

South Seattle, a 44-square-mile community in King County, exemplifies the environmental justice concerns addressed by this initiative and will be the primary focus area for further exploration in this thesis. South Seattle, identified by the pink boundary in Figure 4.9, encompasses a diverse mix of industrial areas, major transportation hubs like the Port of Seattle and Seattle-Tacoma International Airport, and residential neighborhoods home to nearly 200,000 residents.

This community faces a disproportionate burden of air and environmental pollution. High levels of PM2.5, criteria air pollutants, and volatile organic compounds impact the area, likely due to heavy industry, port operations, and heavy traffic in the Duwamish Valley (Washington State Department of Ecology, 2023). Despite currently being in attainment with the national ambient air quality standards for criteria air pollution, South Seattle suffers from some of the highest pollution levels in Washington. This is supported by extensive air quality monitoring data collected from five Ecology monitors. The wealth of data available on this community stems from numerous academic and community-driven studies focused on the Duwamish Valley.

South Seattle also houses a large population vulnerable to air pollution, including people of color, low-income residents, and those with limited English proficiency. The community experiences concerning rates of asthma and lower life expectancy compared to the state average. South Seattle's inclusion as an overburdened community stems from its ranking on the Washington Environmental Health Disparities Map and EJScreen demographics, coupled with elevated levels of PM2.5 and cumulative air pollution. Furthermore, the Climate and Economic Justice Screening Tool and Environmental Justice Index identify most of this area as highly impacted. Public comments during the initiative highlighted concerns about specific sources like the airport, industry, and major transportation corridors. The inclusion of areas south to the SeaTac airport reflects the interconnected nature of air quality concerns.

South Seattle Land Use Adjacencies

South Seattle also houses a large population vulnerable to air pollution, including people of color, low-income residents, and those with limited English proficiency. The community experiences concerning rates of asthma and lower life expectancy compared to the state average. South Seattle's inclusion as an overburdened community stems from its ranking on the Washington Environmental Health Disparities Map and EJScreen demographics, coupled with elevated levels of PM2.5 and cumulative air pollution. Furthermore, the Climate and Economic Justice Screening Tool and Environmental Justice Index identify most of this area as highly impacted. Public comments during the initiative highlighted concerns about specific sources like the airport, industry, and major transportation corridors. The inclusion of areas south to the SeaTac airport reflects the interconnected nature of air quality concerns.

Understanding the independent sources of pollutants is crucial for comprehending their spatial distribution across a region. However, what holds even more significance is the adjacencies of these sources to each other and to vulnerable land uses. While numerous communities within this area exhibit unique land use conditions, South Park emerges as a focal point for analysis. This neighborhood's distinctive characteristics, including its proximity to industrial zones, transportation infrastructure, residential areas, and civic/commercial spaces, make it an example of complex land use adjacencies.

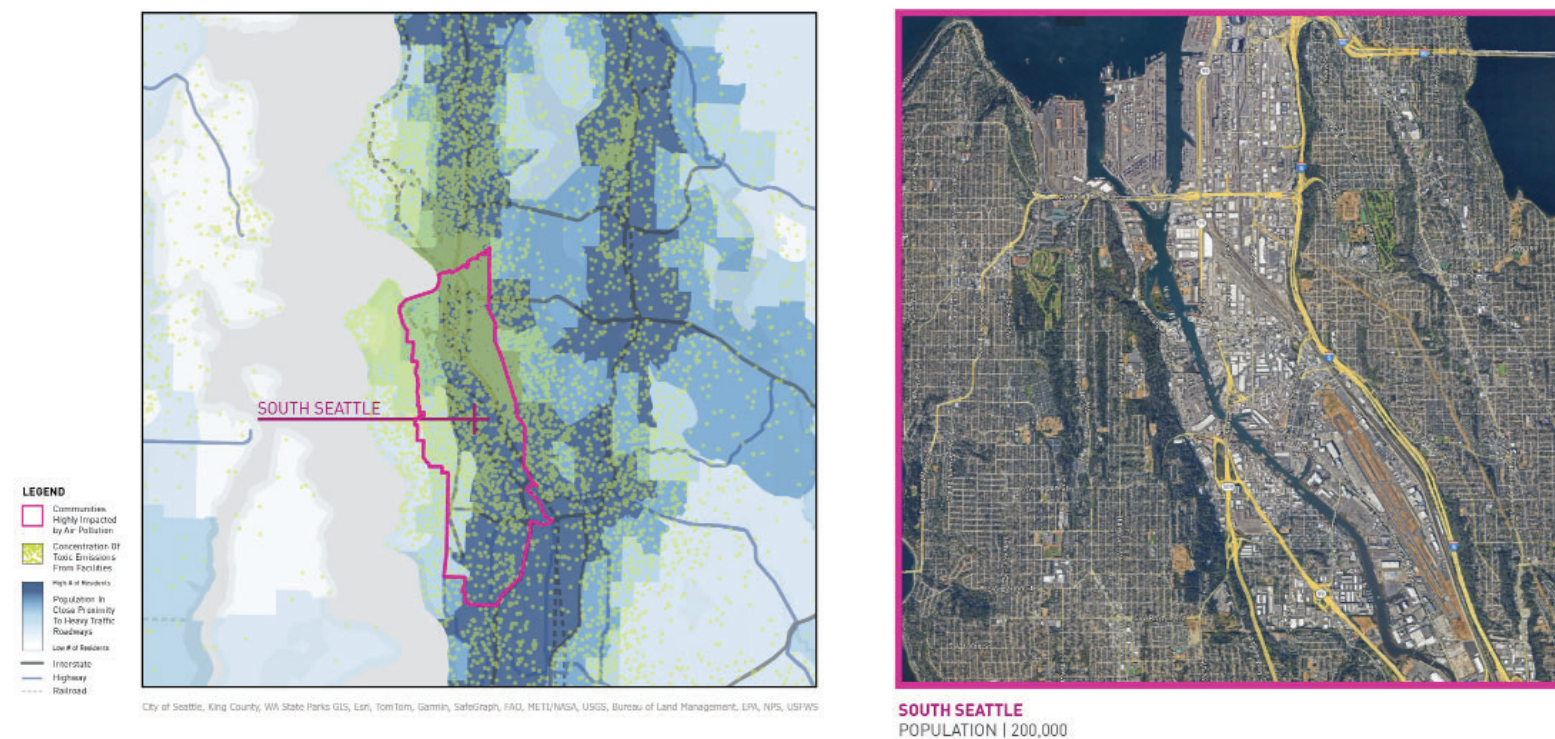


FIG 4.9 South Seattle Land Use Trends. (2024). Daquan Proctor.

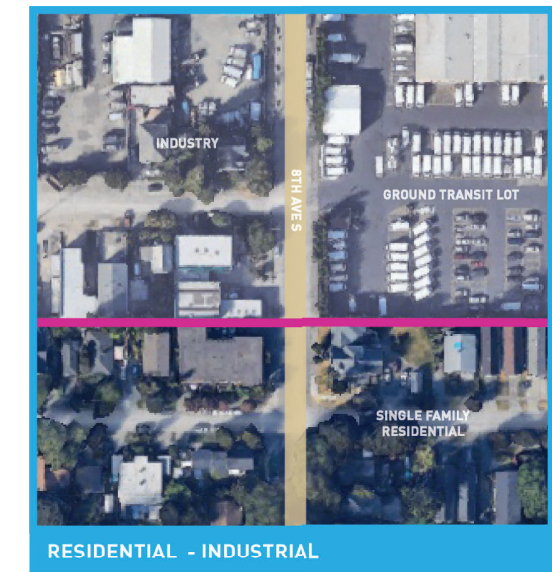
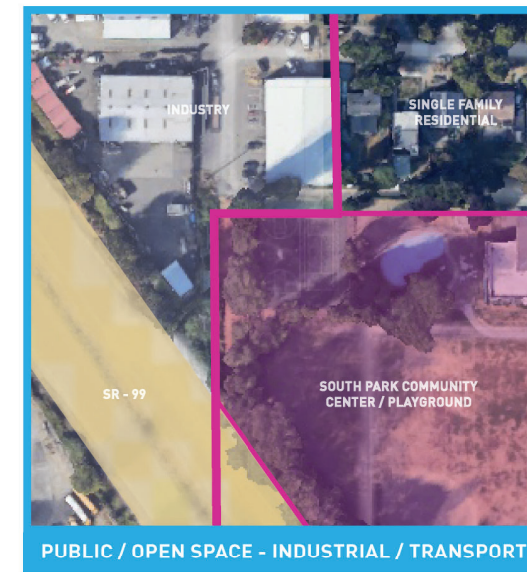
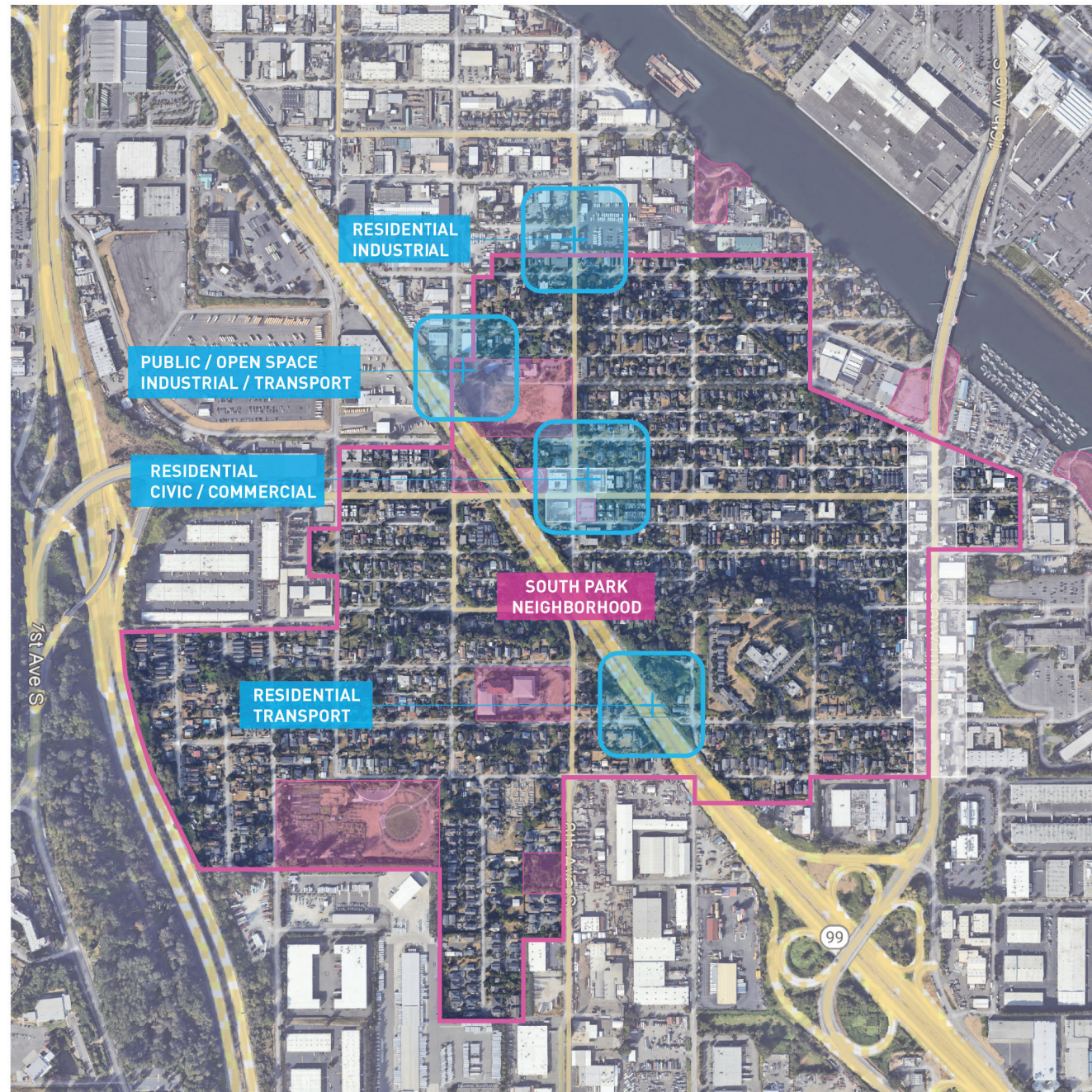


FIG 4.10 Identified Land Use Mix Conditions. (2024). Daquan Proctor.

To develop a deeper understanding of these dynamics, four distinct land use mixes, illustrated in Figure 4.10 have been identified for examination. These mixes serve as lenses through which existing land use adjacency conditions can be studied, ultimately guiding the development of responsive built environment interventions. The identified land use mixes include:

- Public Open Space - Industrial / Transportation
- Residential - Industrial
- Residential - Civic / Commercial
- Residential - Transportation

To gather comprehensive insights, site walks were conducted for each of these land use mixes. During these site visits, field photography and detailed observations were carried out to document the current conditions, including the strengths, challenges, and opportunities for intervention. These site walks involved systematic exploration and assessment of each area, ensuring a thorough understanding of the real-world implications of land use adjacencies.

Public Open Space - Industrial / Transportation

South Park Playground is one of the few public open spaces in South Park, Seattle, serving as a crucial community hub within the larger South Park Community Center complex. This park, a vital space for outdoor recreation, supports vulnerable populations, including youth and elders, fostering physical health and social interaction. However, its location adjacent to SR-99, a moderately trafficked highway, and nearby industrial activities to the north, presents significant environmental challenges (Figure 4.11).

The existing planting buffer between the highway and the park is underutilized, offering limited protection against vehicle emissions. This buffer, primarily composed of deciduous trees, becomes ineffective during winter months when the trees shed their leaves, reducing their ability to filter pollutants. Additionally, the buffer is discontinuous, with gaps between plantings and insufficient low-level shrub growth, allowing pollutants to travel unimpeded under the tree canopies.

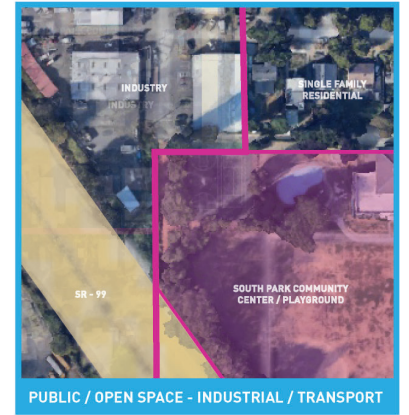
The inadequate buffer extends around the northern end of the park, providing minimal separation from the adjacent industrial zone. This industrial area is characterized by high concentrations of impervious surfaces, intensifying the urban heat island effect and accumulating dust and debris from industrial activities. The underdeveloped streetscapes, with long stretches of monolithic facades and minimal greenery, fail to offer environmental benefits such as pollutant filtration and temperature regulation.

The industrial roads, lined with unimproved surfaces, contribute to air quality issues as particulate matter resuspends under windy conditions. This creates dust storms that not only affect the park but also the adjacent residential areas. The lack of effective vegetation in this zone exacerbates these issues, as there is little resistance to the wind tunnels formed by the large, blank facades.

To mitigate these impacts, South Park Playground would benefit from a more effective vegetation strategy. This could include diverse plantings that provide year-round coverage and better air filtration, as well as more comprehensive low-level shrub growth to block pollutants at ground level. Improving the industrial streetscapes with greenery and developing more resilient landscaping practices could significantly enhance the environmental quality and community health in South Park.



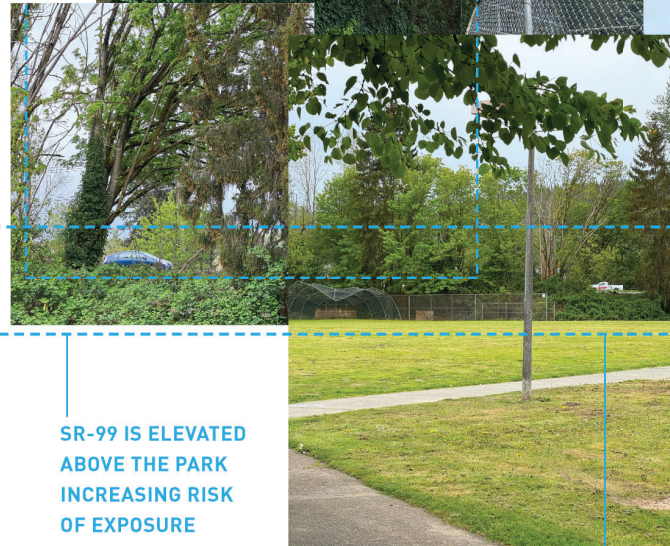
FIG 4.11 Public Open Space - Industrial Transportation Site Map. (2024). Daquan Proctor.



TREES IN PLANTING BUFFER ARE PRIMARILY DECIDUOUS PROVIDING MINIMAL WINTER PROTECTION

VULNERABLE USES SITED IN CLOSE PROXIMITY TO TRANSPORTATION + INDUSTRIAL ACTIVITY

INDUSTRIAL STREETSCAPES ARE UNDERDEVELOPED WITH SPANS OF BLANK FACADES, UNIMPROVED ROADS AND MINIMAL PLANTING



SR-99 IS ELEVATED ABOVE THE PARK INCREASING RISK OF EXPOSURE



LANDSCAPED AREAS ARE PRIMARILY MOWN LAWN THAT PROVIDES MINIMAL AIR QUALITY BENEFIT + HIGH MAINTENANCE



PLANTING BUFFER IS DISCONTINUOUS WITH SEVERAL GAPS, MINIMAL SHRUB / LOW GROWTH, AND UNDERUTILIZES THE AVAILABLE WIDTH FOR PLANTING

INDUSTRIAL ROADS HARBOR DUST AND PARTICULATE MATTER THAT RESUSPEND UNDER WINDY CONDITIONS, CREATING DUST STORMS IMPACTING ADJACENT AREAS



FIG 4.12 Public Open Space - Industrial Transportation Field Observations. (2024). Daquan Proctor.

Residential - Industrial

In South Park, Seattle, multiple factors converge to exacerbate air quality impacts and environmental concerns, particularly along 8th Ave S, a major north-south neighborhood thoroughfare (Figure 4.13). As a collector arterial, 8th Ave S serves as a crucial route for both neighborhood and industrial traffic, with street types ranging from urban village neighborhoods to industrial access zones depending on the land use zoning. This results in high volumes of traffic, including a significant proportion of trucks and heavy-duty vehicles, which emit high concentrations of harmful diesel NOx emissions.

The lack of a separated bike lane on 8th Ave S means that bicycles share the street with vehicular traffic. This, combined with the absence of roadside planting to buffer cyclists and pedestrians from vehicular emissions, places individuals engaging in active transportation at heightened risk of exposure to polluted air. The environmental concerns are further compounded by the residential-industrial adjacencies in the area.

In South Park, residential blocks often abut industrial blocks with minimal or no buffer, and in some instances, residential and industrial land uses exist on the same block with less than 10 feet of physical separation. This close proximity allows polluted air to infiltrate residential buildings through natural ventilation pathways and building envelope vulnerabilities. Many residential properties rely on natural ventilation to cool their homes and show visible signs of envelope vulnerabilities, allowing contaminated outdoor air to compromise indoor air quality.

Furthermore, these residential properties often have little to no planting in their yards or adjacent rights-of-ways, which could otherwise provide filtration and buffering from pollutants. The lack of vegetation exacerbates the air quality issues, leaving residents with minimal protection against the emissions from nearby industrial activities and heavy traffic.

To address these challenges, it is crucial to implement strategic green infrastructure along 8th Ave S. This could include the introduction of separated bike lanes and planting along sidewalks and roadways to enhance natural air filtration and provide a buffer for cyclists and pedestrians. Additionally, creating more substantial buffers between residential and industrial zones, and enhancing building envelopes to minimize air infiltration, could improve indoor air quality for residents.

