PRIORITIZING UNDERSERVED COMMUNITIES FOR THERMAL COMFORT STREET RETROFIT IN EUGENE, OR

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UNIVERSITY OF OREGON | MASTER OF LANDSCAPE ARCHITECTURE

APPROVAL

Submitted for partial fulfillment for the
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ABSTRACT

In consideration of climate change and the increasing trend of extreme weather events, communities see more urgent needs for preparation, especially for protecting their vulnerable populations. Given the growing climate challenges, this project aims to develop a design proposal for thermally comfortable walkable and bikable street network within the vulnerable communities in Eugene, Oregon, to address the increasing urban heat island (UHI) effects and heat waves .

The project first focuses on prioritizing vulnerable communities in Eugene through spatial analysis using American Community Survey (ACS) socio-economic data and the UHI map. Using expert surveys and Garret's Ranking Technique, 25 block groups were identified and prioritized for thermal comfort street implementation. After considering the locations of vulnerable communities, I propose a city-wide thermal comfort street network along with specific street design recommendations of four selected block groups based on the urban form types and demographic characteristics. This proposal could help the City of Eugene to efficiently allocate its resources for climate change adaptation through prioritizing vulnerable communities and implementing effective design interventions.

CHAPTER 1

BACKGROUND

INTRODUCTION

Eugene is characterized by its natural environment. It was ranked 7 as best green city in 2010 (Livability.com, 2010) . However, a recent research led by Vivek Shandas identified Eugene's urban heat islands (UHI) and the result shows that a substantial area of Eugene is, in fact, within the UHI zone. Even though Eugene has a vast Ridgeline Trail System, a trail system that stretches along the southern edge of the City with large, semi-connected forests, the forests are only mitigating UHI most efficiently on the southern parts of the City. The rest of Eugene is still heavily influenced by the heat. Temperatures in Eugene had even reached above 90°F for 17 days in 2017 and 16 days in 2018 (US Climate Data, 2019).

Meanwhile, the population in Eugene, OR has been growing steadily in the past decades. The current population estimates as of July 1, 2017 is 163, 135 (U.S. Census Bureau, 2017). In 2015, Portland State University (PSU) projected Eugene to be having a population increase of approximately 40,000 people between 2015 and 2035 (20 years), and almost 90,000 people between 2015 and 2065 (50 years) (Portland Statae University, 2015). This anticipated population increase will further contribute to higher urban heat within the city in the future as more housing will be developed.

UHI effect will only be more intense and frequent in the context of climate change (Environmental Protection Agency, 2017). Under this situation, underserved communities within Eugene will suffer the most. There are growing numbers of senior population. As of 2017, there are 14.9% of people aged 65 years old and over, with approximately 10.6% of 45 to 54 years old, 5.4% of 55 to 59 years old, and 6.1% of 60 to 64 years old (U.S. Census Bureau, 2017), Underserved communities, such as communities with high elderly population or high poverty population, would be more vulnerable to health risks under climate change. Furthermore, the roads on these underserved communities tend to have less well-established vegetated sidewalk and bikeway network. As a result, these communities generally become the major contributor of UHI, and the residents of these communities experience environmental injustice. Walking within these communities poses higher threats to the residents' health and well-being, and the combined UHI effects of these communities affect the City as a whole (Environmental Protection Agency, 2017).

Green infrastructure could safeguard the health of community members by improving air and water qualities, as well as by providing thermal comfort streets to pedestrians especially during summer (Environmental Protection Agency, 2018). Thus, improving thermal comfort walkable network for these underserved communities is crucial not only to benefit the residents of these communities to travel safely, it benefits the City as well to mitigate UHI and to better prepare the City for climate change adaptation.

PROJECT GOAL, OBJECTIVES, & SIGNIFICANCE

GOAL

This project aims to create a walkable network for the underserved communities in Eugene and use such network to prepare the city for UHI effect and climate change adaptation.