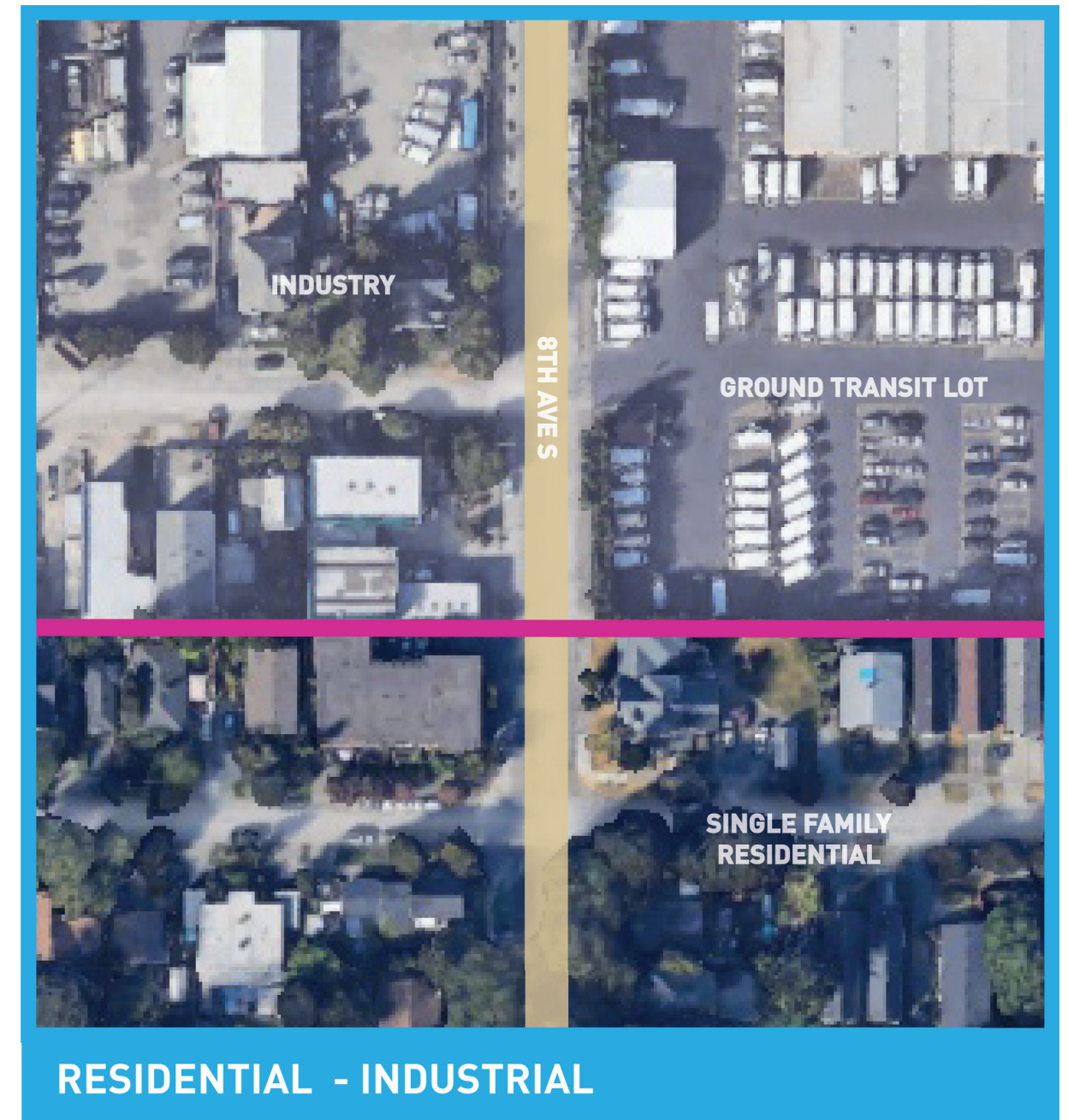
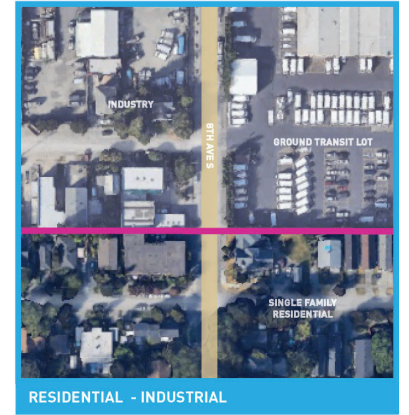


FIG 4.13 Residential - Industrial Site Map. (2024). Daquan Proctor.



INDUSTRIAL ROADS HARBOR DUST AND PARTICULATE MATTER THAT RESUSPEND UNDER WINDY CONDITIONS, CREATING DUST STORMS IMPACTING ADJACENT AREAS

CLOSE PROXIMITY TO HIGH CONCENTRATIONS OF TRANSPORT FLEETS

SAME BLOCK RESIDENTIAL INDUSTRIAL ADJACENCIES WITH MINIMAL BUFFER

INFILTRATION OF POLLUTED AIR THROUGH NATURAL VENTILATION AND BUILDING ENVELOPE VULNERABILITIES

EXISTING STREETSIDE AND YARD PLANTINGS PROVIDE MINIMAL RESIDENTIAL BUFFER



HIGH CONCENTRATIONS OF IMPERVIOUS SURFACES + UNDERDEVELOPED STREETSAPES INTENSIFY AIR QUALITY IMPACTS

WIDE SIDEWALKS AND ROADWAYS ARE UNDERUTILIZED FOR POTENTIAL AIR QUALITY BENEFIT, HOWEVER EFFORTS ARE BEING MADE TO IMPROVE THE STREETScape

RESIDENTIAL INDUSTRIAL ADJACENCIES WITH MINIMAL TO NO PLANTING BUFFER

STREETScape PLANTING IS ON SIDEWALK INTERIOR PROVIDING MINIMAL PROTECTION TO PEDESTRIANS + BICYCLISTS SHARE THE ROAD WITH VEHICULAR TRAFFIC

FIG 4.14 Residential - Industrial Field Observations. (2024). Daquan Proctor

Residential - Civic / Commercial

One of the largest environmental challenges impacting residential areas in South Park is the documented decline in urban canopy, occurring at a faster rate in the Duwamish Valley and South Park specifically (Figure 4.15). Reasons for this decline include urban development, such as tree-displacing construction or sidewalk upgrades, increased stressors resulting from climate change, and aging trees. This decline is especially concerning in South Park, one of Seattle's most underserved neighborhoods in terms of urban canopy.

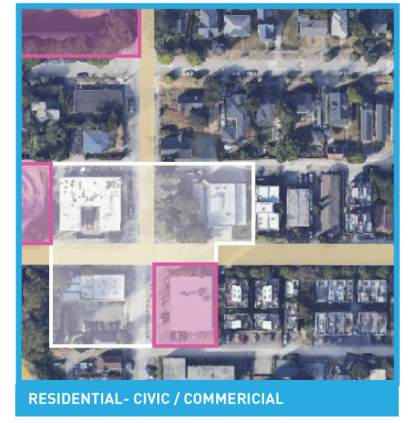
Single-family residential streets in South Park have planting strips with considerable widths to support larger trees. However, neighborhood commercial streets, such as S Cloverdale Street, have little to no area dedicated to planting strips and limited presence of street trees. Beyond planting, residential streets typically have low vehicle volumes, supporting active transportation like walking and biking in the street. Streets such as S Thistle Street and 10th Ave S have implemented "healthy streets" initiatives, closing roads to through traffic and permitting only local vehicular access. This frees up the road for walking, biking, and playing, laying the groundwork for future neighborhood greenways.

However, these active transportation accommodations and infrastructure lose connectivity outside of residential streets when crossing major neighborhood arterials such as S Cloverdale Street and 8th Ave S. These arterials lack dedicated bicycle infrastructure and have sidewalks of varying conditions. The lack of walkable neighborhood amenities exacerbates vehicle dependency, discouraging active transportation. Moreover, higher-density development along S Cloverdale Street, characterized by long, unmodulated facades, creates urban street canyon conditions. These conditions trap air pollutants at the street level due to altered airflow patterns, resulting in higher pollutant concentrations even without considering the higher traffic volume S Cloverdale Street supports.

To address these challenges, improving the streetscape with more planting, pedestrian-friendly designs, and enhanced connectivity between residential areas and key destinations is essential. Incorporating evergreen and low-growing plants in residential planting strips and yards can help rebuild the urban canopy, providing year-round air filtration and aesthetic benefits. Specifically, along S Cloverdale Street, implementing dedicated bike lanes and improving sidewalk conditions with added buffers between pedestrians and vehicular traffic would enhance safety and connectivity. This would encourage more residents to engage in active transportation, reducing reliance on vehicles and subsequently lowering emissions. Moreover, creating attractive destinations within neighborhood commercial and residential zones, such as markets, parks, plazas, and community centers, can promote active transportation by providing residents with accessible and appealing places to walk, bike, and gather.



FIG 4.15 Residential - Civic / Commercial Site Map. [2024]. Daquan Proctor.

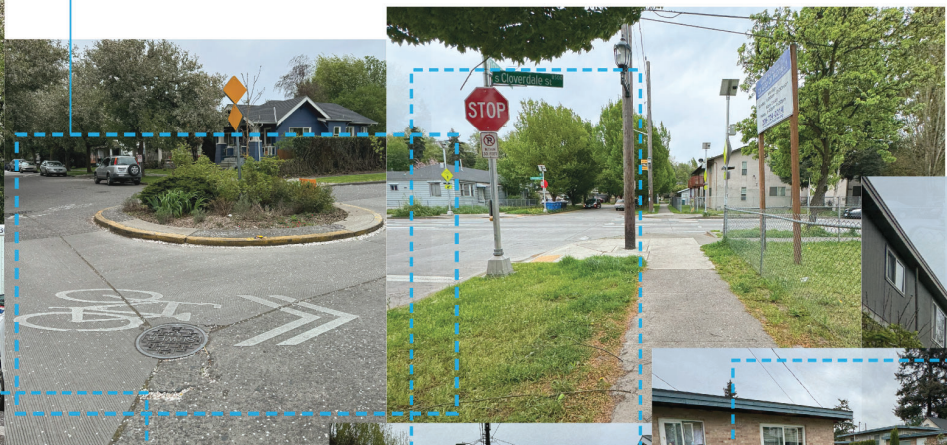


RESIDENTIAL- CIVIC / COMMERCIAL

RESIDENTIAL PLANTING STRIPS + YARDS CONTAIN MINIMAL EVERGREEN + LOW GROWTH PLANTS, LIMITING AIR QUALITY BENEFITS



BICYCLE CONNECTIVITY FROM RESIDENTIAL STREETS TO CLOVERDALE IS CHALLENGE BY LACK OF DEDICATED / SHARED ROAD USE



TRAFFIC POLLUTION INFILTRATION THROUGH NATURAL VENTILATION + ENVELOPE VULNERABILITIES



SIDEWALK INFRASTRUCTURE UPGRADES



URBAN DEVELOPMENT, CLIMATE CHANGE, AND AGING TREES ARE LEADING CAUSES OF DECLINING URBAN CANOPY



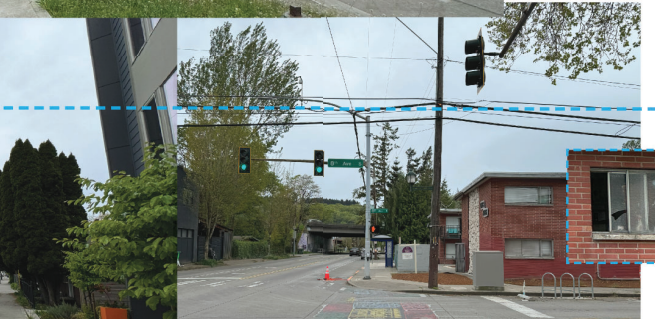
LOCAL ACCESS STREET CLOSURES REDUCE VEHICULAR EMISSIONS IN RESIDENTIAL AREAS AND PROMOTE ACTIVE TRANSPORT



SIDEWALK CONDITION ALONG CLOVERDALE IS VARIABLE WITH MINIMAL TO NO BUFFER



HIGHER DENSITY DEVELOPMENT WITH LONG SPANS OF MONOLITHIC FACADES CREATE URBAN CANYONS



NEIGHBORHOOD COMMERCIAL / CIVIC ZONE STREETScape IS UNDERUTILIZED / HAS FEW DESTINATIONS THAT ENCOURAGE ACTIVE TRANSPORTATION

FIG 4.16 Residential - Civic / Commercial Field Observations. (2024). Daquan Proctor

Residential - Transportation

In South Park, many homes are in close proximity to the TRAP from SR-99, with unobstructed pathways for pollution dispersion from the highway into adjacent residential areas (Figure 4.17). This issue is compounded by a vast majority of homes along the highway relying on natural ventilation to cool their homes, some of which also have apparent envelope deficiencies that allow contaminated outdoor air from the highway to infiltrate and compromise indoor air quality. The surrounding residential streetscape fabric, as observed in other land use conditions, is underperforming in terms of buffering and air filtration potential. The lack of a substantial street tree canopy and buffering vegetation in the planting strip reduces the area's capacity for natural air filtration and pollution reduction. This condition extends to the highway itself, with the median and shoulders being underutilized for air filtering benefits.

Neighborhood connectivity is significantly impacted by the presence of SR-99, which divides South Park and hinders movement between different parts of the neighborhood. The narrow overpass and pedestrian Duwamish Trail running along SR-99 serve as one of only two pedestrian crossing points, limiting accessibility and exposing pedestrians to pollution from vehicular traffic. This trail and overpass is the route many neighborhood children and residents take to reach Concord Elementary or the neighborhood amenities east of SR-99.

To address these issues, enhancing green infrastructure and other physical barriers along roadways and medians is crucial. Transforming underutilized spaces into planting areas with diverse vegetation can serve as natural filters, trapping pollutants and providing noise barriers. Planting more trees and establishing robust planting buffers can improve air quality and reduce noise pollution. Improving pedestrian infrastructure by increasing crossing points over SR-99 and buffering the Duwamish Trail from SR-99 would enhance connectivity and reduce exposure to pollution. Additionally, strategies to reduce air infiltration into homes, such as filtered natural ventilation and building envelope weatherization improvements, are necessary to protect indoor air quality.



FIG 4.17 Residential - Transportation Site Map. (2024). Daquan Proctor.



NATURAL VENTILATION ADJACENT TO HEAVY TRAFFIC ROADWAY

RESIDENTIAL USE ADJACENT TO HEAVY TRAFFIC ROADWAY

HIGHWAY MEDIAN UNDERUTILIZED

RESIDENTIAL - TRANSPORT

ENVELOPE UPGRADES REDUCE AIR INFILTRATION

WEST SEATTLE HIGH-RISE BRIDGE SAFETY PROGRAM
 Reconnect West Seattle Home Zone – South Park
 Thank you for your patience and input to help shape these projects!
 More Info: 206-465-7317
 Seattle Department of Transportation
 Vision ZERO

ROADSIDE BUFFER UNDERUTILIZES AVAILABLE SPACE FOR PLANTING

MINIMAL STREET TREE CANOPY + BUFFERING PLANTING STRIP

NEIGHBORHOOD CONNECTIVITY DIVIDED BY SR-99, NARROW OVERPASS IS ONE OF TWO PEDESTRIAN CROSSING POINTS

PEDESTRIAN TRAIL RUNS ALONG HIGH TRAFFIC ROADWAY WITH MINIMAL PLANTING BUFFER BETWEEN ROADWAY

FIG 4.18 Residential - Transportation Field Observations. (2024). Daquan Proctor.

Built Environment Challenges



VULNERABLE USES
NEAR POLLUTION



COMPROMISED
INDOOR AIR QUALITY



CONCENTRATED
IMPERVIOUS SURFACES



UNDERPERFORMING
ROADSIDE PLANTING



DECLINING URBAN
TREE CANOPY



LIMITED ALTERNATE
TRANSPORTATION

FIG 4.19 Documented Built Environment Challenges to Achieving Clean Air. (2024). Daquan Proctor.

Across the four studied land use conditions, several recurring themes emerged as built environment challenges to achieving clean air (Figure 4.19).

Vulnerable Uses Near Pollution: Many residential areas, schools, community spaces, and parks are situated close to major traffic routes and industrial zones. This proximity exposes vulnerable populations, including children and the elderly, to higher levels of air pollution from vehicle emissions and industrial activities. The lack of adequate buffers and separation between these uses exacerbates the exposure and related health risks.

Compromised Indoor Air Quality: Buildings located near high pollution levels often experience compromised indoor air quality due to the infiltration of outdoor air pollutants. This can occur through natural ventilation, windows, doors, and other envelope vulnerabilities. Poor indoor air quality can lead to adverse health effects, particularly for those with pre-existing conditions.

Concentrated Impervious Surfaces: Urban areas with extensive impervious surfaces, contribute to the heat island effect and reduce the natural absorption and filtration of rainwater. Impervious surfaces can exacerbate air quality issues by reflecting and absorbing heat, which can increase the formation of ground-level ozone. These surfaces prevent natural infiltration, increasing runoff and harboring of dust and debris.

Underperforming Roadside Planting: The effectiveness of roadside planting in mitigating air pollution is often compromised by poor plant selection, inadequate maintenance, and discontinuous planting strips. Many areas lack sufficient greenery that can act as a barrier to pollutants, failing to provide the air filtration benefits of well-maintained vegetation.

Declining Urban Tree Canopy: The urban tree canopy is declining due to factors such as aging trees, urban development, and climate change. Trees play a crucial role in improving air quality by absorbing pollutants, providing shade, and cooling the urban environment. The loss of trees diminishes these benefits, making it harder to achieve cleaner air and a healthier environment.

Limited Alternate Transportation Infrastructure: There is often a lack of infrastructure to support alternative transportation modes such as cycling, walking, and public transit. This limitation forces greater reliance on personal vehicles, contributing to higher emissions and poorer air quality. Enhancing infrastructure for active transportation can reduce traffic congestion, lower emissions, and promote healthier lifestyles.

Addressing these challenges requires a comprehensive approach guided by a health equity design framework, as outlined in the next chapter. This framework is grounded in the relationship between the built environment and health outcomes, aiming to address the layered forces contributing to health disparities. It emphasizes the need to center equity in the design process to identify and address disparities in access to resources, opportunities, and environmental conditions impacting health. Emphasizing collaboration among stakeholders, evidence-based interventions, and community participation, the framework aims to create sustainable solutions that benefit all individuals, especially those in marginalized communities impacted by air pollution.



05

AIRWISE DESIGN GUIDE

This chapter outlines the Health Equity Design Framework and design strategies for improving air quality in overburdened communities highly impacted by air pollution include addressing identified built environment challenges to achieving clean air.

HEALTH EQUITY DESIGN FRAMEWORK

“AirWise: Collective Action for Clean Air” proposes to implement a multifaceted theoretical approach to establish a Health Equity Design Framework, which examines the intricate relationship between the built environment and health outcomes. This framework is informed by an array of research and theories that link health equity discourse with environmental and social determinants of health, aiming to address the layered forces contributing to health disparities. Providing a structured approach to integrating health equity considerations into the planning, design, and implementation of projects and policies. By centering equity in the design process, practitioners can identify and address disparities in access to resources, opportunities, and environmental conditions that impact health outcomes.

Core Theories and Frameworks

Health Equity

The foundation of the Health Equity Design Framework builds upon ETR’s Health Equity Framework (Peterson et al., 202). This model defines health equity as the fair access to resources and opportunities needed to achieve optimal physical, emotional, and social well-being. It emphasizes the need to address systemic forces driving health disparities by shifting focus from individual-level behaviors to population-level outcomes. This model identifies four factors influencing health equity outcomes:

- **Physiological Pathways:** Focuses on how environmental and experiential factors impact biological, physical, cognitive, and psychological abilities.
- **Systems of Power:** Analyzes historical disenfranchisement and the unequal distribution of health determinants.
- **Relationships and Networks:** Examines community resilience and advocacy.
- **Individual Factors:** Considers strategies at the personal or household level to mitigate exposure to harmful health determinants.

Environmental Justice

Theories of environmental justice contextualize the systemic inequities in the distribution of environmental risks and benefits. An extensive body of research consisting of numerous studies and meta-analyses confirm that race and class significantly influence proximity to environmental hazards. “Race, Class and Environmental Health: A Review and Systematization of the Literature” synthesized 54 studies, concluding that race and class are primary determinants of proximity to environmental hazards, alongside the extent of remediation efforts (Brown, 1995). More recently, “Assessing Evidence of Environmental Inequities” reviewed 49 studies and found ubiquitous evidence of racial disparities in environmental hazards underscoring the significant influence of race on the distribution of environmental hazards, with less conclusive evidence for class-based disparities (Ringquist, 2005). Key concepts include:

Racial and Socioeconomic Disparities: Race is the primary determinant in proximity to environmental hazards, with evidence showing that these hazards are more frequently sited in existing low-income and minority communities.

Climate Change Impacts: Marginalized communities are more severely affected by climate change, lacking the resources to adapt and mitigate its effects.

Bottom-Up Decision Making: The research emphasizes the need for bottom-up decision-making that empowers impacted and overburdened communities. Actively including and engaging minority and low-income communities in decision-making processes is essential, particularly regarding the siting of new developments with potential environmental impacts. Community involvement is crucial in deciding remediation metrics, approaches, and timelines to ensure equitable environmental health outcomes.

Social Determinants of Health (SDOH)

Social Determinant of Health framework examines how social, economic, and environmental factors influence health outcomes. According to the CDC and the Healthy People 2030 framework there are 5 categories of SDOH including: Economic Stability, Education Access and Quality, Social and Community Context, Healthcare Access and Quality, and Neighborhood and Built Environment (CDC, n.d.).

Contextualizing these social determinants within this thesis, the neighborhood and built environment emerge as particularly relevant, as they exert significant influence on air quality health outcomes.