OBJECTIVES

The project focuses on the underserved communities within Eugene considering their social, environmental, and physical conditions. It:

- prioritizes block groups that fall under Title VI Communities of Concern in Central Lane Metropolitan Planning Organization's (MPO) 2018 data (Central Lane Metropolitan Planning Organization, 2018) using the following criteria:

    1. percentage area affected by high temperature UHI zone
    2. percentage tree canopy cover
    3. household in poverty
    4. disabled population
    5. elderly population
    6. minority population
    7. unemployed population
    8. household with no cars
    9. population with limited English
    10. population density

- assigns each block group an urban form type related to UHI

- provides design recommendations

    1. selects 4 adjacent block groups for a more integrated design
    2. analyzes each block groups' locations, demographics, and proximity to local amenities
    3. provides design recommendations to each of the 4 block groups

SIGNIFICANCE

The product of this project helps the City to allocate resources more efficiently by identifying and prioritizing the needs of having green pedestrianized streets in underserved communities within Eugene. At the same time, it provides design recommendations to reduce heat-related risks and mitigate UHI for the corresponding urban form type. In addition, by linking the green walkable networks to public transportation and bike networks, the study contributes to a safer multimodal network and promotes the use of public transit and bikes.

RESEARCH QUESTIONS

1. Where in Eugene is most severely impacted by urban heat island?

2. Where in Eugene is most underserved with complete, green streets?

3. How can Eugene use green streets to cope with climate change?

4. How can the green streets provide social activities / interesting routes to encourage walking/biking within the underserved communities?

Photo: A west Eugene neighborhood is located right next to an industrial area. A narrow vegetated swale in a bad condition is the only buffer between them.

DEFINITIONS

Communities of Concern - Defines as concentration of one or more of these socio-economic factors: minority population, households in poverty, elderly population, and people with disabilities (Central Lane Metropolitan Planning Organization, n.d.).

Environmental Justice – 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 (EPA, 2018).

Title VI of the Civil Rights Acts of 1964 – No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance (Civil Rights Division Department of Justice, 2016).

Underserved communities – Communities with concentration of one or more of these seven socio-economic factors: minority population, households in poverty, elderly population, disabled population, unemployed population, household with no cars, and population with limited English, which did not receive fair or enough allocation of resources for development, implementation, and enforcement of environmental laws, regulations, and policies in comparison to other communities within the city.

Urban heat island – Describes built up areas that are hotter than nearby rural areas (Environmental Protection Agency, 2019).

Vulnerable communities - Experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with , adapt to, or recover from climate change impacts. These disproportionate effects are caused by physical (built and environmental, social, political, and/or economic factor(s). which are exacerbated by climate impacts. These factors include but are not limited to race, class, sexual orientation and identification, national origin, and income inequality (State of California Governor's Office of Planning & Research, 2018).

CHAPTER 2

LITERATURE REVIEW

URBAN HEAT ISLAND

DISCOVERY OF URBAN HEAT ISLAND

Urban heat island (UHI) has been an issue since 1810s. The phenomenon was first discovered by Luke Howard, a chemist from Britain (Lee, 2013). He discovered the temperature difference between London and its surrounding rural areas and concluded that dense population and buildings in cities contribute to heat retention, thus causing cities to retain more heat than rural areas (Lee, 2013). Even though he was not the one who named the phenomenon, his discovery has sparked a lot of researches and design solutions related to the UHI effect, both in local and global levels, for the past two centuries.

URBAN HEAT ISLAND CAUSES, IMPACTS & RELATION TO CLIMATE CHANGE

Since then, researchers have identified key causes of UHI, including urbanization, urban sprawl, increasing population, increasing use of manufactured materials, and increase in heating and cooling energy needs (Mohajerani, Bakaric, & Jeffrey-Bailey, 2017), (Yin, Yuan, Lu, Huang, & Liu, 2018), (Arifwidodo & Chandrasiri, 2015), (Hirano & Fujita, 2012), and (Lemonsu, Viguié, Daniel, & Masson, 2015).

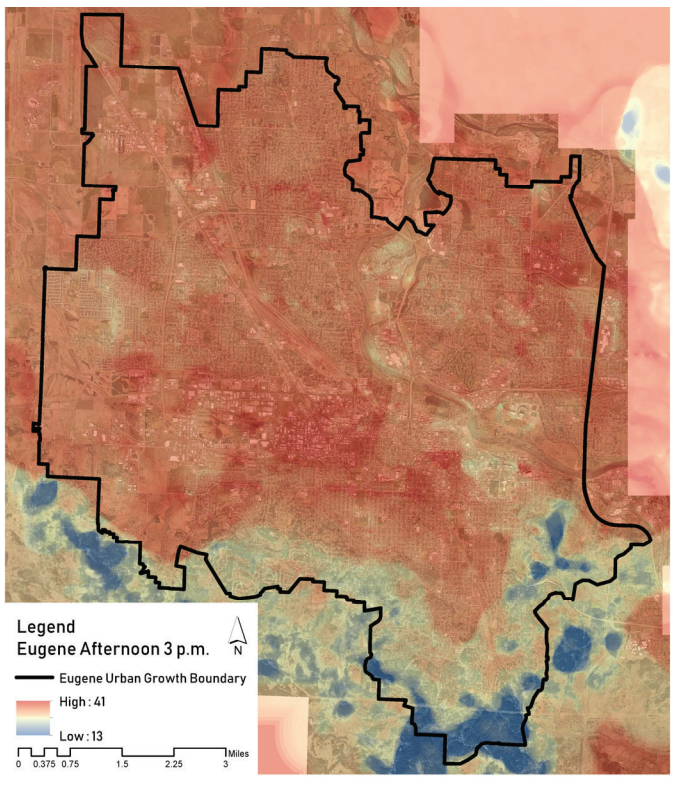
The Environmental Protection Agency (EPA) identified four major impacts climate change has on our society, increased energy consumption, elevated emissions of air pollutants and greenhouse gases, compromised human health and comfort, and impaired water quality (Environmental Protection Agency, 2017). Records between 1979 and 2003 shows that heat was the underlying or contributing cause of death for nearly 8,000 Americans (Environmental Protection Agency, 2017). Heat cramps, heat exhaustion, heat stroke, respiratory difficulties and other heat-related illnesses, will be more common (Environmental Protection Agency, 2017).

With climate change becoming more extreme, the temperature within UHIs will only further increase the already higher temperatures within cities (Environmental Protection Agency, 2017). By 2050, UHI effect is expected to add a further 2°C, (equivalent to 3.6°F), to climate change estimates for the most populated cities (Estrada, Botzen, & Tol, 2017). A study led by an international team of economists from the world's major cities quantified the combined impacts of global and local climate change on cities (Estrada, Botzen, & Tol, 2017). After analyzing 1,692 cities, they calculated that "the accumulated total costs of urban impacts of global and local climate change for all cities during this century could be about 2.6 times those without UHI effects (Estrada, Botzen, & Tol, 2017). Losses for the worst-off cities could even reach up to 10.9% of GDP by the end of the century, compared with a global average of 5.6% (Estrada, Botzen, & Tol, 2017). Thus, any efforts to relieve UHI effect should be done sooner and more strategically for public health and for achieving higher economic benefits.