Neighborhood and Built Environment: Living conditions, including housing quality, transportation, and access to healthy foods, impact health. Studies, such as “Poverty Area Residence and Changes in Physical Activity Level: Evidence From the Alameda County Study,” highlight the independent impact of neighborhood characteristics on mortality rates. Living in a poverty area is associated with a 50% increased risk of premature mortality, emphasizing the need to consider these factors alongside individual health characteristics (Yen & Kaplan, 1998). Neighborhoods influence health outcomes through various socioeconomic factors, community support networks, and levels of disorder (Gomez et al., 2015). The built environment, including walkability, access to health-promoting resources, and the presence of undesirable amenities, also shapes opportunities for health promotion and well-being. Neighborhoods affect health through a broader spectrum of risks, such as polluted air, extreme heat, contaminated water, and limited access to healthy foods and quality housing. These environmental conditions contribute significantly to health disparities within communities (Child Welfare League of America, n.d.). Key determinants relevant to air quality health outcomes include:

Air Quality: Poor air quality is a significant health risk, linked to respiratory and cardiovascular diseases.

Housing Quality: Substandard housing is associated with increased health issues.

Land Use: Poorly planned land use can contribute to environmental hazard exposure.

Accessibility and Transportation: Ability to reach essential services by vehicle or alternative means.

Social Infrastructure: Community spaces and support networks foster socialization and well-being.

Guiding Principles

In synthesizing the extensive research conducted for this project, it became evident that a holistic approach to urban planning and development is essential for promoting health equity. The guiding principles outlined below are derived from the critical findings of my research and are intended to serve as a foundational framework for decision-making in the design proposal. These principles emphasize the importance of prioritizing wellbeing, community involvement, interdisciplinary collaboration, evidence-driven strategies, and adaptable approaches. By incorporating these elements, the design proposal aims to create communities that support the wellbeing of all community members, particularly those in underserved areas.

Design for Wellbeing

Prioritize physical, mental, and social health in urban planning and development initiatives. Create environments that foster healthy behaviors, promote social connections, and enhance overall well-being. This involves designing communities with healthy housing, accessible green spaces, and safe pathways for physical activity. Support social life through mixed-use developments and inclusive gathering spaces.

Bottom-Up Approach

Ensure that community voices and needs drive the planning and implementation processes by actively involving community members in identifying needs, setting priorities, and developing solutions. Leverage the expertise and lived experiences of residents and support capacity building to strengthen local organizations and leaders. Use workshops, focus groups, and public forums for co-creating interventions.

Interdisciplinary Collaboration

Foster partnerships across disciplines with public health experts, urban planners, architects, landscape architects, social workers, environmental scientists, policymakers, community leaders, activists, and other stakeholders to develop comprehensive teams and provide holistic health equity design interventions.

Evidence-Driven Interventions

Utilize research and data to inform development of health equity strategies. Synthesize existing research to identify effective interventions and best practices. Develop evaluation frameworks to assess the impact of interventions, track progress, and make data-driven adjustments. Ensures that research findings are effectively communicated to stakeholders for informed decision-making and advocacy.

Adaptable and Tactical Approaches

Implement flexible, preferably low-cost, and context-specific solutions that can be adjusted based on community needs and feedback.

GROUNDING COMMUNITY INITIATIVES

The Health Equity Design Framework emphasizes the importance of a bottom-up approach, ensuring that community voices and needs drive the planning and implementation process. While direct community engagement in developing air quality interventions was outside the scope of this thesis due to time limitations, it grounds itself in ongoing community initiatives to build capacity around existing goals and work in the Duwamish Valley.

DRCC, the primary organization centralizing community health and equity initiatives in the Duwamish Valley, focuses on improving local air quality as a key action area. The Cumulative Health Impact Analysis (CHIA) conducted in 2013 by DRCC/TAG and Just Health Action highlighted alarming levels of air pollution in neighborhoods like Beacon Hill, Georgetown, and South Park (ZIP code 98108), primarily due to industrial emissions, vehicular traffic, and other sources (Cummings & Gould, 2013). The analysis reveals that these areas have the highest concentrations of diesel and benzene particles in Seattle, along with significant pollution from waste sites listed in the Toxic Emissions Inventory. This environmental burden has tangible health consequences, with residents facing increased risks of developing asthma, especially among vulnerable groups like children, the elderly, and foreign-born residents. The disparities are stark, with residents in South Park and Georgetown experiencing significantly shorter life expectancies compared to wealthier neighborhoods like Laurelhurst in North Seattle.

Clean Air Program

DRCC launched the Duwamish Valley Clean Air Program in 2014, building on the priorities set in the 2009 Duwamish Valley Vision Plan responding to community input (Duwamish River Community Coalition, n.d.). The program aims to improve air quality and reduce asthma rates and other health disparities among residents in the Duwamish Valley. It employs a bottom-up, community engagement approach to advance health equity. DRCC collaborates with private and public agencies through community science projects, storytelling events, and research partnerships to identify and prioritize actions that promote respiratory health. Key initiatives include the Duwamish Vision Plan and Map, Healthy Home Impact Assessment, Fan Filter Distribution, and climate justice platforms. The program's current focus is on employing "turn the curve thinking" to pinpoint root causes of asthma rates and develop an action plan with measurable outcomes.

Clean Air Action Plan

The Clean Air Action Plan, developed through a 16-month, racially equitable, results-based accountability process, includes specific, actionable steps to achieve these goals (Duwamish River Community Coalition, n.d.). This action plan emphasizes community involvement, feedback, consultation, and engagement to address the root causes of air pollution and promote accountability and collaboration. The Clean Air Action plan proposes four pathways to reduce asthma in the Duwamish Valley, as summarized in Figure 5.1 and the list below:

Transportation Emissions: Implement measures to reduce emissions from transportation within the Duwamish Valley, including advocating for cleaner transportation policies and technologies.

Industrial and Construction Emissions: Work towards changing laws to lower pollution and emissions from industrial and construction sources, ensuring stricter enforcement of existing regulations.

Indoor Air Quality: Focus on improving indoor air quality in housing, schools, and community spaces through various interventions, such as better ventilation and the use of air purifiers.

Green Spaces and Community Science: Increase community green spaces, which can filter air pollutants, and support community science activities to engage residents in monitoring and improving air quality.



In a Glimpse: Duwamish Valley Clean Air Program Action Plan

We would love to hear from you! Please join us in upcoming community participatory Clean Air Program events and opportunities to inform the action plan and additional ongoing efforts to advance health equity and climate justice in the Duwamish Valley!

Contact Adrienne at adrienne@drcc.org



Acknowledgements: DRCC Coalition members, Duwamish Valley Community (representation from South Park and Georgetown), DRCC Technical Advisors, American Lung Association, City of Seattle, Seattle Office of Sustainability & Environment, Concord Elementary, DIRT Corps, Environmental Protection Agency, EarthJustice, Duwamish Valley Youth Corps, King County International Airport, Front and Centered, Just Health Action, Port of Seattle/Northwest Seaport Alliance, Public Health Seattle King County, Puget Sound Clean Air Agency, Puget SoundKeeper, The Nature Conservancy, Seattle Parks Foundation, South Neighborhood Association, Western Washington University, Urban Waters Federal Partnership, US Forest Service, SeaMar, the UW EDGE Center and community advocates!

FIG 5.1 In a Glimpse: Duwamish Valley Clean Air Action Plan. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/clean-air-program>.



photo: DVYC

Action Plan Progress

Improving air quality, reducing rates of asthma, and additional health disparities among Duwamish Valley residents is a top priority.

Through research, community-led action, and policy all focused on reducing air pollution, the Duwamish Valley Clean Air Program participants strive to reduce a wide range of health impacts by acting on specific activities following firm accountability measures to advance climate justice and health equity in the Duwamish Valley.

Using a holistic approach, the strategies of the clean air action plan were designed in partnership with community to “turn the curve” of childhood asthma hospitalization rates with specific actions and progress indicators.

In 2020, we brought together over 25 partners consisting of government agencies, non-profit organizations, academic institutions, and community members to engage in a 16 month Results Based Accountability (RBA) process that centers racial equity to develop the Air Action Plan to reduce asthma prevalence in the Duwamish Valley.



Reducing vehicle emissions in the Duwamish Valley

- **Puget Sound Clean Air Agency (PSCAA)** has received grant funding to replace ten diesel-fueled yard trucks in with all-electric yard trucks and supports air education with free box fan events in the Duwamish Valley. PSCAA has partnered with Villa Comunitaria for EV carshares.
- **Front & Centered** trained interested communities on transportation justice, mobility mapping, and the policy process. Recently awarded \$400,000 to shape implementation of the Healthy Environment for All (HEAL) Act and create an Environmental Justice Community Participation Fund.
- **City of Seattle Office of Sustainability** has been working closely with the DRCC, African Chamber of Commerce, International Council on Clean Transportation, and community to create an equitable implementation plan to offer city funded incentives for the purchase or lease of new electric drayage trucks, including charging stations funded by Seattle City Light.
- **King County International Airport Community Coalition (KCIACC)** focuses on eliminating impacts of leaded fuels in state policy and passing a county ordinances to eliminate the negative impacts King County International Airport (KCIA) has on Duwamish Valley neighbors by opposing the expansion and relocation of the airport’s leaded fuel farm to accommodate an increase in flight operations.
- **Northwest Seaport Alliance/Port of Seattle:** Clean Truck Program and regional clean truck collaborative continue to make progress.

Reduce pollution from industry and other source emissions through existing legal means

- **Puget Sound Clean Air Agency (PSCAA)** has elevated equity and environmental justice in its strategic plan for the next 7 years.
- **Earth Justice and DRCC** continue to advocate through city, state, and federal rule making to reduce emissions from freight and transit corridors in the Duwamish Valley.
- **Western Washington** with Dr. Abel developed materials to teach youth about pollution disparity mapping, established a statistical rationale for moss samples, producing a ground truth of the antiquated air quality regulations and inflexible monitoring systems operated by clean air authorities.
- **The Nature Conservancy** continues to support community organizations and leaders with education and policy support to help shape the Department of Ecology’s overburdened communities’ initiative.
- **Front & Centered** is working closely with community to develop and define the concept of “overburdened communities” for policy recommendations along with DRCC and many more!

Improve indoor air quality in multifamily housing as well as community spaces and schools

Puget Sound Clean Air Agency (**PSCAA**) for calendar year 2022, in collaboration with Duwamish River Community Coalition (DRCC) distributed:

- Duwamish River Festival, 102 filters, 45 fans
- DRCC World Asthma Day, 400 filters, 100 fans
- South Park Senior Center, 80 filters, 25 fans
- Tukwila Community Center, 150 filters, 85 fans
- Four social media smoke-ready posts, includes filter-fans
- **One Roof Foundation** supported the installation of HEPA indoor air purifiers in all 42 Concord School classrooms in collaboration with UW EDGE Center Assisted DRCC, Concord School and + maintenance & use training. Submitted grant request for indoor/outdoor air quality monitoring and low-cost filters for DV homes with children with asthma.
- **University of Washington & (UW) EDGE Center** ongoing assistance for indoor air filters at Concord and looks forward to launching the asthma intervention project for families with DRCC and partners.
- **American Lung Association** conducted ~26 healthy home assessments through partnerships with DRCC and community health workers.
- **King County** asthma program provides community health worker visits. Many participants also receive HEPA air filter. DRCC working with King County to grow programming in the Duwamish Valley

Improve outdoor air quality through physical environmental changes

- **PSCAA** concluded air toxics (antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, mercury, selenium) samples study conducted at Seattle College Campus, Georgetown home, South Park, South Park industrial area, Georgetown Steam Plant.
- **UW EDGE Center** Ultrafine air particle (UFP) data collection in flight path neighborhoods, including DV, and SeaTac area schools. Phase 1 Healthy Air, Healthy Schools study complete; data collection for effect of green infrastructure on UFP air quality ongoing.
- **City of Seattle Office of Sustainability** invested \$75,000 in maintenance of existing green infrastructure in the Duwamish Valley, \$300,000 in engagement for and implementation of greening efforts, including tree planting on private properties in the industrial areas of South Park and Georgetown, and ensuring maintenance and establishment continue in future years.
- **Seattle Parks Foundation** secured \$46K in private funding for Duwamish Valley Youth Corps & DIRT Corps tree canopy project in 2022.

FIG 5.2 Clean Air Action Plan Progress. (n.d.). Duwamish River Community Coalition <https://www.drcc.org/clean-air-program>.

DRCC and their partners have made substantial progress in implementing actionable measures towards the goals of the Clean Air Program Action Plan, as outlined in Figure 5.2. Below is a select overview of the various Duwamish Valley programs, initiatives, and studies spearheaded by DRCC, along with other community-driven efforts synergistic with the goals outlined in the Clean Air Program Action Plan. These initiatives are informative to the development of interventions investigated in this thesis, demonstrating a comprehensive approach to improving air quality and promoting health equity.

Duwamish Valley Youth Corp (DVYC) Moss Study



FIG 5.3 DVYC Members Collecting Moss Sample. (2021). Duwamish River Community Coalition. <https://www.drcc.org/moss-study>.
FIG 5.4 DVYC Members Preparing Moss Samples for Analysis. (2021). Duwamish River Community Coalition. <https://www.drcc.org/moss-study>.

The “DVYC Moss Study” conducted between 2019 and 2021 in partnership with the Duwamish River Community Coalition’s Clean Air Program is a community science project aimed at measuring indicators of metal pollution in the Duwamish Valley (Duwamish River Community Coalition & U.S. Forest Service, 2021). The study is part of ongoing efforts to create a healthier living and working environment in the area, aligned with the community’s vision outlined in the Duwamish Valley Vision 2009.

Metals are naturally present in the environment, but urban and industrial zones often experience elevated levels due to various sources like traffic and industrial activities. These metals, when airborne as small particles, can pose health risks when inhaled, particularly affecting the respiratory system.

The study involved collaboration between the Duwamish Valley Youth Corps, federal scientists from the US Forest Service, local government bodies, universities, community leaders, and health advocates. The Youth Corps, composed of 26 Duwamish Valley teenagers, learned how to collect and prepare moss samples from street trees (Figure 5.3/5.4). Moss serves as a bioindicator of air pollution, especially heavy metals. This grassroots effort aimed to assess metal pollution levels in Georgetown and South Park, informing strategies to mitigate air pollution and improve community health.

Partners in the study included the Duwamish Infrastructure Restoration Team (DIRT Corps), Just Health Action, Street Sound Ecology, City of Seattle’s Office of Sustainability and Environment, Western Washington University’s Huxley College of the Environment, and the University of Washington’s Department of Environmental and Occupational Health. Key findings from the “DVYC Moss Study” included:

- The ability of trained local youth to collect scientifically reliable moss samples, demonstrating the efficacy of community-based participatory research.
- Elevated levels of Arsenic, Chromium, Cobalt, and Lead in moss samples from the Duwamish Valley compared to similar studies in Seattle parks and residential areas of Portland, Oregon. Arsenic and Chromium levels were notably higher, with concentrations approximately twice as high as in Portland.
- Higher metal concentrations observed in industrial areas of South Park and Georgetown along the Duwamish River, indicating localized pollution sources.

These findings underscore the importance of community involvement in environmental monitoring and highlight areas for targeted interventions to reduce metal pollution and safeguard the health of Duwamish Valley residents.

Duwamish Valley Youth Corp (DVYC) Tree Planting



FIG 5.5 DVYC Advertising Neighborhood Tree Giveaway. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/duwamish-valley-youth-corps>

FIG 5.6 DVYC Members During Tree Planting Initiative. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/duwamish-valley-youth-corps>

The Duwamish Valley Youth Corps (DVYC) is a youth engagement program established by DRCC committed to enhancing environmental and community resilience, primarily focusing on improving water quality through various youth driven initiatives (Duwamish River Community Coalition, n.d.). While these efforts are mainly centered around water quality, they also have synergistic benefits for air quality. DVYC plays a pivotal role in addressing stormwater pollution and enhancing water quality while also showcasing the community's capacity for restoration and green infrastructure projects.

One of their primary initiatives is creating rain gardens, which serve as natural filters for stormwater, preventing pollutants from reaching water bodies and indirectly supporting cleaner air (UW Department of Environmental and Occupational Health Sciences, n.d.). Their involvement in composting soils further adds to these efforts, as the nutrient-rich compost aids in healthier plant growth. Additionally, DVYC actively engages in tree planting, strategically planting trees in underserved areas, increasing urban tree canopy and reducing urban heat island effect (Figure 5.5/5.6). Moreover, DVYC's emphasis on supporting native habitats and promoting green spaces has a direct positive impact on environmental resilience and air quality. By removing non-native plant species and encouraging native vegetation, they create ecosystems that support cleaner air through natural processes like carbon sequestration and oxygen production.

Duwamish Air Improvement Study for Youth (DAISY)



FIG 5.7 Box Fan Filter Community Education Event. (n.d.). Duwamish River Community Coalition. <https://www.drcc.org/clean-air-program>.

FIG 5.8 DAISY Community Advocacy Team Members. (n.d.). Duwamish River Community Coalition. <https://deohs.washington.edu/edge/>

The Duwamish Air Improvement Study for Youth (DAISY) is a joint effort between University of Washington researchers and Duwamish Valley community advocates, supported by a five-year grant from the National Institute for Environmental Health Sciences (NIEHS) (Duwamish River Community Coalition, n.d.). This project targets the high rates of childhood asthma in Seattle's South Park and Georgetown neighborhoods, which have the highest childhood asthma hospitalization rates in the city according to a 2013 community-led study funded by the Environmental Protection Agency (Cummings & Gould, 2013). Residents in these neighborhoods face higher levels of air pollutants like diesel emissions and particulate matter, known to trigger asthma attacks, which can easily infiltrate homes and classrooms where children spend most of their time.

The NIEHS grant is in the process of establishing a community-based air quality monitoring network to track pollutants from car and truck traffic. Participants will receive a healthy home assessment to identify and monitor various asthma triggers. In addition, the project will distribute low-cost box fan air filters, illustrated in Figure 5.7, to families with asthmatic children in South Park and Georgetown, aiming to improve the air quality inside their homes. The study will evaluate the effectiveness of these air filters by measuring improvements in indoor air quality and changes in the children's asthma symptoms.

A key part of the DAISY project is the formation of a local Community Advocacy Team seen in Figure 5.8. This team will help decide where to place the air monitors and how to use the study results to push for policy changes and local initiatives to enhance air quality and children’s health. Through these comprehensive measures, DAISY aims to create a healthier living environment for the children of South Park and Georgetown, addressing the root causes of asthma and improving overall community health.

Reconnect South Park



FIG 5.9 DVYC Engagement Event at the Georgetown Steamplant. (n.d.). Reconnect South Park. <https://reconnectsouthpark.org/rsp-media>.
FIG 5.10 Reconnect South Park Community Engagement Event. (n.d.). Reconnect South Park. <https://reconnectsouthpark.org/rsp-media>.

This project is funded by a Department of Transportation Reconnecting Communities and Neighborhoods Grant, which aims to revitalize neighborhoods that have been historically burdened by transportation infrastructure. Beginning in 2023, the Reconnect South Park Coalition engaged the South Park community and Duwamish Valley stakeholders to assess how State Route 99 (SR 99) meets their needs and explore potential improvements (Reconnect South Park, n.d.). The coalition aims to gather comprehensive input from local residents, organizations, businesses, and workers to understand their concerns and aspirations for SR 99 (Figure 5.9/5.10). The objectives include evaluating the physical, environmental, and health impacts of the highway and developing a Community Vision Plan that reflects community preferences for future changes.

The coalition will explore several strategic options for transforming SR 99 to enhance community well-being and environmental health:

Mitigate SR-99: Reduce Highway Impacts

This approach involves maintaining the current highway while mitigating its negative effects on the neighborhood. Proposed improvements include sound walls, better pedestrian access, connected greenways, new crossings, green infrastructure, and habitat restoration.

Redesign SR-99: Highway-to-Boulevard Conversion

This strategy aims to transform SR-99 into a multifunctional neighborhood boulevard through South Park. It would revise traffic infrastructure, including crossings, lights, and roundabouts, to restore residential street connections.

Remove SR-99: Reroute Traffic and Reclaim the Land

This plan proposes removing SR-99 through South Park to reclaim over 44 acres of land for community use. This reclaimed space could be used for affordable housing, community-owned businesses, greenspaces, habitat restoration, and other amenities to benefit the residents of South Park and the Duwamish Valley.

Lid SR-99: Partial Undergrounding for Pass-through Traffic

This option involves lidding a section of the highway to maintain its current pass-through functionality while exploring the potential for restored neighborhood connections, multimodal pathways, and new greenspaces.

The Reconnect South Park Coalition is committed to working towards an alternative future for SR-99 that undoes past damage and creates new opportunities. Community input will be crucial in guiding the development and evaluation framework for these alternative futures.

BUILT ENVIRONMENT CHALLENGES AND OPPORTUNITIES

Transforming the identified built environment challenges into opportunities for design interventions involved a process driven by the health equity design framework. Each challenge was viewed as a potential catalyst for evidence-based community-scale design interventions that support clean air and well-being (Figure 5.11). Through grounding the existing initiatives within the community, the aim was to uncover synergies and develop strategies that support and strengthen the community’s mission and ongoing efforts to promote equity and healthy environments.