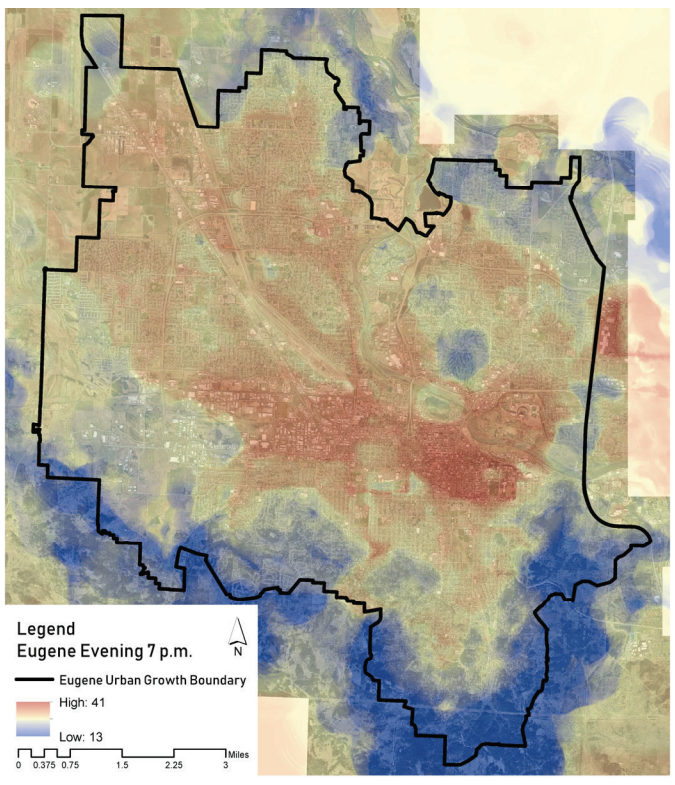
EUGENE URBAN HEAT ISLAND

Voelkel & Shandas (2018) mapped out Eugene's urban heat island in the morning, afternoon, and evening in August 2016. The maps show that downtown and west Eugene are generally hotter than south Eugene, where the Ridgeline Trail System is (Figure 1). These hotter locations are also where the underserved communities located.

AFTERNOON 3 P.M.



EVENING 7 P.M.



MORNING 6 A.M.

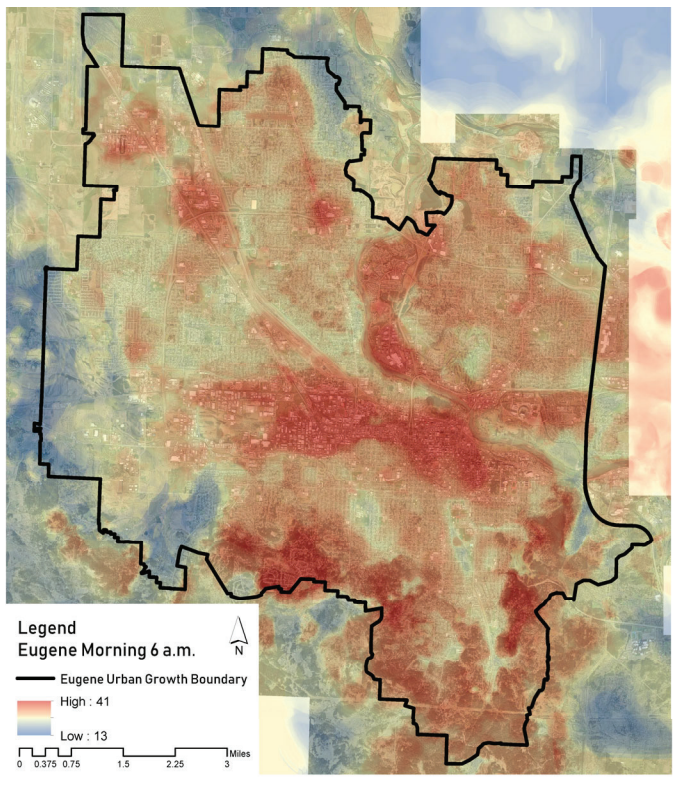


Figure 1. Eugene's UHI maps overlay showing air temperature in the morning (6 a.m.), afternoon (3 p.m.), and evening (7 p.m.) in August 2016. The urban heat island maps were obtained from Volelkel & Shandas (2018).

ENVIRONMENTAL JUSTICE & TITLE VI

Environmental Justice is "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 (EPA, 2018). Environmental justice movement in the U.S. has a prolonged history. Title VI of the Civil Right Acts of 1964 states that "no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance (Civil Rights Division Department of Justice, 2016). Federal agencies providing financial assistance "should either initiate fund termination proceedings or refer the matter to the Department of Justice for appropriate legal action" if recipients are found to have violated Title VI (Civil Rights Division Department of Justice, 2016).

Yet, the major discussion of environmental justice began only 3 decades ago. It started when North Carolina planned to move contaminated soil from the states' roadsides to a landfill located in Warren County, one of only few counties in the states with a majority of black population in 1982 (Office of Legacy Management, n.d.). (Palmer, 2016). The decision triggered protests by environmental advocates seeking social justice and environmental protection (Palmer, 2016). Even though the advocates lost the battle, the event started the controversy that "the nation's environmental problems disproportionately burden its low-income people of color" (Palmer, 2016). President Clinton issued Executive Order 12898 to "make environmental justice a part of the federal decision-making process" (Office of Legacy Management, n.d.). The order also focuses on "the health and environmental conditions in minority, tribal, and low-income communities", aiming to achieve environmental justice and foster nondiscrimination (Office of Legacy Management, n.d.). Federal agencies need to "make environmental justice as an integral part of their missions and to establish an environmental justice strategy" (Office of Legacy Management, n.d.).