**VULNERABLE USES
NEAR POLLUTION**



**CONTINUOUS
PLANTING BUFFER**

**TOPOGRAPHIC BUFFER /
PHYSICAL BARRIER**

AIR FILTRATION TOWER



**COMPROMISED
INDOOR AIR QUALITY**



**FILTERED NATURAL
VENTILATION**

**ENVELOPE AIRTIGHTNESS /
WEATHERIZATION**

HEALTHY MATERIALS

AIR PURIFIER / AIR FILTER



**CONCENTRATED
IMPERVIOUS SURFACES**



**DEPAVING +
REVEGETATING**

**PERMEABLE
PAVING**

PHOTOCATALYTIC PAVING



**UNDERPERFORMING
ROADSIDE PLANTING**



**AIR FILTRATION
PLANT SELECTION**

**CONTEXT RESPONSIVE
ROADSIDE PLANTING**

GREEN SCREEN



**DECLINING URBAN
TREE CANOPY**



**CLIMATE ADAPTIVE
PLANTING**

**URBAN CANOPY
EXPANSION**



**LIMITED ALTERNATE
TRANSPORTATION
INFRASTRUCTURE**



**SUPERBLOCK
STREETS**

**MULTIMODAL
CONNECTIVITY**

**SEPARATED
TRANSPORT LANES**

**MIXED USE / COMPLETE
COMMUNITIES**

FIG 5.11 Air Quality Built Environment Challenges to Opportunities. (2024). Daquan Proctor

The following sections introduce and illustrate each of these strategies in greater depth. While a single strategy may be relevant across multiple land use adjacencies and conditions, each strategy is represented within the context of a specific land use condition. Field photography serves as a tool to depict existing conditions and proposed interventions.

Each strategy section features a proposed perspective showcasing all the interventions within their setting, alongside an orthographic design drawing or axonometric view for a more detailed representation of individual strategies. These graphics are accompanied by a description of the strategy itself and relevant case studies or research that demonstrate its effectiveness in enhancing air quality.

PUBLIC OPEN SPACE - INDUSTRIAL / TRANSPORTATION



FIG 5.12 Public Open Space - Industrial / Transportation Existing Condition. (2024). Daquan Proctor.

Existing Conditions

The current landscape faces several significant challenges that impact both the environment and the community. One major concern is the proximity of vulnerable public spaces, such as the playfield, playground, courts, and community center, to heavy traffic and industrial activity. This adjacency exposes these vulnerable areas to high levels of pollution, posing serious health risks to residents, particularly for children who are more susceptible to respiratory and developmental issues caused by poor air quality.

The existing roadside planting, which serves as a buffer, is underperforming. The vegetation is discontinuous and sparse, failing to provide adequate air filtration and leaving adjacent areas susceptible to airborne pollutants. The lack of a robust green barrier means that harmful emissions from vehicles and industrial processes easily infiltrate recreational and community spaces.

The industrial zone to the north contributes significantly to local degradation of air quality. This area is characterized by minimal planting and a high concentration of impervious surfaces, such as concrete and asphalt, which exacerbate particulate matter pollution through the resuspension of dust. The high concentration of pavement intensifies the urban heat island effect, with temperatures in the industrial zone and adjacent areas being higher than in surrounding areas with less hardscape. This makes outdoor activities less enjoyable and potentially hazardous during hot weather. The combination of heavy traffic, industrial emissions, underperforming green buffers, and extensive impervious surfaces creates a challenging environment that undermines the health and well-being of the community.



FIG 5.13 Public Open Space - Industrial / Transportation Proposed Interventions. (2024). Daquan Proctor.

Proposed Interventions

To address these identified built environment challenges, a series of strategic interventions have been proposed to reduce community exposure to harmful pollutants from industry and transportation sources. One key measure is the introduction of a context-responsive roadside planting scheme, which relies on a dense, continuous strip of evergreen vegetation of varied heights. These plantings, carefully selected for their beneficial air filtration characteristics, will absorb pollutants and particulate matter, significantly reducing air pollution exposure and creating healthier outdoor community spaces.

Additionally, reshaping portions of the landscape to form topographic buffers will create natural barriers that help mitigate the spread of pollutants. These earthworks will provide additional protection by diverting polluted air and reducing its direct impact on public areas. The implementation of air filtration towers will introduce advanced technology to actively clean the air in the most polluted zones. Strategically placed, these towers will work in conjunction with natural vegetation to reduce airborne pollutants.

Addressing the industrial area to the north, reducing impervious surfaces through depaving and promoting revegetation will minimize dust resuspension and naturally filter industrial emissions. Replacing pavement with green spaces will boost ecological health and help mitigate the impacts of the urban heat island effect. Where paving is necessary, using permeable materials will reduce vehicular emissions, road dust, and surface temperatures.

Context Responsive Roadside Planting [Open Road]

Intervention Description

Context responsive roadside planting involves strategically placing vegetation along highways to achieve air quality goals. In the case of open roads, this strategy utilizes a continuous and dense planting buffer with vegetation of varying heights arranged in ascending tiers. This design aims to create a barrier effect, filtering air pollutants and improving roadside air quality with minimal planting width of 30' recommended.

Air Quality Benefit Timeframe

20 - 30 Years

Evidence

A 2019 highway field study found that tall, dense roadside vegetation can reduce downwind pollutant levels by up to 30% on average, with specific reductions of 50% for ultrafine particles, 27% for black carbon, 20% for nitrogen dioxide, and 19% for carbon monoxide (Deshmukh et al., 2019). In contrast, highly porous vegetation had little effect on particle concentrations and slightly increased gaseous pollutants. These findings suggest that dense, tall vegetation barriers can be used by urban planners to reduce traffic-related air pollution and its health impacts, though further research is needed to refine these strategies and improve predictive models.



CONTEXT RESPONSIVE ROADSIDE PLANTING [OPEN ROAD]

IN OPEN ROAD CONDITIONS ALONG A HIGHWAY, A CONTINUOUS AND DENSE PLANTING BUFFER WITH VEGETATION OF VARYING HEIGHTS ARRANGED IN ASCENDING ORDER CAN REDUCE UP TO 30% OF DOWNWIND AIR POLLUTANTS



FIG 5.14 Open Road Context Responsive Planting Intervention Diagram. (2024). Daquan Proctor

Air Filtration Plant Selection

Intervention Description

Planting the right vegetation plays a critical role in maximizing air filtration benefits of roadside strategies. While all plants offer some level of air quality improvement, their effectiveness varies greatly. Several documented traits influence a plant's ability to capture pollutants: plant type/foilage longevity, canopy density/porosity, leaf shape/complexity, and leaf surface features. Generally denser and more complex foliage provide the greatest air quality benefits.

Air Quality Benefit Timeframe

< 1 Year

Evidence

Selecting plant species with specific characteristics can significantly enhance air filtration and improve air quality in urban environments. Plants with rough leaf surfaces, such as those with trichomes, grooves, ridges, or epicuticular wax, are more effective at capturing pollutants like particulate matter (PM) compared to plants with smooth surfaces (Barwise & Kumar, 2020). Smaller and more complex leaves, including needle-like shapes found in coniferous species, demonstrate higher efficiency in PM deposition than larger leaves. Evergreen species with longer foliage longevity are preferable for pollutant deposition, although certain deciduous species with extended in-leaf seasons may also be effective. Additionally, vegetation barrier density, influenced by leaf area density (LAD) and leaf area index (LAI), plays a crucial role in reducing downwind pollutant concentrations. Stomatal traits, such as density and size, contribute to gaseous pollutant uptake, with plants exhibiting extensive stomatal opening periods potentially enhancing air pollutant removal.



AIR FILTRATION PLANT SELECTION

CAREFUL PLANT SELECTION IS CRUCIAL FOR SUCCESSFUL AIR POLLUTION REDUCTION IN A PLANTING BUFFER, AS NOT ALL PLANTS ARE EQUALLY EFFECTIVE. THERE ARE SEVERAL DOCUMENTED TRAITS FAVORABLE FOR AIR POLLUTION REDUCTION

PLANT TYPE / FOLIAGE LONGEVITY



EVERGREEN



DECIDUOUS
W/ LONG IN-LEAF SEASON

CANOPY DENSITY / POROSITY



10-20% POROSITY
TSP < PM10 REDUCTION



20-40% POROSITY
TSP > PM10 REDUCTION

LEAF SHAPE / COMPLEXITY



NEEDLE



SCALE



AWL



LOBED

LEAF SURFACE FEATURES



HAIRY



WAXY



ROUGH



AIR QUALITY TREE
SELECTION TOOL



AIR QUALITY
PLANT TOOLKIT



REFERENCE
ECOSYSTEM MAP

EXISTING AIR QUALITY PLANT SELECTION TOOLS

FIG 5.15 Air Filtration Plant Selection Intervention Diagram. (2024). Daquan Proctor

Topographic Buffer

Intervention Description

Creating topographic buffers such as berms can mitigate the amplified impact of air pollution exposure, especially when pollutant sources are elevated above vulnerable areas. Berms, which are raised barriers typically made of earth, act as physical obstacles that alter the flow of air and pollutants. By blocking or redirecting the movement of polluted air, these structures can reduce the concentration of harmful substances that reach lower-lying regions where people live and work.

Air Quality Benefit Timeframe

1 -5 Years

Evidence

Roadside barriers, encompassing various types like noise walls, solid barriers, earthen berms, vegetative walls, buffers, and functional buffers, are effective strategies for reducing pollutant concentrations downwind of roadways (Rousseau et al., 2023). Their success hinges on several factors such as the layout of the road, local meteorological conditions, the height and design of the barrier, and its placement. For example, solid noise barriers have been proven to decrease air pollution levels by anywhere from 10 to 50 percent when the wind blows across the road. However, their effectiveness diminishes for winds coming from other directions, and gaps in the barriers can compromise their ability to block pollutants effectively. To be truly effective in reducing air pollution, barriers, whether solid or vegetative, should ideally be at least 20 feet tall.

TOPOGRAPHIC BUFFER

CREATING TOPOGRAPHIC BUFFERS LIKE BERMS CAN MITIGATE THE AMPLIFIED IMPACT OF AIR POLLUTION EXPOSURE WHEN POLLUTANT SOURCES ARE ELEVATED ABOVE VULNERABLE AREAS.

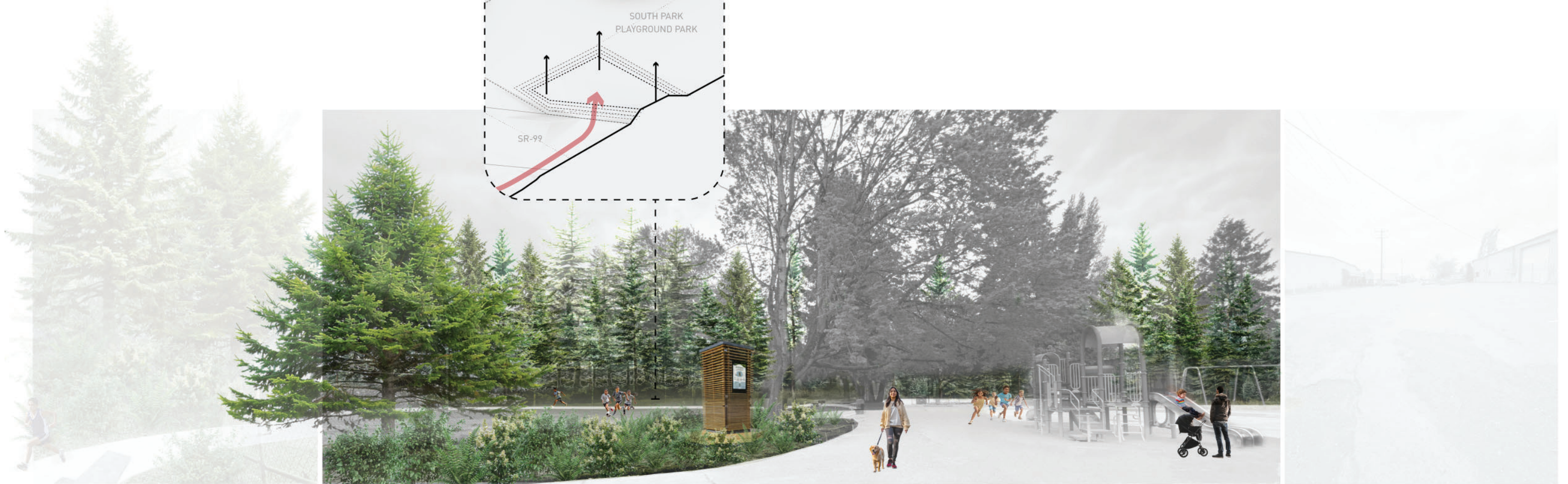
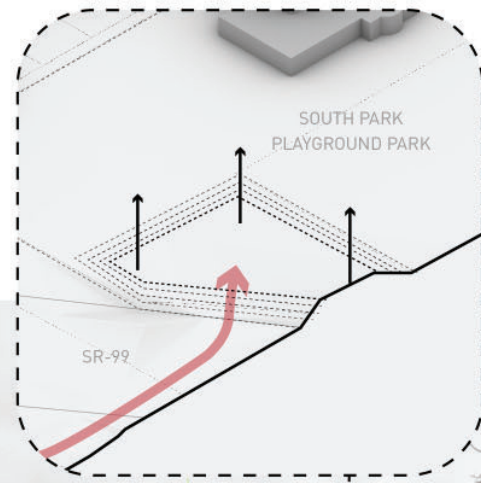


FIG 5.16 Topographic Buffer Intervention Diagram. (2024). Daquan Proctor.

Continuous Planting Buffer

Intervention Description

Establishing a continuous planting buffer is crucial because any gaps between plantings can serve as pathways for pollutants to travel through. To ensure effective pollution mitigation, it is recommended to extend the buffer zone by 150 feet in both directions beyond the affected areas. This extended buffer not only provides a more comprehensive barrier against pollutants but also helps prevent the formation of pathways that could otherwise allow pollutants to bypass the protective vegetation. Additionally, ensuring ground-to-canopy coverage maximizes the buffer's ability to intercept and filter pollutants effectively.

Air Quality Benefit Timeframe

20 - 30 Years

Evidence

For maximum effectiveness, extend vegetation at least 150 feet or as far as feasible beyond areas where humans are sensitive to pollution, on both sides or wrapped around the site (Sacramento Metropolitan Air Quality Management District & Sacramento Tree Foundation, 2020). Vegetative barriers should ideally be at least 30 feet deep, except when space is limited. Small shrubs should fill the vertical space from ground level to 10 feet tall, while larger shrubs should extend from 3 feet off the ground to 17 feet tall. Trees are most effective when their foliage covers the vertical space from 10 feet off the ground to 80 feet or more. Combining vegetative buffers with walls or other roadside barriers enhances their effectiveness in mitigating pollution.

CONTINUOUS PLANTING BUFFER

THE CONTINUITY OF A PLANTING BUFFER IS CRUCIAL, AS GAPS BETWEEN PLANTINGS CAN CREATE PATHWAYS FOR POLLUTANTS TO TRAVEL; IT'S RECOMMENDED TO EXTEND THE BUFFER 150' IN BOTH DIRECTIONS BEYOND AFFECTED AREAS.

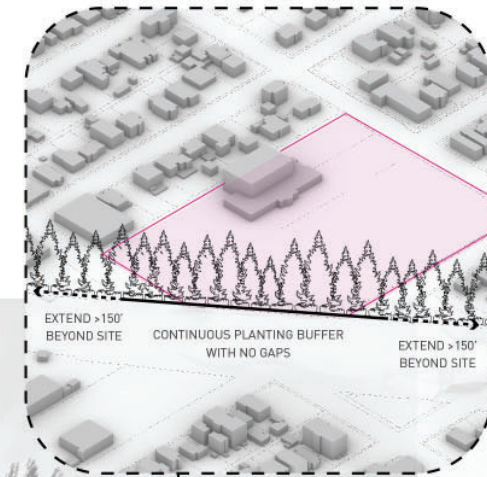


FIG 5.17 Continuous Planting Buffer Intervention Diagram. (2024). Daquan Proctor.

Air Filtration Tower

Intervention Description

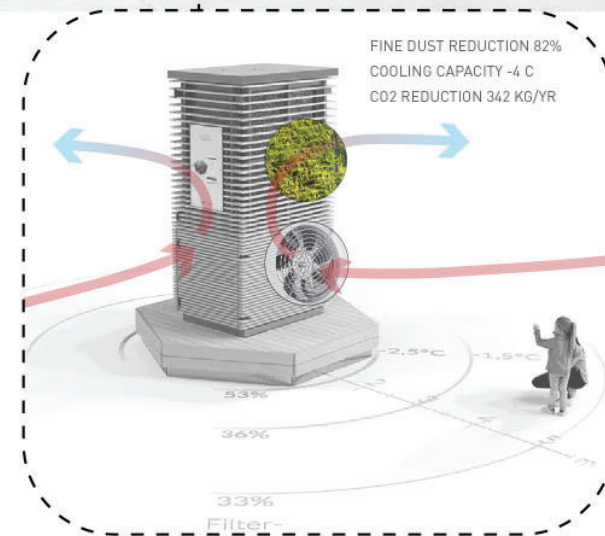
Mechanical air filtration towers are innovative structures that employ fans and filters to draw in outdoor air and purify it from particulate matter. One specific type of these towers utilizes the unique properties of mosses, tapping into their high surface area and metabolic processes. This approach allows the tower to provide the equivalent air purification effect of 81 trees, all within a compact footprint of just 95 square feet. By harnessing the natural filtration capabilities of mosses, these towers offer a sustainable and space-efficient solution to improving air quality in urban environments.

Air Quality Benefit Timeframe

< 1 Year

Evidence

Despite their seemingly simple structure, mosses possess a remarkable ability to attract and capture fine dust particles from the air (Green City Solutions, n.d.). This capability is due to their extensive surface area, which can be up to 30 times larger than a smooth surface. The positively charged surfaces of mosses effectively attract and bind with negatively charged pollutants, including fine dust. The statistics paint a compelling picture of mosses' air-cleansing benefit with approximately 50% of the fine dust particles that land on moss surfaces are directly metabolized by the moss itself. Another 25% of these particles undergo biodegradation by microorganisms that inhabit the moss surface and 25% of the fine dust is stored in the sediment of the moss. In controlled environments like moss farms, mosses can transform into dense carpets in a mere 12 weeks, making them an attractive and rapid solution for improving air quality.



AIR FILTRATION TOWER

MECHANICAL AIR FILTRATION TOWERS UTILIZE FANS AND FILTERS TO DRAW IN AND PURIFY OUTDOOR AIR OF PARTICULATE MATTER. THIS SPECIFIC TOWER TAPS INTO THE HIGH SURFACE AREA AND METABOLIC PROCESS OF MOSSES, PROVIDING THE EQUIVALENT EFFECT OF 81 TREES IN A 95 SQUARE-FOOT FOOTPRINT.

- 

STEP 1
Dirty, warm air is drawn in by the integrated fans.
- 

STEP 2
The air flows through the vertical moss mats and is cleaned and cooled in the process.
- 

STEP 3
Sensors measure the activity of the mosses and ensure that they are optimally cared for.
- 

STEP 4
The moss filter provides cooled and clean air for all around.

FIG 5.18 Air Filtration Tower Intervention Diagram. (2024). Daquan Proctor.

Depaving + Revegetation

Intervention Description

Industrial areas characterized by low vegetation cover have limited control over air pollutants, resulting in poor air quality, increased dust storms, and a more pronounced urban heat island effect. Revegetating these areas can have a substantial impact on reducing air pollution. By introducing more vegetation into these environments, the occurrence of dust storms and intensity of urban heat island effect can be mitigated.

Air Quality Benefit Timeframe

1 - 5 Years

Evidence

“Nature-Based Solutions Can Compete with Technology for Mitigating Air Emissions Across the United States” analyzed air pollution and plant life data across 48 U.S. states, excluding Alaska and Hawaii, to analyze how new vegetation could mitigate the impacts of air pollution, particularly from industrial activities like coal, oil, and gas production (Gopalakrishnan et al., 2019). The researchers discovered that reintroducing vegetation could reduce air pollutant levels by an average of 27% in studied areas. Importantly, they found that utilizing trees and plants for air quality improvement was more cost-effective in 75% of cases compared to investing in air cleaning technologies. The article emphasized the need to integrate nature-based solutions into pollution control strategies, highlighting their potential for cost savings and environmental benefits.

DEPAVING + REVEGETATION

INDUSTRIAL AREAS WITH LOW VEGETATION COVER OFFER MINIMAL SOURCE CONTROL OVER AIR POLLUTANTS, LEADING TO POOR AIR QUALITY, DUST STORMS, AND AN INTENSIFIED URBAN HEAT ISLAND EFFECT. RESEARCH INDICATES THAT REVEGETATING THESE AREAS COULD LOWER AIR POLLUTION BY AS MUCH AS 27%.

CONTINUOUS PLANTING BUFEER

PLANTING CAN CAPTURE DUST AND OTHER AIR POLLUTANTS AND PROVIDE A WINDBREAK

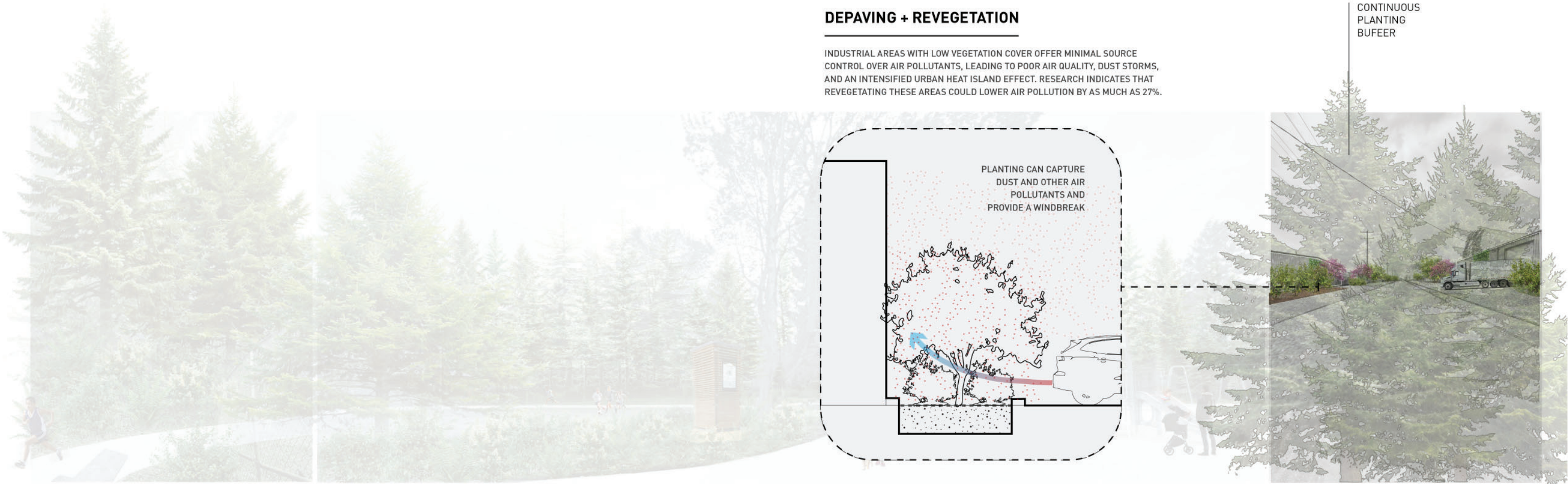


FIG 5.19 Depaving + Revegetation Intervention Diagram. (2024). Daquan Proctor.

Permeable Paving

Intervention Description

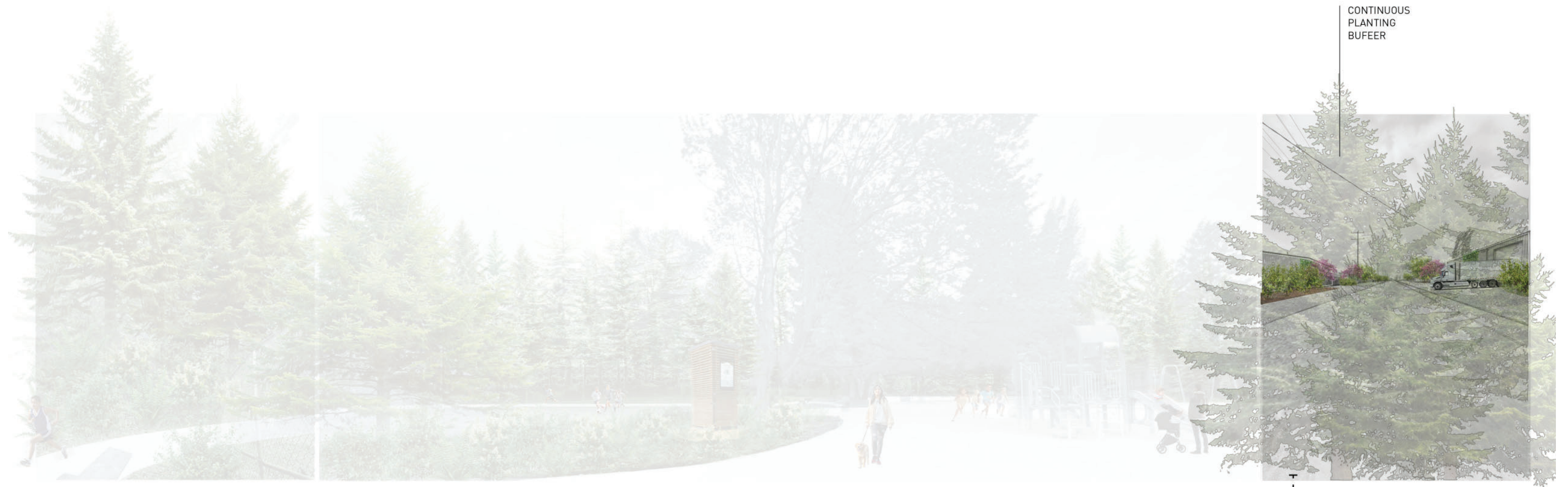
The materials used in hardscaping can influence local air quality. Permeable pavement is a standout choice in hardscaping due to its porous nature, which creates an expanded surface area for capturing pollutants. This unique feature not only helps in reducing pollution but also enhances the paving's cooling capacity. By trapping pollutants and offering a cooling effect, permeable pavement plays a dual role in improving air quality and reducing the intensity of the urban heat island effect.

Air Quality Benefit Timeframe

< 1 - 2 Years

Evidence

“Effects of a porous asphalt pavement on dust suspension and PM10 concentration” compared air quality between dense and porous surfaces, revealing differences in pollutant concentrations (Svensson et al., 2023). The average NOx concentration was found to be 48% higher at the dense pavement site, while the PM10 concentration was a striking 95% higher compared to the porous surface. An important finding was that the porous pavement was frequently moist compared to the dense pavement. This moisture retention capability of the porous surface contributed to the suppression of dust suspension and subsequently lower particle emissions, especially in the hours following rainfall. The study noted permeable paving's ability to remove dust from the surface into its pores, reduce air-pumping suspension forces from tires, and prolong drying of the surface by maintaining moisture within the pavement pores.



CONTINUOUS
PLANTING
BUFEER

PERMEABLE PAVING

THE CHOICE OF HARDSCAPE MATERIALS SIGNIFICANTLY INFLUENCES LOCAL AIR QUALITY. PERMEABLE PAVEMENT'S POROSITY ENHANCES SURFACE AREA FOR POLLUTION DEPOSITION AND CAPTURE, WITH OBSERVED PM10 REDUCTIONS OF UP TO 95% AND NOX REDUCTIONS OF UP TO 48%.

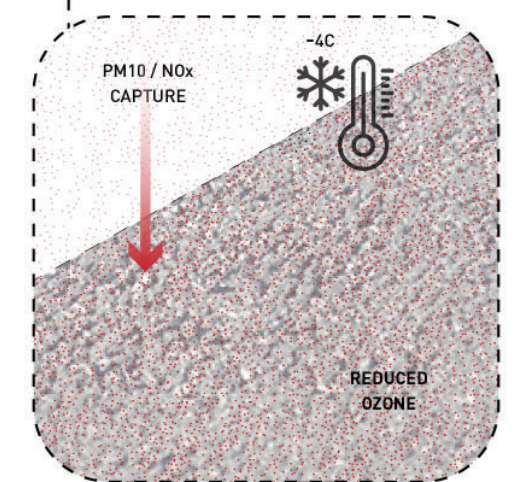


FIG 5.20 Permeable Paving Intervention Diagram. (2024). Daquan Proctor.

RESIDENTIAL - INDUSTRIAL



FIG 5.21 Residential - Industrial Existing Conditions. (2024). Daquan Proctor.

Existing Conditions

The current residential-industrial landscape faces several challenges that negatively impact air quality health outcomes. One major issue is underperforming roadside planting, with limited vegetation in the right-of-way (ROW) and on private properties, which fails to provide necessary green buffers and air filtration, leaving residents exposed to pollutants from industrial activities and traffic.

The existing infrastructure for alternative means of transportation is inadequate. Bicyclists must share the road with industrial traffic, creating unsafe conditions for non-motorized transportation. The pedestrian infrastructure is also limited, with sidewalks offering little protection from traffic and industrial hazards.

Additionally the issue of declining urban tree canopy is particularly apparent here. Industrial areas are notably underplanted and have the largest tree deficits citywide. This lack of greenery contributes to degraded air quality, increased urban heat island effects, and diminished neighborhood ecological value.



FIG 5.22 Residential - Industrial Proposed Interventions. (2024). Daquan Proctor.

Proposed Interventions

To address these challenges, several strategic interventions have been proposed. A primary measure is the implementation of context-responsive roadside planting for shallow urban canyon conditions. In shallow urban canyons, a tiered and layered planting approach will be utilized. This involves distributing vegetation across fragmented planting layers: low shrubs in the ROW planting strip, taller shrubs and small trees in front yards, and larger denser plantings in side and back yards. This method avoids trapping pollutants at street level with overly dense planting, while providing effective air filtration and creating a green buffer between residential and industrial zones, enhancing air quality and reducing pollutant exposure.

The introduction of separated transportation lanes will improve safety and accessibility for bicyclists and pedestrians. By creating dedicated lanes for non-motorized transportation, the proposal aims to protect residents from industrial traffic emissions and encourage the use of alternate transportation modes, promoting a healthier and more sustainable community.

Expanding urban canopy, especially in industrial areas, is another critical intervention. Increasing the number of trees in industrial areas will help address the significant tree deficits impacting the Duwamish Valley, improving air quality, providing shade, and mitigating the urban heat island effect.

Context Responsive Roadside Planting [Shallow Canyon]

Intervention Description

In urban streetscapes, establishing a dense layering of plantings to combat roadside air pollution poses several challenges. This includes scarcity and fragmentation of available spaces, size of spaces available to accommodate large plantings, and constraints related to the types of planting materials that can be used. However, a strategic approach that integrates layered planting areas throughout urban landscapes can overcome these challenges and yield more effective solutions for mitigating air pollution. This strategy involves utilizing various planting zones, such as the planting strip (the area between the sidewalk and the road), front yards of residential and commercial properties, side yards, and backyards.

Air Quality Benefit Timeframe

2 - 20 Years

Evidence

In street canyons, the aspect ratio (AR) of street height to street width is a critical factor influencing air quality (Huang et al., 2021). Shallow street canyons defined by an AR less than 0.5, form semi-enclosed spaces bounded by buildings and the ground, facing minor challenges in natural ventilation and pollutant removal. Deeper canyons with larger AR values weaken ventilation, leading to elevated street level pollutant concentrations. Additionally, the presence of urban vegetation, particularly trees, can further complicate air quality dynamics. While vegetation like trees is essential for urban aesthetics and environmental benefits, their placement and characteristics must be carefully considered. Taller vegetation can degrade air quality in shallow canyons, whereas low-level vegetation such as hedges can improve it. Strategic design of vegetation barriers, including considering their density, height, and crown size for trees is crucial for minimizing negative impacts on air ventilation while still reaping the benefits of green infrastructure.

CONTEXT RESPONSIVE ROADSIDE PLANTING [SHALLOW CANYON]

CREATING A DENSE LAYERING OF PLANTINGS TO SUCCESSFULLY MITIGATE ROADSIDE AIR POLLUTION IN URBAN AREAS FACES CHALLENGES DUE TO LIMITED AND DISCONTINUOUS PLANTING SPACES, ALONG WITH CONSTRAINTS ON PLANTING MATERIALS AND HEIGHTS. A STRATEGY THAT INCORPORATES LAYERED PLANTING AREAS INCLUDING THE PLANTING STRIP, FRONT YARD, SIDE YARDS, AND BACK YARDS CAN FOSTER THE CREATION OF MORE EFFECTIVE AND RESILIENT ROADSIDE BUFFERS IN URBAN STREETSCAPES.

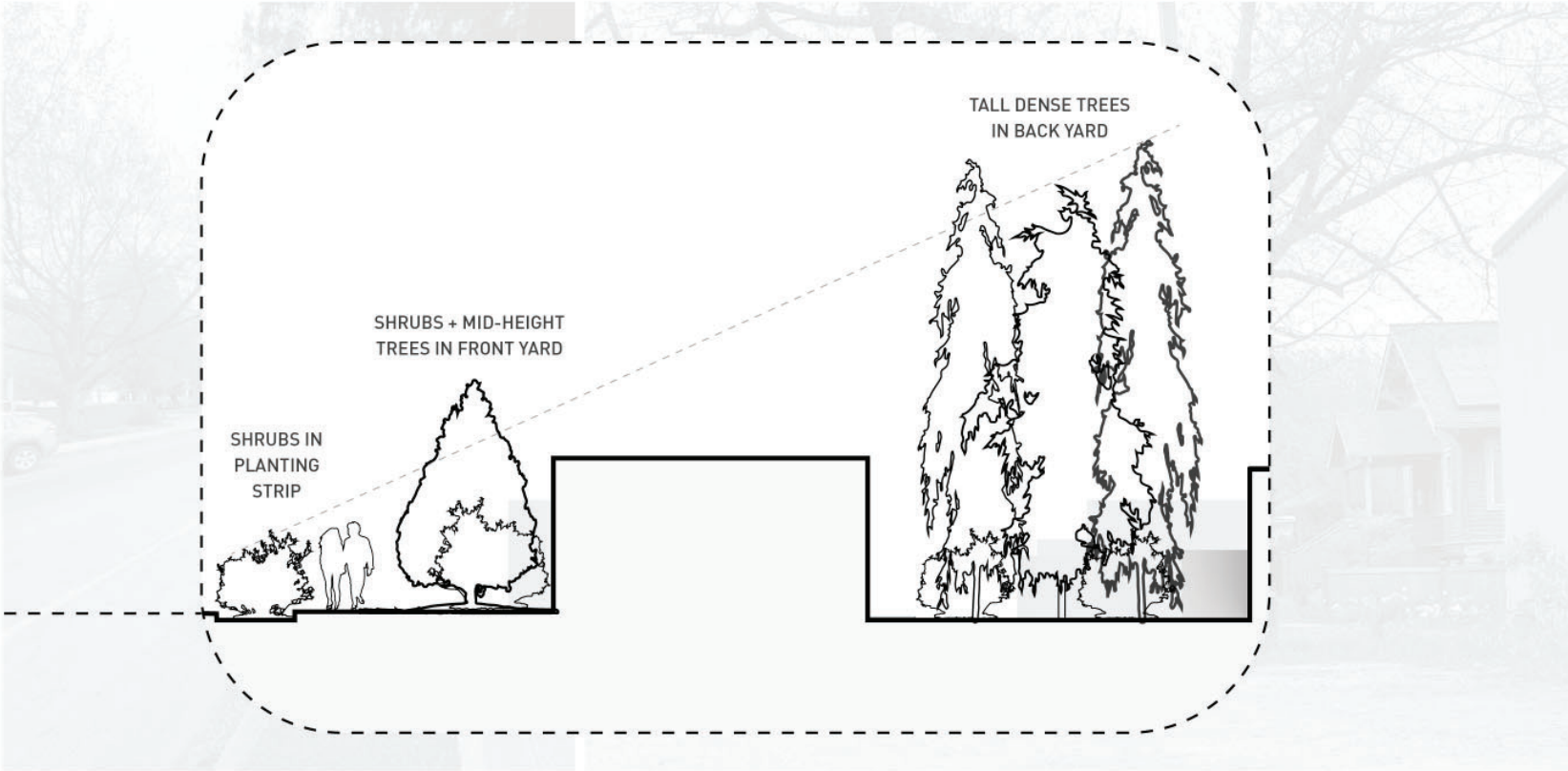


FIG 5.23 Shallow Canyon Context Responsive Planting Intervention Diagram. (2024). Daquan Proctor.

Separated Transportation Lanes

Intervention Description

Current transportation infrastructure planning and design models often concentrate vehicles, pedestrians, and bicyclists in close proximity, leading to increased exposure of bicyclists and pedestrians to vehicle emissions. This exposure is particularly heightened on main roads where bicycles share space with vehicles, leading to significant air pollution exposure for cyclists. However, implementing physical separation between these transportation modes can yield benefits in reducing air pollution exposure. Studies have shown that separating vehicles, pedestrians, and bicyclists can reduce nitrogen oxides (NOx) exposure for individuals using active modes of transportation. This reduction is primarily attributed to the decreased proximity to vehicle emissions, as physical separation creates barriers that help mitigate the direct inhalation of vehicle emissions.

Air Quality Benefit Timeframe

< 1 Year

Evidence

The study “Do new bike lanes impact air pollution exposure for cyclists?—a case study from Berlin” demonstrated the use of low-cost sensors to monitor air quality changes associated with local transport interventions (Schmitz et al., 2021). The study found a notable reduction in NO₂ exposure for cyclists following the installation of a bike lane, especially in lowering concentrated exposure near tailpipe emissions. This reduction amounted to an average NO₂ reduction of 22-19% decrease in exposure levels for cyclists. This reduction was localized to the study area, indicating the positive impact of the bike lane construction on local air quality outcomes.

SEPERATED TRANSPORT LANES

CURRENT LAND USE MODELS OFTEN PLACE VEHICLES, PEDESTRIANS, AND BICYCLISTS CLOSE TOGETHER, EXPOSING ACTIVE TRANSPORT USERS TO VEHICLE EMISSIONS, ESPECIALLY ON MAIN ROADS WHERE BICYCLES SHARE SPACE WITH VEHICLES. PHYSICALLY SEPARATING THESE TRANSPORT MODES CAN REDUCE AIR POLLUTION EXPOSURE BY UP TO 20% FOR NOX.



FIG 5.24 Separated Transportation Lanes Intervention Diagram. (2024). Daquan Proctor.

Urban Canopy Expansion

Intervention Description

Expanding the urban canopy through strategic planting in street ends and unimproved rights of way presents an opportunity to mitigate pollutants and enhance vegetation. While planting in the streetscape is often tightly regulated, these areas offer more flexibility for larger evergreen trees that are not suitable for standard planting strips. By establishing dense evergreen buffers at residential-industrial and residential-transportation street ends, the crossover of pollutants into residential areas can be significantly reduced. Simultaneously, this approach boosts the urban canopy, contributing to improved air quality and overall environmental benefits.

Air Quality Benefit Timeframe

20 - 30 Years

Evidence

“Nature-Based Solutions Can Compete with Technology for Mitigating Air Emissions Across the United States” analyzed air pollution and plant life data across 48 U.S. states, excluding Alaska and Hawaii, to analyze how new vegetation could mitigate the impacts of air pollution, particularly from industrial activities like coal, oil, and gas production (Gopalakrishnan et al., 2019). The researchers discovered that reintroducing vegetation could reduce air pollutant levels by an average of 27% in studied areas. Importantly, they found that utilizing trees and plants for air quality improvement was more cost-effective in 75% of cases compared to investing in air cleaning technologies. The article emphasized the need to integrate nature-based solutions into pollution control strategies, highlighting their potential for cost savings and environmental benefits.

URBAN CANOPY EXPANSION

PLANTING IN THE STREETScape IS TYPICALLY HEAVILY REGULATED, BUT STREET ENDS AND UNIMPROVED RIGHTS OF WAY OFFER MORE FLEXIBILITY, ALLOWING FOR THE PLANTING OF LARGER EVERGREEN TREES NOT SUITABLE FOR THE STANDARD PLANTING STRIP. ESTABLISHING A DENSE EVERGREEN BUFFER AT RESIDENTIAL-INDUSTRIAL AND RESIDENTIAL-TRANSPORTATION STREET ENDS COULD SIGNIFICANTLY DECREASE POLLUTANT CROSSOVER INTO RESIDENTIAL AREAS WHILE INCREASING URBAN CANOPY.

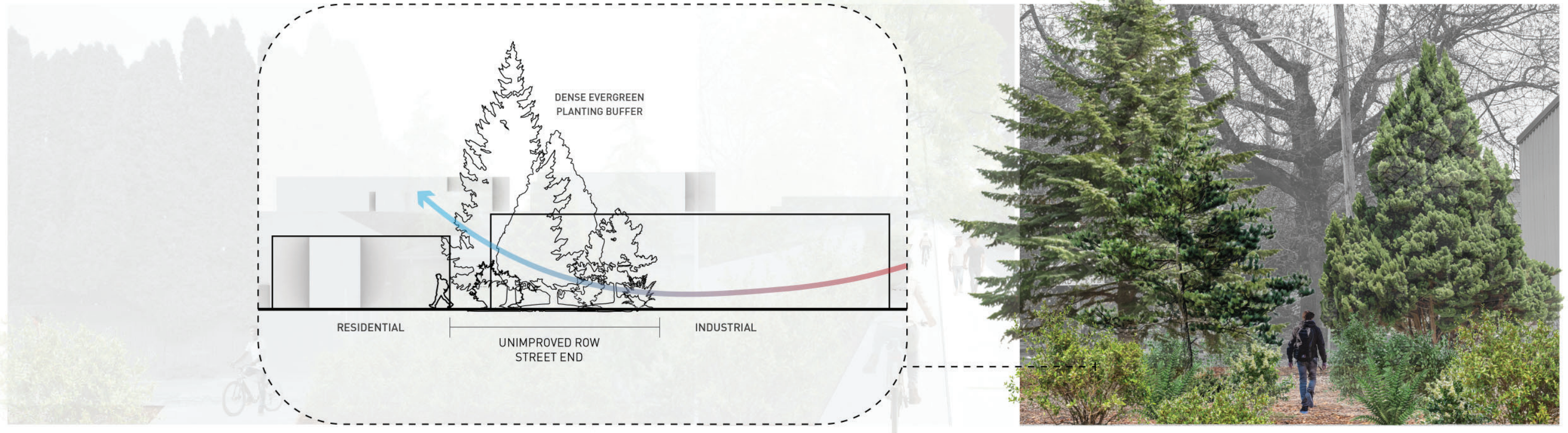


FIG 5.25 Urban Canopy Expansion Intervention Diagram. (2024). Daquan Proctor.

RESIDENTIAL - CIVIC / COMMERCIAL



FIG 5.26 Residential - Civic / Commercial Existing Conditions. (2024). Daquan Proctor

Existing Conditions

The current residential-civic/commercial landscape faces several significant challenges from underperforming planting to accessibility and connectivity challenges for active transportation networks. Urban development and climate change are compromising street tree canopies, resulting in reduced shade, poorer air quality, and diminished ecological value. This decline also exacerbates the urban heat island effect, making outdoor spaces less comfortable and increasing energy costs for cooling buildings.

Additionally, the existing roadside planting is underperforming due to higher density development and minimal planting areas available. This lack of adequate planting buffers fails to mitigate pollution and noise from busy streets, negatively impacting the quality of life for residents and commercial patrons

Another issue is the limited infrastructure and connectivity for alternate transportation modes. The areas along 8th Ave S and S Cloverdale St lack sufficient infrastructure to support safe and efficient travel between residential and commercial zones. This inadequacy discourages the use of sustainable transportation options such as biking and walking, leading to increased reliance on vehicles and higher traffic congestion.



FIG 5.27 Residential - Civic / Commercial Proposed Interventions. (2024). Daquan Proctor.

Proposed Interventions

To address these challenges, several interventions have been proposed. Implementation of climate-adaptive planting involves selecting tree and plant species that are resilient to changing climate conditions, ensuring a robust and sustainable urban tree canopy. These plants will provide necessary shade, improve air quality, and enhance the overall aesthetic of the streetscape.

Context-responsive roadside planting in avenue canyons will involve a strategic mix of vegetation, including slim columnar trees, shrubs/hedges, and innovative green infrastructure such as green screens, walls, or roofs. This approach accommodates higher density development and prevents pollutants from being trapped at street level while providing effective air filtration and noise reduction. Green screens, which are vertical structures covered in vegetation, help mitigate pollution, provide privacy, and can define transportation lanes in a small footprint.

Promoting mixed-use and complete communities will ensure that residential, commercial, and civic spaces are well-integrated. This approach supports a vibrant, walkable environment where people can live, work, and play without needing to rely heavily on vehicles. Improving multimodal connectivity is essential to creating a more integrated and accessible transportation network. This involves developing dedicated bike lanes, pedestrian paths, and improved transit connections to link residential areas with commercial and civic spaces, promoting sustainable transportation options. Introducing superblocks will reorganize traffic patterns to prioritize pedestrians and cyclists, reduce vehicular traffic within residential areas, and create more walkable and livable streets. Implementing traffic optimization measures such as smart traffic signals, dedicated bus lanes, and optimized route planning will enhance overall transportation efficiency and reduce emissions.

Climate Adaptive Planting

Intervention Description

Seattle's urban tree cover, particularly in the Duwamish Valley, is facing a rapid decline primarily due to climate stressors. To address this issue, it is crucial to focus on climate-adaptive planting strategies. While selecting air quality-friendly plants remains essential, preserving and expanding the existing urban canopy is equally important. One effective approach is to prioritize climate-adaptive plantings for new or replacement street trees. By choosing tree species that are resilient to changing climate conditions, such as heatwaves, droughts, and pests, we can safeguard neighborhood canopies and ensure their long-term sustainability.

Air Quality Benefit Timeframe

20 - 30 Years

Evidence

Urban trees play a crucial role in enhancing the quality of life for city residents and bolstering community resilience in the face of climate change impacts (Sievers, 2022). The Climate Tree Species Guide created in 2021 by Davey's Resource Group, American Forests, City Forest Credits, and The Nature Conservancy, is a comprehensive tool that assesses over 180 tree species, considering their adaptability, suitability, and vulnerability to climate stressors specifically in the Puget Sound region. As climate projections indicate a trend towards warmer temperatures and shifts in precipitation patterns, the importance of resilient urban forestry becomes increasingly evident. By choosing tree species that are resilient to these changing climatic conditions, cities can build robust urban tree canopies that continue to deliver essential ecosystem services such as air purification, temperature regulation, and stormwater management. Diversification of tree species is a key strategy recommended by the guide. Planting a variety of tree species instead of relying heavily on a single species promotes biodiversity and strengthens the resilience of urban forests.

CLIMATE ADAPTIVE PLANTING

SEATTLE'S URBAN TREE COVER, ESPECIALLY IN THE DUWAMISH VALLEY, IS DECLINING RAPIDLY, LARGELY DUE TO CLIMATE STRESSORS. WHILE CHOOSING AIR QUALITY-FRIENDLY PLANTS IS VITAL, IT'S EQUALLY IMPORTANT TO PRESERVE AND EXPAND THE EXISTING URBAN CANOPY. PRIORITIZING CLIMATE-ADAPTIVE PLANTINGS FOR NEW OR REPLACEMENT STREET TREES WILL HELP SAFEGUARD NEIGHBORHOOD CANOPIES.

INCENSE CEDAR

WA NATIVE (TESTED AS SURROGATE FOR WESTERN RED CEDAR)
DROUGHT / HEAT / URBAN

WESTERN REDBUD

CA NATIVE (LOW MAINTENANCE)
DROUGHT / HEAT / URBAN

JAPANESE PAGODATREE

NON-NATIVE (FAST GROWING)
DROUGHT / HEAT / URBAN



FIG 5.28 Climate Adaptive Planting Intervention Diagram. (2024). Daquan Proctor.

Superblock Streets

Intervention Description

The Superblock strategy is a transformative urban design approach that prioritizes people over cars. It reimagines city blocks, typically consisting of a grid of at least nine blocks, to promote active and public transportation and decenter the use of private vehicles. Cars are restricted to designated perimeter roads, with the exception of local street access, freeing up interior streets for residents to enjoy.

Air Quality Benefit Timeframe

1 - 5 Years

Evidence

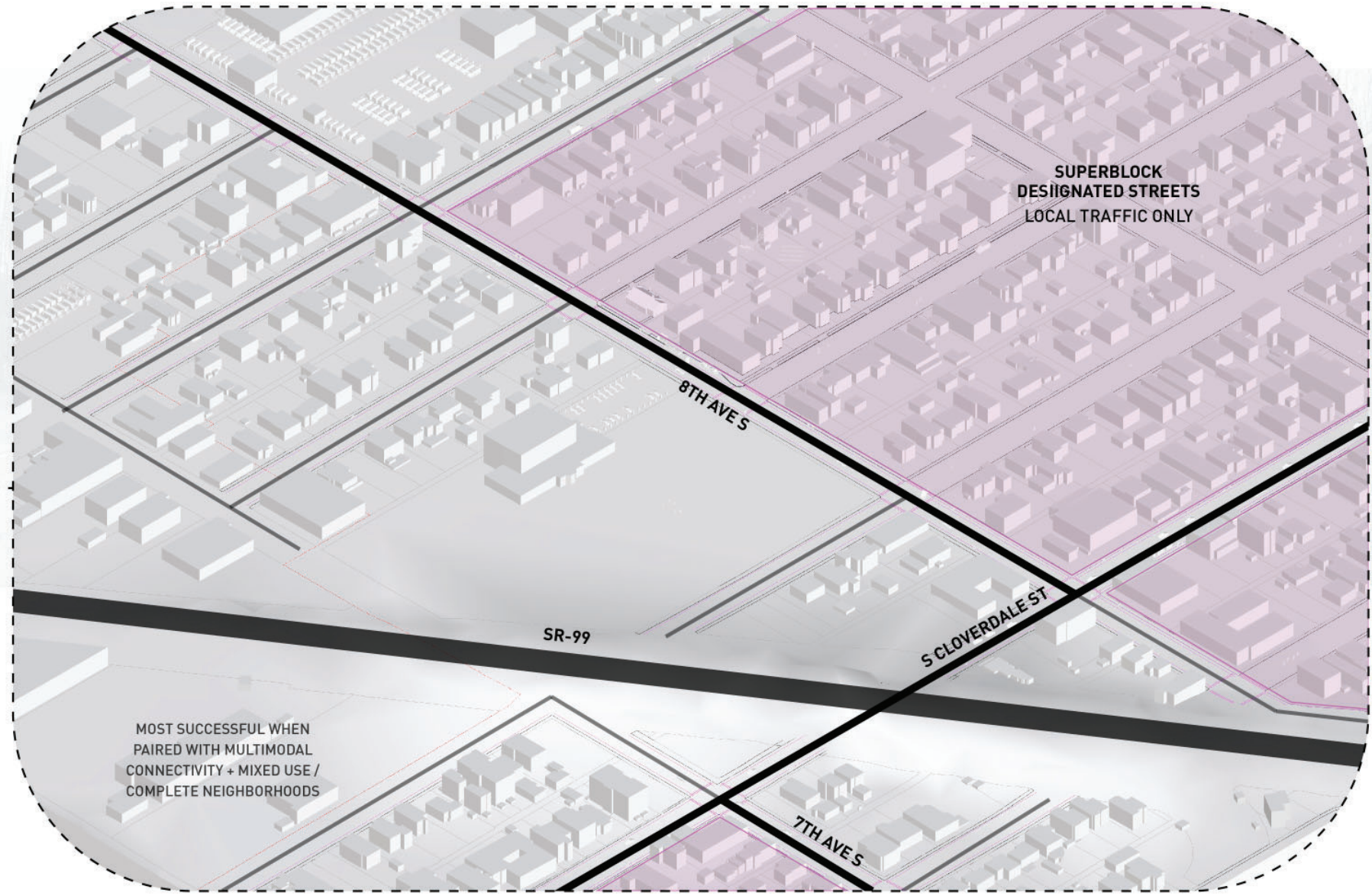
Research conducted in Barcelona, a leader in implementing Superblocks, revealed notable reductions in harmful pollutants such as nitrogen dioxide (NO₂) by 25% and particulate matter (PM₁₀) by 17% (World Health Organization, 2021). These air quality enhancements are directly associated with tangible health benefits, with projections indicating that widespread implementation of Superblocks across Barcelona could prevent nearly 700 deaths annually. Superblocks effectively reduce air pollution by restricting vehicular access, thereby contributing to improved public health outcomes. Additionally, Superblocks create safer, quieter, and more socially engaging spaces for residents, fostering community interactions and enhancing overall well-being. These urban configurations promote active modes of transportation like walking and cycling, consequently encouraging physical activity and reducing reliance on motor vehicles. However, the implementation of Superblocks is not without challenges as it requires extensive planning and community engagement to ensure successful implementation.

SUPERBLOCK STREETS

SUPERBLOCK URBAN DESIGN AIMS TO CHANGE NEIGHBORHOODS' RELATIONSHIP WITH VEHICLES, BLOCKING THROUGH TRAFFIC TO ENHANCE WALKABILITY, ACTIVE TRANSPORTATION, AND NEIGHBORHOOD GREENWAYS. PILOT PROGRAMS HAVE SHOWN REDUCTIONS OF UP TO 25% IN NITROGEN DIOXIDE (NO2) AND 17% IN PARTICULATE MATTER (PM10).



PLANTERS CLOSING OFF STREETS WITHIN THE SUPERBLOCK FOR LOCAL TRAFFIC ONLY



MOST SUCCESSFUL WHEN PAIRED WITH MULTIMODAL CONNECTIVITY + MIXED USE / COMPLETE NEIGHBORHOODS

FIG 5.29 Superblock Streets Intervention Diagram. (2024). Daquan Proctor.

Green Screen

Intervention Description

Green screens have been highlighted in urban planning literature as a highly effective strategy for planting in mid to deep urban canyons. These screens are favored for their small footprint and minimal utilization of streetscape area, making them suitable even for space-constrained urban environments. One of the key advantages of green screens is their versatility; they can be easily mounted on building facades, maximizing their impact without occupying valuable ground space. Findings consistently indicate significant reductions in harmful pollutants such as nitrogen dioxide (NO₂) and particulate matter (PM₁₀).

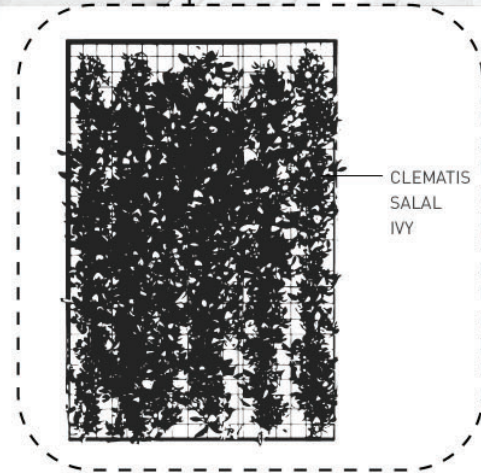
Air Quality Benefit Timeframe

< 1 - 2 Years

Evidence

The “Impact of green screens on concentrations of particulate matter and oxides of nitrogen in near road environments” evaluated the effectiveness of a green screen, specifically an ivy barrier, in blocking vehicle emissions from a nearby road into a playground area (Tremper et al., 2015). The study measured NO_x and PM₁₀ levels on both sides of the screen using reference NO_x analyzers and indicative PM analyzers, assessing the concentration difference as the ivy screen matured. Results showed that the ivy screen functioned as an efficient pollution barrier once the ivy had grown sufficiently, with a notable impact observed upon maturity. Concentrations of pollutants like NO₂ and PM₁₀ decreased by 24% and 38%, respectively, on the playground side of the screen, surpassing the measurement uncertainty and indicating significant effectiveness. During school hours specifically, reductions of up to 36% for NO₂ and 41% for PM₁₀ were noted, highlighting the screen’s effectiveness during periods of peak emissions and exposure, such as daytime hours.

GREEN
SCREEN
FAXADE



GREEN SCREEN

IN THE LITERATURE, GREEN SCREENS ARE REPEATEDLY HIGHLIGHTED AS ONE OF THE TOP STRATEGIES FOR PLANTING ALONG MID-DEEP URBAN CANYONS. THESE SCREENS HAVE A SMALL FOOTPRINT AND TAKE UP MINIMAL STREETScape AREA, AND THEY CAN BE MOUNTED ON BUILDING FACADES. RESEARCH SHOWS THAT GREEN SCREENS CAN REDUCE CONCENTRATIONS OF NO₂ BY UP TO 36% AND PM₁₀ BY UP TO 41%.

FIG 5.30 Green Screen Intervention Diagram. (2024). Daquan Proctor.

Context Responsive Roadside Planting [Avenue Canyon]

Intervention Description

In densely populated areas like S Cloverdale Street, where higher density streets can exacerbate ground-level air quality concerns, careful attention is necessary when planning roadside plantings. Avenue canyons with a height-to-width ratio of approximately 0.5 pose a specific challenge, as large canopy street trees may inadvertently trap pollutants at ground level. To address this, a strategic mix of vegetation is recommended, including slim columnar trees, shrubs/hedges, and innovative green infrastructure like green screens, walls, or roofs.

Air Quality Benefit Timeframe

2 - 10 Years

Evidence

In street canyons, the aspect ratio (AR) of street height to street width is a critical factor influencing air quality (Huang et al., 2021). Shallow street canyons defined by an AR less than 0.5, form semi-enclosed spaces bounded by buildings and the ground, facing minor challenges in natural ventilation and pollutant removal. Deeper canyons with larger AR values weaken ventilation, leading to elevated street level pollutant concentrations. Additionally, the presence of urban vegetation, particularly trees, can further complicate air quality dynamics. While vegetation like trees is essential for urban aesthetics and environmental benefits, their placement and characteristics must be carefully considered. Taller vegetation can degrade air quality in shallow canyons, whereas low-level vegetation such as hedges can improve it. Strategic design of vegetation barriers, including considering their density, height, and crown size for trees.

CONTEXT RESPONSIVE ROADSIDE PLANTING [AVENUE CANYON]

ON HIGHER DENSITY STREETS LIKE CLOVERDALE, PARTICULAR ATTENTION IS REQUIRED TO PREVENT ROADSIDE PLANTINGS FROM WORSENING GROUND-LEVEL AIR QUALITY. IN AVENUE CANYONS [HEIGHT/WIDTH RATIO OF ~ 0.5], LARGE CANOPY STREET TREES CAN TRAP POLLUTANTS AT THE GROUND LEVEL. SUGGESTED ROADSIDE PLANTINGS INCLUDE SLIM COLUMNAR TREES, SHRUBS/HEDGES, AND GREEN SCREENS/WALLS/ROOFS.

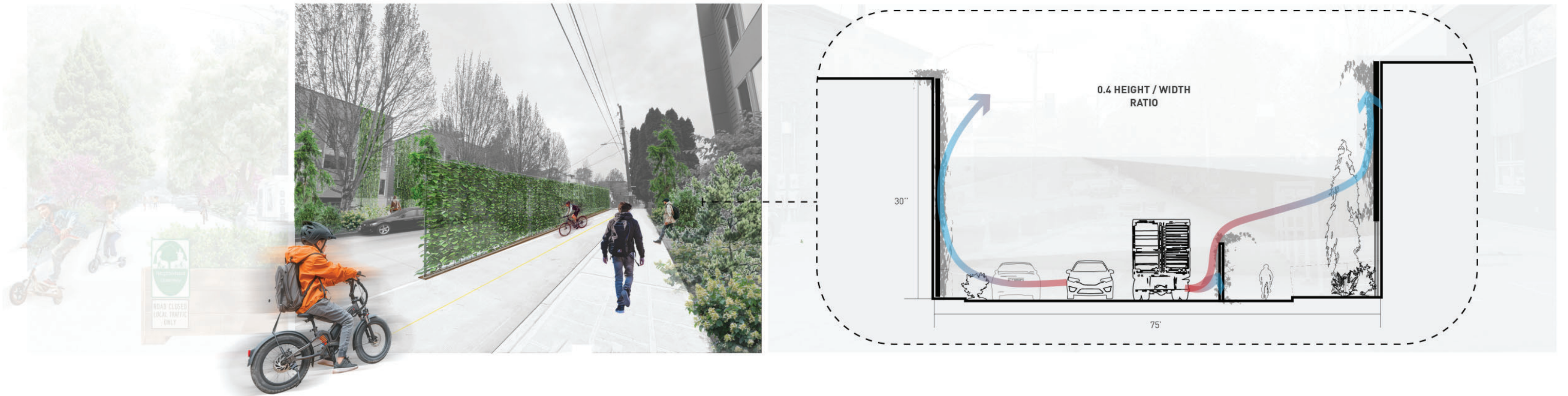


FIG 5.31 Avenue Canyon Context Responsive Roadside Planting Intervention Diagram. (2024). Daquan Proctor.

Multimodal Connectivity

Intervention Description

Multi-modal transportation strategies tackle the inequities associated with car dependency but also bring a range of community health and livability benefits such as enhanced air quality. Promoting and facilitating alternate forms of transportation such as walking, cycling, and public transit, communities can decrease their overall reliance on vehicles and subsequently reduce vehicle miles traveled.

Air Quality Benefit Timeframe

1 - 5 Years

Evidence

The analysis of UFP (Ultrafine Particles) and PM2.5 (Particulate Matter 2.5) data showcased the potential benefits of complete streets on air quality (Zhu et al., 2016). Morning sessions consistently exhibited higher UFP concentrations, yet complete streets demonstrated a notable reduction in UFP concentrations compared to incomplete streets during specific sessions. Particularly, Downtown Los Angeles, Santa Monica, and Willowbrook sites displayed statistically lower UFP concentrations on complete streets, suggesting that complete streets can mitigate air pollution exposure. However, the study found no significant differences in PM2.5 concentrations between complete and incomplete streets, indicating a more consistent distribution of particulate matter. Overall, these findings underscore the positive impact of complete streets on reducing street users' exposure to harmful air pollutants, contributing to improved environmental quality.



MULTIMODAL CONNECTIVITY

MULTI-MODAL TRANSPORTATION NOT ONLY ADDRESSES THE INEQUITIES OF CAR DEPENDENCY BUT ALSO PROVIDES A SUITE OF COMMUNITY HEALTH AND LIVABILITY BENEFITS, INCLUDING IMPROVED AIR QUALITY AND DECREASED NOISE POLLUTION. MAKING ALTERNATE FORMS OF TRANSPORTATION MORE ACCESSIBLE CAN REDUCE OVERALL VEHICLE DEPENDENCY AND VEHICLE MILES TRAVELED.

FIG 5.32 Multimodal Connectivity Intervention Diagram. (2024). Daquan Proctor.

Traffic Management Optimization

Intervention Description

The integration of sensors and machine learning techniques into traffic management systems is revolutionizing real-time traffic optimization. These advanced systems can now prioritize various objectives simultaneously, including reducing wait times and idling emissions, giving precedence to pedestrians, cyclists, or public transit, and leveraging air quality sensors and AI to detect air pollution hotspots and adjust strategies accordingly. This integration not only enhances traffic efficiency but also contributes to a more sustainable and healthier urban environment by mitigating the impacts of traffic congestion and pollution.

Air Quality Benefit Timeframe

2 - 5 Years

Evidence

Traffic signal management systems have been found to significantly reduce stop-and-go driving and vehicle idling, leading to localized pollutant concentration reductions of up to 50% compared to areas without these systems (California Environmental Protection Agency & Air Resources Board, 2017). "Strategies to Reduce Air Pollution Exposure Near High-Volume Roadways" highlights the potential impact of well-coordinated traffic signals on emissions. For instance, a well-timed green wave along a road section can reduce emissions of HC, CO, and NOX by 50%, while signal coordination can reduce emissions of HC, NO, and CO by 10-20% per unit of distance. Additionally, increasing the green split of major directions at intersections has shown reductions in CO, HC, and NOX emissions ranging from 2.6% to 14.6%. These findings underscore the importance of implementing efficient traffic signal strategies to achieve significant reductions in air pollutant emissions and improve air quality in urban areas.

TRAFFIC MANAGEMENT OPTIMIZATION

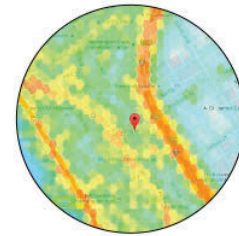
SENSORS AND MACHINE LEARNING TECHNIQUES ARE NOW BEING INTEGRATED INTO TRAFFIC MANAGEMENT SYSTEMS, ENABLING REAL-TIME OPTIMIZATION OF TRAFFIC FLOWS. THESE SYSTEMS CAN BE CONFIGURED TO PRIORITIZE MULTIPLE OBJECTIVES, SUCH AS REDUCING WAIT TIMES AND IDLING EMISSIONS, GIVING PRIORITY TO PEDESTRIANS, CYCLISTS, OR PUBLIC TRANSIT, AND EVEN UTILIZING AIR QUALITY SENSORS AND AI TO IDENTIFY AIR POLLUTION HOTSPOTS AND ADAPT ACCORDINGLY.



IDLING
REDUCTION



ACTIVE TRANSPORT
PRIORITIZATION



AIR QUALITY SENSOR
AI INTEGRATION



FIG 5.33 Traffic Management Optimization Intervention Diagram. (2024). Daquan Proctor.

Mixed Use / Complete Communities

Intervention Description

Mixed-use communities and complete neighborhoods, characterized by their accessibility to essential services within walking distance, play a crucial role in promoting active street life and encouraging alternative transportation methods. This design philosophy fosters a vibrant urban environment where residents can conveniently access amenities without heavily relying on vehicles, thereby reducing vehicle dependency and the associated emissions.

Air Quality Benefit Timeframe

5 - 10 Years

Evidence

Dense, mixed-use neighborhoods play a crucial role in reducing transportation emissions and improving community well-being (Jarrah, 2023). These areas combine housing, workplaces, and amenities, promoting a more sustainable lifestyle with reduced car dependency. By implementing smart growth strategies like transit-friendly zoning, anti-sprawl policies, and codes that encourage compact development, local governments can create environments that support walking, biking, and public transit while reducing greenhouse gas emissions from personal vehicles. Additionally, rethinking zoning codes to allow for mixed-use areas and promoting denser development in central business districts can further reduce reliance on cars. It is essential for land use policies to prioritize equity, engaging disadvantaged communities in planning processes and ensuring access to affordable housing and transportation options. Collaboration between local governments and communities is key to creating inclusive, environmentally friendly urban spaces that benefit all residents.



MIXED USE / COMPLETE COMMUNITIES

MIXED-USE COMMUNITIES AND COMPLETE NEIGHBORHOODS, WHERE ALL ESSENTIAL SERVICES ARE WITHIN WALKING DISTANCE, FOSTER AN ACTIVATED STREETScape AND ENCOURAGE ALTERNATIVE FORMS OF TRANSPORTATION. THIS DESIGN PROMOTES A VIBRANT URBAN ENVIRONMENT WHERE RESIDENTS CAN EASILY ACCESS AMENITIES WITHOUT HEAVY RELIANCE ON VEHICLES, REDUCING VEHICLE DEPENDENCY AND ASSOCIATED EMISSIONS.

FIG 5.34 Mixed Use / Complete Communities Intervention Diagram. (2024). Daquan Proctor.

RESIDENTIAL - TRANSPORTATION



FIG 5.35 Residential - Transportation Existing Conditions. (2024). Daquan Proctor.

Existing Conditions

The current residential-transportation landscape faces several challenges to achieving healthy air. The major issue is compromised indoor air quality due to pollution infiltration from SR-99 into adjacent building envelopes, leading to poor air quality inside homes and other buildings. This is especially concerning for residents' health, as prolonged exposure to pollutants can cause respiratory issues and other health problems.

The concentration of impervious surfaces due to the large stretches of pavement from SR-99 contribute to increased particulate matter resuspension and intensified urban heat island effects. These extensive paved areas elevate temperatures and exacerbate air quality conditions for nearby residential areas.

The existing roadside planting along the highway median and shoulder is underperforming. The sparse and inadequate vegetation fails to provide effective air filtration value, leaving the adjacent areas exposed to pollutants and noise from the highway. Moreover, the proximity of vulnerable uses, such as housing and an elementary school, to SR-99 further amplifies the risks associated with poor air quality and noise pollution.



FIG 5.36 Residential - Transportation Proposed Interventions. (2024). Daquan Proctor.

Proposed Interventions

To address these challenges, several interventions have been proposed. The implementation of filtered natural ventilation systems alongside enhancing building envelope airtightness and weatherization will prevent pollutants from infiltrating indoor spaces, creating a healthier living environment. The use of healthy materials in construction and renovation will further improve indoor air quality. These materials, free from harmful chemicals and pollutants, will reduce indoor emissions and promote better health outcomes for residents. Additionally, installing air purifiers and air filters will provide an extra layer of protection, ensuring that any remaining pollutants are effectively removed from indoor environments.

On the external front, photocatalytic paving will be employed to break down pollutants on road surfaces, reducing the amount of harmful emissions from the highway. This innovative approach will help improve overall air quality in the vicinity of SR-99. Context-responsive roadside planting in the highway median will involve densely planting hardy shrubs and low-lying plants, the median can effectively mitigate air pollution and benefit nearby communities. The introduction of physical barriers, such as sound walls, will further shield adjacent vulnerable uses from the direct impacts of SR-99.

Filtered Natural Ventilation

Intervention Description

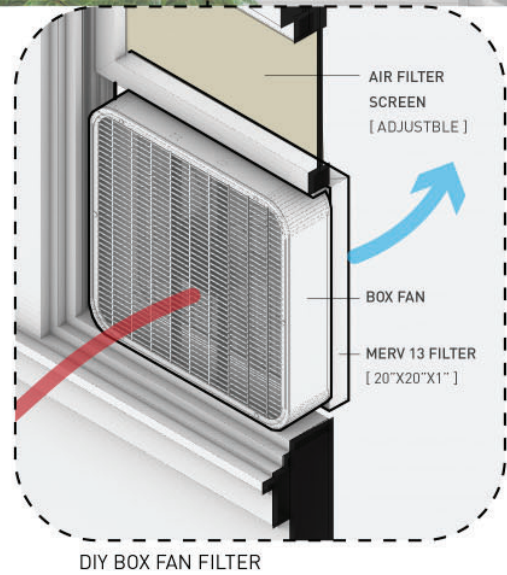
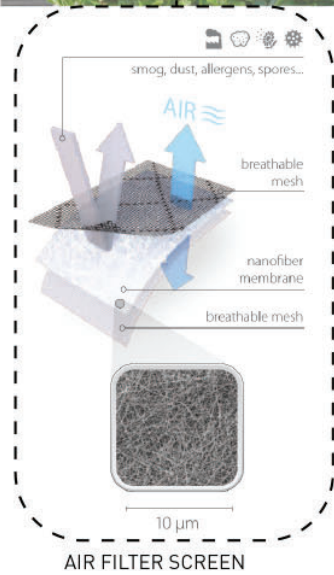
When researching recommendations to improve indoor air quality, natural ventilation emerges as the top strategy appearing in a range of sources including the Environmental Protection Agency (Environmental Protection Agency, 2023). Yet, in regions with polluted outdoor air, it is important to consider additional measures to minimize infiltration and exposure to external pollutants. Various approaches are available to tackle this challenge, such as the use of nanofiber air filter screen window inserts and do-it-yourself fan filters. These methods play a vital role in reducing the infiltration of outdoor air, thereby supporting passive ventilation strategies and ensuring a healthier indoor environment.

Air Quality Benefit Timeframe

< 1 Year

Evidence

Homemade filter fans, consisting of a box fan and a MERV-13 furnace filter, can achieve up to a 90% reduction in air pollution in smaller rooms when used properly with windows and doors closed to prevent polluted air from reentering (Puget Sound Clean Air Agency, n.d.). It takes 15 minutes to clear 90% of particles out of a small room, 25 minutes for a medium size room, and 2 hours for a large room. Depending on how leaky your house is, it can take between 3.5 and 10 hours for particle levels inside to reach particle levels outside if all of the doors and windows are closed. Leaving a window open for 25 minutes or a door open for 10 minutes can let outdoor particles fully enter a small or medium size room. The RESPILON® adjustable air filter screen provides effective filtration down to 0.01 µm ultrafine dust and 0.1 µm smog particles reaching up to 94.1% efficiency (Respilon, n.d.). It offers unparalleled protection against various pollutants, including mold, bacteria, plant spores, sea salt aerosols, pollen, dusts, diesel fumes, and PM2.5.



FILTERED NATURAL VENTILATION

NATURAL VENTILATION IS OFTEN HIGHLIGHTED AS A PRIMARY STRATEGY FOR ENHANCING AIR QUALITY. HOWEVER, IN AREAS WITH POLLUTED OUTDOOR AIR, ADDITIONAL CONSIDERATIONS ARE NEEDED TO MINIMIZE EXPOSURE TO EXTERNAL POLLUTANTS. SEVERAL APPROACHES EXIST TO ADDRESS THIS ISSUE, INCLUDING NANOFIBER AIR FILTER SCREEN WINDOW INSERTS AND DIY FAN FILTERS. THESE METHODS CAN HELP REDUCE THE AMOUNT OF OUTDOOR AIR INFILTRATION WHILE STILL FACILITATING PASSIVE VENTILATION STRATEGIES.

FIG 5.37 Filtered Natural Ventilation Intervention Diagram. (2024). Daquan Proctor.

Envelope Airtightness / Weatherization

Intervention Description

The integrity of a building's envelope plays a critical role in safeguarding indoor air quality by preventing the infiltration of exterior pollutants. Designing a continuous, airtight, and well-insulated envelope, especially with high-performance windows, is paramount for optimal indoor air quality. Such measures act as a barrier against pollutants like particulate matter, volatile organic compounds (VOCs), and other contaminants present in outdoor air. Deficiencies in the building envelope, such as gaps, cracks, or poor insulation, can compromise indoor air quality by allowing pollutants to seep indoors. However, these deficiencies can be addressed through retroactive weatherization initiatives. By identifying and sealing leaks, upgrading insulation, and improving ventilation systems, building owners and occupants can significantly reduce the infiltration of outdoor pollutants.

Air Quality Benefit Timeframe

< 1 Year

Evidence

The National Evaluation of the Weatherization Assistance Program (WAP) revealed that participants experienced reduced emergency room visits and health-related costs, particularly in cases of asthma (Young, n.d.). Asthma, a prevalent chronic illness affecting millions of adults and children in the U.S., is exacerbated by indoor air pollutants like allergens, molds, and dust mites. Weatherization efforts targeting indoor ventilation and air quality showed a notable decrease in asthma-related emergency room visits by 11.5% and hospitalizations by 3.1% over a 12-month period. Moreover, high-cost asthma patients saw a reduction in doctor visits by 11.8%.

ENVELOPE AIRTIGHTNESS / WEATHERIZATION

THE INTEGRITY OF A BUILDING'S ENVELOPE IS CRUCIAL IN PREVENTING EXTERIOR POLLUTANTS FROM INFILTRATING INDOORS. DESIGNING A CONTINUOUS, AIRTIGHT, AND WELL-INSULATED ENVELOPE WITH HIGH-PERFORMANCE WINDOWS IS OPTIMAL. DEFICIENCIES IN THE ENVELOPE CAN BE REMEDIATED THROUGH RETROACTIVE WEATHERIZATION INITIATIVES.

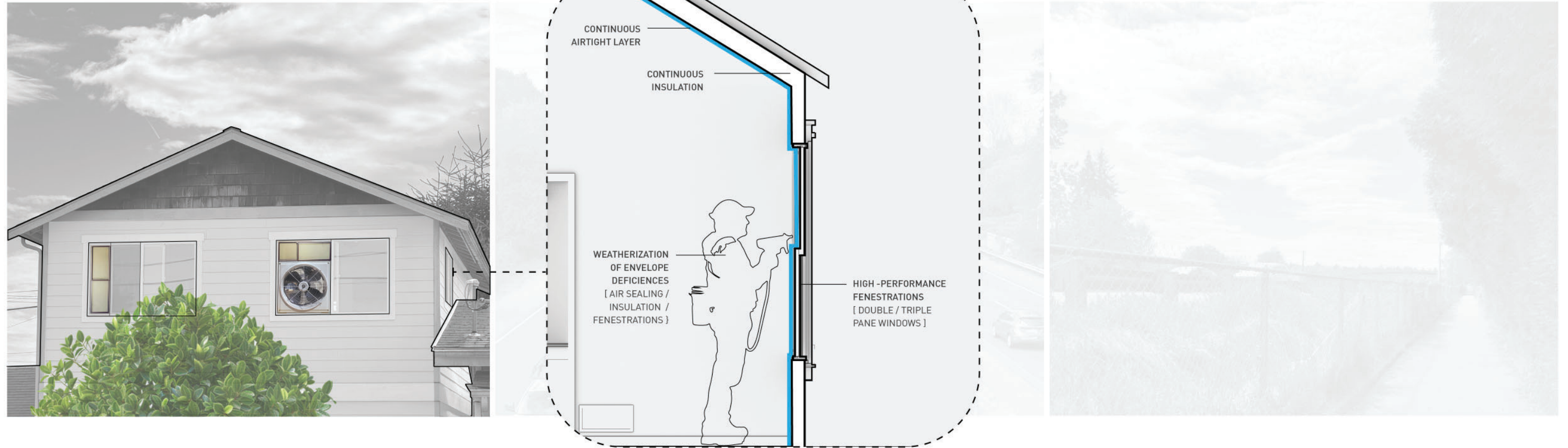


FIG 5.38 Envelope Airtightness / Weatherization Intervention Diagram. (2024). Daquan Proctor.

Healthy Materials

Intervention Description

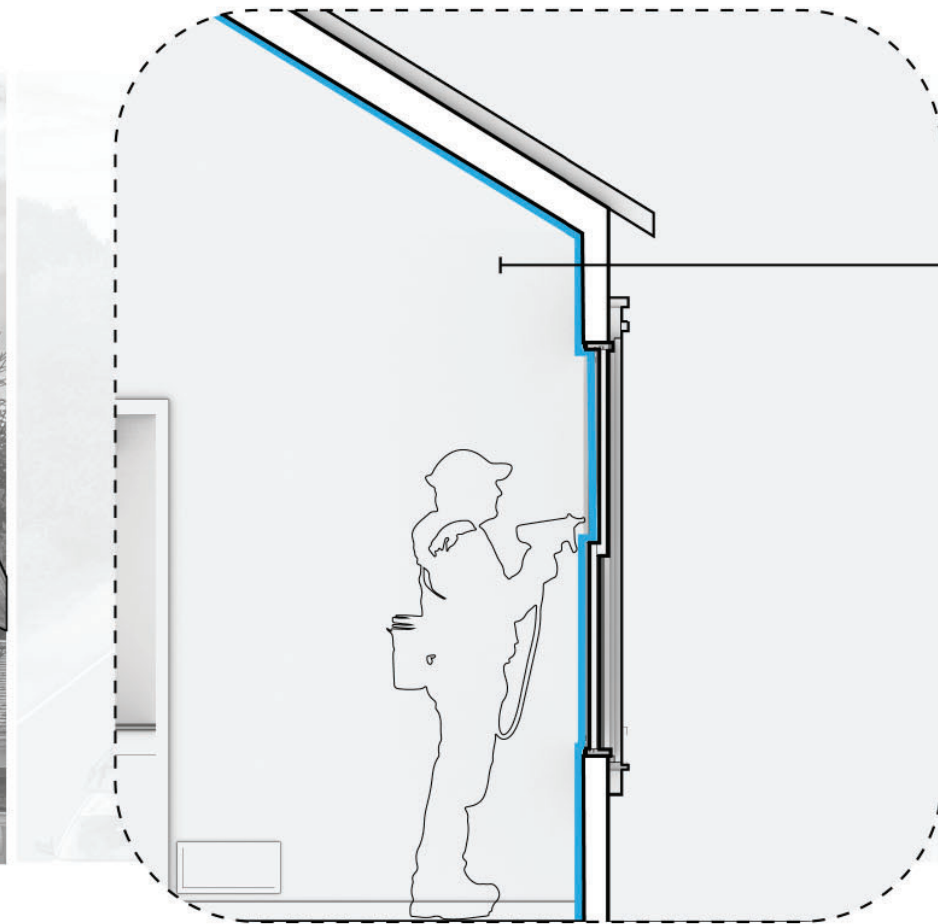
Building materials, finishes, and furnishings are significant contributors to indoor air pollution, especially in older homes using materials with adverse health impacts. It's important to avoid ILFI's "Red List" materials, opt for natural alternatives, and integrate pollution-capturing materials for improved indoor air quality. Choosing materials certified by programs like ILFI's "Declare" ensures they are free from harmful chemicals, while natural options like wood, stone, and low-VOC paints reduce emissions. Incorporating pollution-capturing technologies like VOC-capturing wall panels further improve indoor air quality.

Air Quality Benefit Timeframe

1 Year

Evidence

Indoor air quality is a significant concern due to various pollutants like microorganisms, CO₂, and VOCs from building materials, furniture, and cleaning supplies (Montjoy, 2023). These contaminants can lead to respiratory issues and affect mental well-being. Architects can improve air quality by prioritizing natural ventilation, maximizing exposure to natural light, and incorporating plants. Choosing modern, non-toxic, sustainable building materials like wood and bamboo can offer stress-relief benefits and lower VOC emissions. Opting for solid surface flooring such as wood or low-VOC sealant tiles instead of carpets and laminate flooring helps reduce air pollutants. Architects should also select low-carbon-footprint wall finishes and avoid synthetic gypsum drywall to improve indoor air quality. Green insulation materials like sheep's wool and cotton can further contribute to healthier indoor air.



HEALTHY MATERIALS

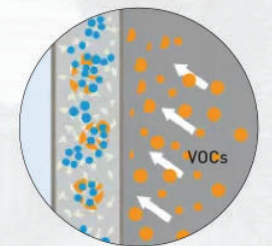
BUILDING MATERIALS, FINISHES, AND FURNISHINGS SIGNIFICANTLY CONTRIBUTE TO INDOOR AIR POLLUTION SOURCES. OLDER HOMES OFTEN USE MATERIALS WITH HEALTH IMPACTS, HIGHLIGHTING THE IMPORTANCE OF AVOIDING ILFI'S "RED LIST" MATERIALS, CHOOSING NATURAL ALTERNATIVES, AND INCLUDING POLLUTION-CAPTURING MATERIALS TO MITIGATE AIR POLLUTION FROM MATERIAL SOURCES.



AVOID MATERIALS ON ILFI'S "RED LIST"



OPT FOR NATURAL BUILDING MATERIALS



INCORPORATE POLLUTION CAPTURING MATERIALS

FIG 5.39 Healthy Materials Intervention Diagram. (2024). Daquan Proctor.

Air Purifier / Air Filter

Intervention Description

In conjunction with various indoor air quality measures, technological interventions such as air purifiers and filters are additional strategies for reducing exposure to contaminated indoor air. These devices work by actively capturing and removing airborne pollutants, including dust, pollen, mold spores, pet dander, and volatile organic compounds (VOCs), thereby improving the overall quality of the indoor environment. Air purifiers employ advanced filtration systems, such as HEPA (High-Efficiency Particulate Air) filters or activated carbon filters, to trap and eliminate microscopic particles and odors. They are particularly beneficial for individuals with allergies, asthma, or respiratory sensitivities, as they can significantly reduce the presence of allergens and irritants in the air.

Air Quality Benefit Timeframe

< 1 Year

Evidence

Achieving a reduction of up to 90% in airborne particles can be accomplished through the use of different air purification methods, each offering varying speeds and effectiveness (Puget Sound Clean Air Agency, n.d.). For instance, with a commercial air purifier or a filter fan operating at low speed, this remarkable reduction in particles takes approximately 35 minutes. This process becomes even more efficient when the filter fan is set to medium speed, capable of achieving the same 90% reduction in just 20 minutes. However, for those seeking a quicker turnaround, setting the filter fan to high speed accomplishes this substantial reduction in a mere 15 minutes. These timeframes demonstrate the efficacy of utilizing air purification technologies and the versatility the filter fan provides for faster filtration rates than the HEPA air purifier.



AIR PURIFIER / AIR FILTER

ALONGSIDE OTHER INDOOR AIR QUALITY STRATEGIES, TECHNOLOGICAL INTERVENTIONS LIKE AIR PURIFIERS AND FILTERS ARE EFFECTIVE IN REDUCING EXPOSURE TO CONTAMINATED INDOOR AIR.

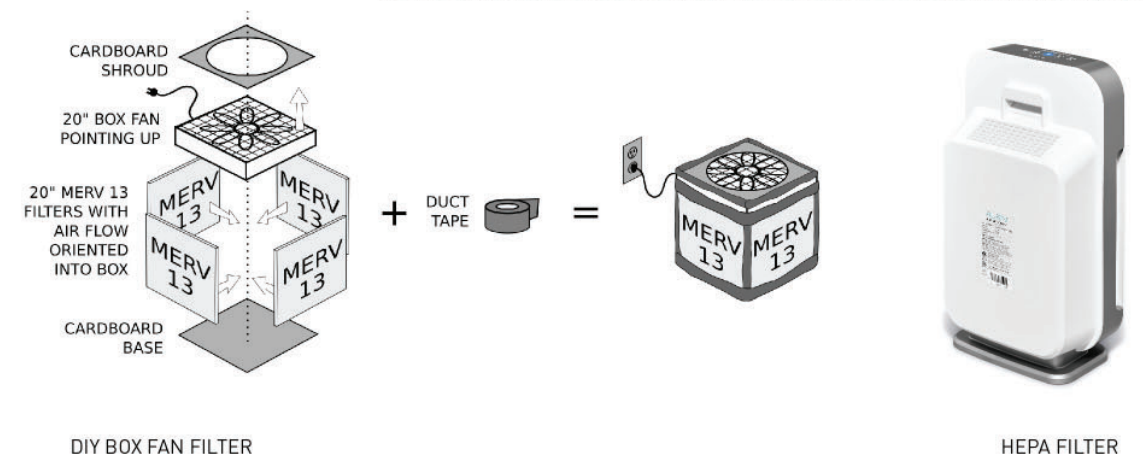


FIG 5.40 Air Purifier / Air Filter Intervention Diagram. (2024). Daquan Proctor.

Photocatalytic Paving

Intervention Description

Photocatalytic pavement is an approach that utilizes sunlight to purify the air. This advanced pavement material is infused with titanium dioxide, a catalyst that initiates reactions when exposed to sunlight. These reactions effectively decompose pollutants such as nitrogen oxides and volatile organic compounds (VOCs), transforming them into less harmful substances.

Air Quality Benefit Timeframe

< 1 Year

Evidence

Research into the viability of photocatalytic paving began in Japan in the early 1970s and has since expanded to Europe and North America (Pavement Technology Inc., n.d.). This technology utilizes titanium dioxide (TiO₂) to transform asphalt and concrete pavements into pollution-reducing and heat-reducing surfaces. Ongoing advancements in photocatalytic paving include the development of various TiO₂-enhanced products aimed at rejuvenating and preserving roadways and other transportation-related infrastructure. Notably, photocatalytic paving has demonstrated up to a 60% reduction in nitrogen oxide (NO_x) emissions.



FIG 5.41 Photocatalytic Paving Intervention Diagram. (2024). Daquan Proctor.

Context Responsive Roadside Planting [Median]

Intervention Description

Highway medians, which frequently suffer from insufficient plantings, present a prime opportunity for enhancing air quality. Although safety and visibility regulations often restrict the inclusion of trees due to median width constraints, these areas can still be optimally utilized. By strategically planting robust shrubs and low-growth vegetation, the median's width can serve as an ideal space for vegetation that actively mitigates air pollution along the highway and benefits nearby communities. This approach not only beautifies the landscape but also contributes significantly to reducing harmful pollutants, fostering a healthier environment for both motorists and residents in adjacent areas.

Air Quality Benefit Timeframe

2 Years

Evidence

The study conducted by Georgia State University found that trees and bushes planted near highways play a significant role in reducing air pollution caused by motor vehicles (Greenwald et al., 2024). Over two three-month periods, researchers observed a 37% reduction in soot and a 7% reduction in ultrafine particles at sites with vegetation compared to similar sites without vegetation. These findings, published in PLoS One, highlight the potential of roadside vegetation to mitigate the health risks associated with motor vehicle pollution, such as asthma, chronic bronchitis, lung cancer, and heart attacks. While roadside vegetation doesn't address carbon dioxide emissions or ozone pollution, it can effectively trap small particles.



CONTEXT RESPONSIVE ROADSIDE PLANTING [MEDIAN]

HIGHWAY MEDIANS OFTEN LACK ADEQUATE PLANTINGS AND CAN BE BETTER UTILIZED TO IMPROVE AIR QUALITY. WHILE THE WIDTH OF THIS MEDIAN PRECLUDE TREES FOR SAFETY AND VISIBILITY REQUIREMENTS, THE WIDTH IS SUITABLE FOR ROBUST PLANTING OF SHRUBS AND LOW-GROWTH PLANTS THAT CAN REDUCE AIR POLLUTION LEVELS ALONG THE HIGHWAY AND IN ADJACENT COMMUNITIES.

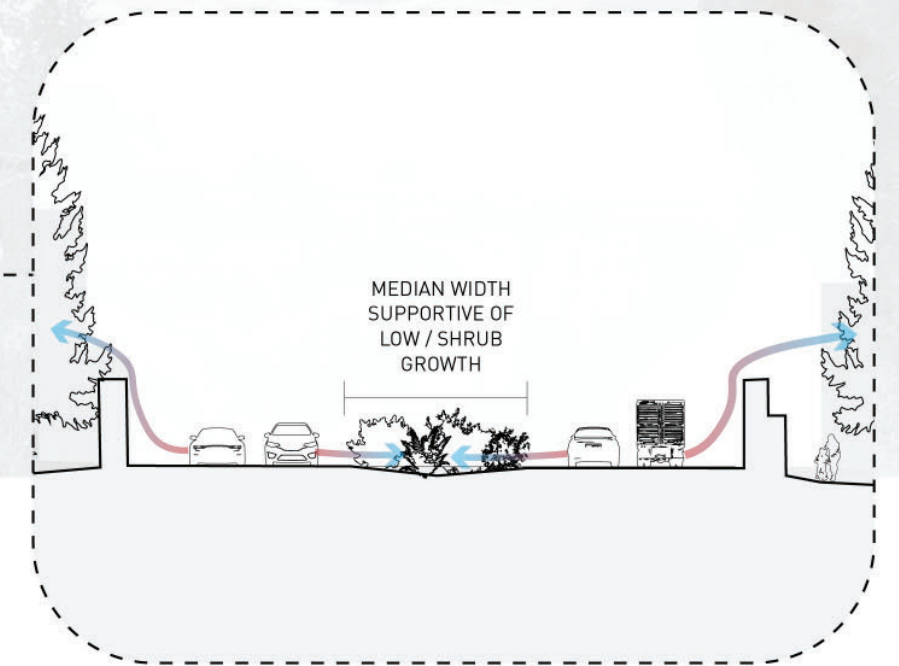


FIG 5.42 Median Context Responsive Roadside Planting Intervention Diagram. (2024). Daquan Proctor.

Physical Barrier

Intervention Description

Physical barriers like noise walls or gabion structures play a vital role in mitigating air pollution along roadways. By acting as robust boundaries, they alter airflow patterns and effectively reduce pollutant concentrations. Studies show that within 50 to 165 feet of these barriers, pollutants like particulate matter and nitrogen oxides can decrease by up to 50%, with a noticeable impact extending up to 1000 feet away, where reductions of up to 30% are still achievable. These barriers not only offer immediate protection to sensitive areas but also provide secondary benefits like noise reduction and visual screening, making them a versatile solution for improving air quality in urban environments.

Air Quality Benefit Timeframe

1 Year

Evidence

Roadside barriers, encompassing various types like noise walls, solid barriers, earthen berms, vegetative walls, buffers, and functional buffers, are effective strategies for reducing pollutant concentrations downwind of roadways (Rousseau et al., 2023). Their success hinges on several factors such as the layout of the road, local meteorological conditions, the height and design of the barrier, and its placement. For example, solid noise barriers have been proven to decrease air pollution levels by anywhere from 10 to 50 percent when the wind blows across the road. However, their effectiveness diminishes for winds coming from other directions, and gaps in the barriers can compromise their ability to block pollutants effectively. To be truly effective in reducing air pollution, barriers, whether solid or vegetative, should ideally be at least 20 feet tall.

PHYSICAL BARRIER

PHYSICAL BARRIERS SUCH AS NOISE BARRIERS OR GABION WALLS SERVE AS HARD BOUNDARIES THAT CHANGE THE AIRFLOW OF ROADSIDE CONTAMINANTS. THEY'RE IDEAL FOR SCREENING SENSITIVE AREAS WHEN OTHER STRATEGIES FALL SHORT. THESE BARRIERS CAN LOWER NEAR-ROAD AIR POLLUTION CONCENTRATIONS BY UP TO 50% WITHIN 50 TO 165 FEET OF THE BARRIER, AND THE IMPACT CAN STILL BE SIGNIFICANT—REDUCING POLLUTION BY AS MUCH AS 30% UP TO 1000 FEET AWAY FROM THE BARRIER..



FIG 5.43 Physical Barrier Intervention Diagram. (2024). Daquan Proctor.

AIR QUALITY INTERVENTION SUMMARY AND APPLICATIONS

Throughout this chapter, we have examined a series of strategic interventions designed to address various built environment challenges that impact community air quality health outcomes. The proposed interventions are tailored to specific land use conditions, including residential, industrial, commercial, and transportation zones, each facing unique issues related to air quality, infrastructure, and environmental degradation.

Public Open Space - Industrial/Transportation:

- Challenges: Proximity to heavy traffic and industrial activity, underperforming roadside planting, high impervious surfaces, urban heat island effect.
- Interventions: Context-responsive roadside planting, topographic buffers, air filtration towers, depaving and revegetation, permeable paving.

Residential - Industrial:

- Challenges: Underperforming roadside planting, limited alternative transportation infrastructure, declining urban tree canopy.
- Interventions: Context-responsive roadside planting for shallow urban canyons, separated transport lanes, urban canopy expansion.

Residential - Civic/Commercial:

- Challenges: Declining urban tree canopy, limited infrastructure and connectivity for alternate transportation, underperforming roadside planting.
- Interventions: Climate-adaptive planting, superblock streets, context-responsive roadside planting for avenue canyons, green screens, multimodal connectivity, traffic management optimization, mixed-use and complete communities.

Residential - Transportation:

- Challenges: Compromised indoor air quality, concentrated impervious surfaces, underperforming roadside planting, proximity to pollution.
- Interventions: Filtered natural ventilation, envelope airtightness/weatherization, healthy materials, air purifiers/filters, photocatalytic paving, context-responsive roadside planting for medians, physical barriers.

These strategies collectively offer a comprehensive approach for mitigating the adverse effects of urbanization and industrial activity on air quality and community health.

Community members, urban planners, policymakers, and other stakeholders can leverage this information to advocate for and implement similar interventions in their own neighborhoods through the following means:

Community Engagement and Advocacy: Community members can use these strategies to advocate for healthier environments by participating in local planning meetings, engaging with policymakers, and collaborating with environmental organizations. By presenting evidence-based solutions, residents can influence the implementation of interventions that improve air quality and overall well-being.

Localized Adaptation: While the specific interventions are tailored to particular conditions, the underlying principles of green infrastructure, air filtration, and transportation optimization can be adapted to various urban settings. For instance, climate-adaptive planting and context-responsive roadside planting can be customized to fit local vegetation types and climatic conditions.

Collaborative Planning: Successful implementation of these interventions requires collaboration between different stakeholders, including city planners, public health officials, environmental experts, and the community. Creating multidisciplinary teams can ensure that interventions are both scientifically sound and practically feasible.

Policy Development: Policymakers can use these strategies as a basis for developing regulations and incentives that promote sustainable urban design. This includes zoning laws that encourage green infrastructure, funding for air quality improvement projects, and incentives for adopting sustainable building practices.

Education and Awareness: Educating the public about the benefits of these interventions is crucial. Community workshops, informational campaigns, and school programs can raise awareness about the importance of air quality and the role of green infrastructure in creating healthier urban environments.

The interventions outlined in this chapter provide a roadmap for transforming urban landscapes into healthier, more sustainable, and more livable spaces. By addressing the root causes of air pollution and environmental degradation, these strategies aim to create equitable and resilient communities. Through informed advocacy, localized adaptation, collaborative planning, policy development, and public education, community members and stakeholders can work together to implement these solutions, fostering environments where residents can thrive.



06 REFLECTIONS

This chapter synthesizes conclusions and reflections from the research process and comments from the community exhibition.

REFLECTIONS AND CONCLUSIONS

The “AirWise: Collective Action for Clean Air” thesis embarked on an investigation to address significant documented health disparities resulting from poor air quality in urban environments, focusing specifically on Seattle, Washington. Utilizing a comprehensive research methodology that supported the development of a Health Equity Design Framework, this study integrates various perspectives and tools to uncover and address environmental injustices that disproportionately impact marginalized communities. The aim is to provide actionable design interventions that foster healthier and more equitable urban settings.

Summary of Research

This research adopts a health equity framework to explore the intricate relationships between air quality, urban design, and health disparities. By using GIS mapping, comprehensive literature reviews, field photography, and case studies / research studies, the thesis provides a detailed understanding of the spatial and demographic factors influencing these disparities, which include:

Health Disparities and Air Quality: The study confirms that air pollution significantly impacts respiratory and cardiovascular health, with marginalized communities experiencing the highest burdens. The correlation between poor air quality and health issues such as asthma, bronchitis, and cardiovascular diseases is well-documented.

Historical Context: Historical practices like redlining and industrial zoning have entrenched environmental inequities, leading to persistent health disparities. These practices have confined minority and low-income populations to areas with higher pollution levels, exacerbating their vulnerability.

Current Challenges: Contemporary urban development and transportation policies continue to exacerbate these issues. The concentration of polluting industries and major transportation routes in or near marginalized neighborhoods perpetuates the cycle of poor health outcomes.

Categories of Design Strategies

The thesis proposes several high-level categories of design interventions aimed at mitigating the adverse effects of poor air quality and promoting health equity. These strategies are designed to be practical, community-led, and scalable to other urban areas facing similar challenges. The strategies directly address the specific challenges identified in the research and field observations and include:

Vulnerable Uses Near Pollution: Many residential areas, schools, community spaces, and parks are situated close to major traffic routes and industrial zones. The introduction and enhancement of green spaces, earthworks, and context responsive planting, can act as natural buffers, reducing the spread of pollutants and providing cleaner air. Urban green spaces also offer recreational areas that promote physical and mental well-being, creating healthier environments for vulnerable populations, including children and the elderly.

Compromised Indoor Air Quality: Buildings located near high pollution levels often experience compromised indoor air quality due to the infiltration of outdoor air pollutants. Implementing design standards that prioritize air quality, such as using non-toxic building materials, advanced ventilation systems, and air purifiers, can significantly improve indoor air quality. Ensuring that buildings are well-sealed and using high-quality insulation can prevent the ingress of outdoor pollutants, thus protecting the health of residents, especially those with pre-existing conditions.

Concentrated Impervious Surfaces: Urban areas with extensive impervious surfaces contribute to the heat island effect and reduce natural absorption and filtration of rainwater. Strategies like replacing impervious surfaces with permeable materials, increasing the use of green roofs, and enhancing the urban tree canopy can mitigate these effects. These measures can help reduce ground-level ozone formation and decrease the urban heat island effect.

Underperforming Roadside Planting: The effectiveness of roadside planting is often compromised by poor plant selection, inadequate maintenance, and discontinuous planting strips. Enhancing roadside planting with appropriate vegetation and ensuring continuous, well-maintained planting strips can significantly improve air quality. Properly selected and maintained plants can act as natural air filters, absorbing pollutants and providing cooling benefits.

Declining Urban Tree Canopy: The urban tree canopy is declining due to factors such as aging trees, urban development, climate change and a lack of stewardship. Trees play a crucial role in improving air quality by absorbing pollutants, providing shade, and cooling the urban environment. Increasing the urban tree canopy through climate adaptive planting and maintenance can help restore these benefits, making it easier to achieve cleaner air.

Limited Alternate Transportation Infrastructure: There is often a lack of infrastructure to support alternative transportation modes such as cycling, walking, and public transit. Developing safe and connected biking and walking paths, enhancing public transportation infrastructure, and creating car-free zones can reduce reliance on personal vehicles, lower vehicular emissions, and promote healthier lifestyles. These interventions can also reduce traffic congestion and improve overall air quality in urban areas.

Reflections

Thesis Process

Developing this thesis has been a challenging yet rewarding journey. The integration of various research methodologies provided a comprehensive understanding of the complex factors influencing air quality and health disparities. The place-conscious approach allowed for a detailed exploration of Seattle's unique environmental and social landscape, making the findings and proposed strategies particularly relevant to the local context.

The research process involved extensive data collection and analysis, which was critical in identifying the specific needs and vulnerabilities of different communities in Seattle. GIS mapping and field photography provided visual and spatial insights that enriched the narrative and supported the design proposals. The incorporation of case studies / research studies offered valuable lessons from other urban areas and initiatives, highlighting best practices and innovative solutions that could be adapted to Seattle's context.

Community Feedback and Exhibition

On May 31st a community exhibition at the Georgetown Steamplant provided an opportunity to share my work with and receive feedback from the community, stakeholders, and my peers on the viability of my proposals (Figure 6.1/6.2). Following the community exhibition, several valuable insights and lessons emerged:

Community Engagement: Community members commended the depth of my research and the clarity of the information presented. Many visitors were shocked by the number of people exposed to air quality exceeding WHO limits and the number of deaths attributed to air pollution. This feedback underscored the need for practical and effective strategies, as it provided a reality check for the design proposals, highlighting potential challenges and opportunities for improvement.

Stakeholder Collaboration: Discussions with local community organizations, urban planners, and environmental groups were crucial in assessing the feasibility and potential impact of the proposed interventions. Specifically, conversations with members of the Duwamish Valley Sustainability Association (DVSA) confirmed synergies between my work and the Clean Air Program. As a result, DVSA invited me to their podcast to discuss transportation-based sources and interventions for air quality, fostering further collaborative opportunities.

Sustainability and Scalability: The exhibition helped gauge the long-term sustainability of the strategies and their scalability to other urban areas facing similar challenges. The evocative and descriptive graphics received positive comments, and discussions emphasized the importance of maintaining and expanding these interventions over time to achieve lasting improvements in air quality and health outcomes.



FIG 6.1 AirWise Community Exhibit Opening Event. (2024). Daquan Proctor.
FIG 6.2 Daquan Proctor posing with AirWise Exhibit. (2024). Daquan Proctor.

Future Directions

The findings of this thesis underscore the need for continued research and action to address air quality disparities. Future studies could expand on this work by exploring additional cities, refining design interventions based on community feedback, and developing more comprehensive policy recommendations. Specific areas for future research include:

Longitudinal Studies: Conducting longitudinal studies to monitor the long-term health impacts of the proposed interventions and to track improvements in air quality over time.

Technological Innovations: Exploring in further detail new technologies for air quality monitoring and pollution reduction, such as advanced filtration systems, green building materials, and sustainable transportation solutions.

Policy Analysis: Analyzing the effectiveness of existing policies and regulations related to air quality and health equity, and identifying gaps that need to be addressed through new legislative initiatives.

Moreover, fostering stronger collaborations between academic researchers, community organizations, and government agencies will be essential in driving forward the initiatives proposed in this thesis. Building a coalition of stakeholders committed to health equity and environmental justice can amplify the impact of the research and ensure that the proposed strategies are effectively implemented.

Conclusion

“AirWise: Collective Action for Clean Air” has provided a robust framework for understanding and addressing environmental health disparities in urban settings. The research and design strategies outlined in this thesis highlight the critical role of the built environment in shaping health outcomes and emphasize the transformative potential of inclusive, community-led urban design interventions. The recent community exhibition was a prime opportunity to showcase this research, gather invaluable feedback, and build momentum for action.

Engaging with community members, local organizations, and other stakeholders during the exhibit translated the thesis findings into tangible discussions on improving air quality and health outcomes for the residents of Seattle and beyond. The positive reception, including commendations on the depth of research and the evocative graphics, as well as the invitation to the DVSA podcast, demonstrated the potential for meaningful collaboration. This journey is just the beginning, and with continued effort and partnership, it holds the promise of making a significant impact on urban health equity and environmental justice.

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