Lane Council of Governments (LCOG) is the Central Lane Metropolitan Planning Organization (MPO) that works closely with local governments and transit providers and distributes federal transportation dollars for the Central Lane County area (Lane Council of Governments, n.d.). They created a Communities of Concern map to help guide their decision-making process (Figure 2). Central Lane MPO defines Communities of Concern as "concentrations of one or more of these four socio-economic factors, minority population, elderly population, household in poverty, people with disabilities" (Central Lane Metropolitan Planning Organization, n.d.). These data include both Eugene and Springfield, OR.

LCOG's demographic data includes more socio-economic factors, such as unemployed population, household with no cars, and population with no English. Some of these are essential but often neglected and not protected under Title VI when it comes to decision making process for environmental justice communities.

Thus, this research will include the other socio-economic factors to prioritize underserved communities.

Title VI Communities of Concern in the Central Lane MPO Area

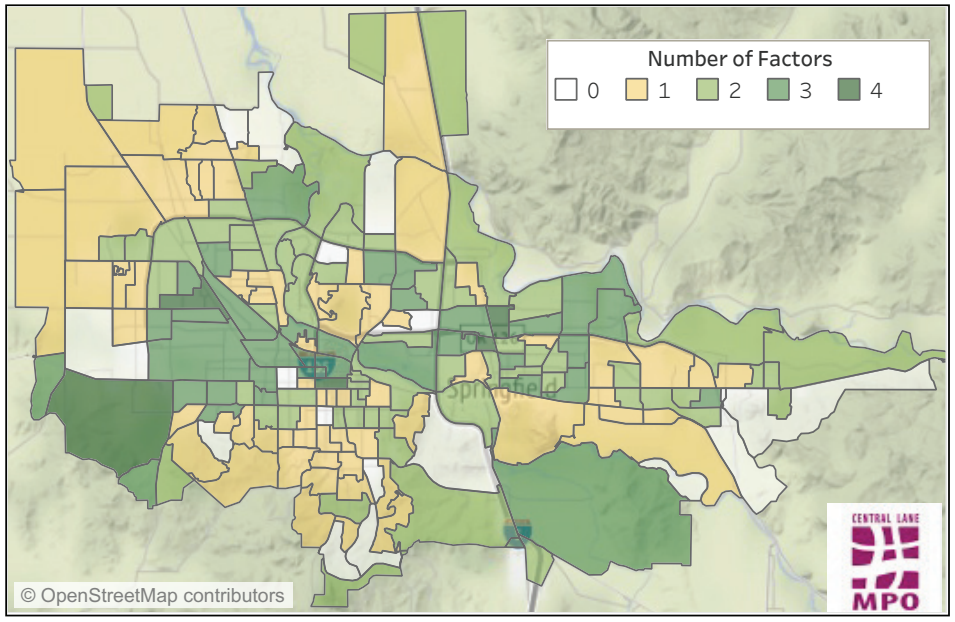
Data Source: 2012-2016 American Community Survey (5-Year ACS) at the Block Group level.

Title VI defines Communities of Concern as concentrations of one or more of these four socio-economic factors:

- Minority Population
- Elderly Population
- Households in Poverty
- People with Disabilities

The map indicates the Block Groups in which the percentage is higher than the region-wide average for one or more of these factors. The bar graphs show how each Block Group compares to the overall distributions of these four factors within the Central Lane MPO area.

-Hover over the map or bar graphs to see values for each Block Group.
-Click on the map to highlight the corresponding Block Group on the bar charts.
-Click on a bar chart to highlight the corresponding Block Group on the map and other charts.
-Clicking on a bar chart will also access a link to the source data for that Block Group.
-Draw a box on either the map or bar charts to highlight multiple Block Groups.



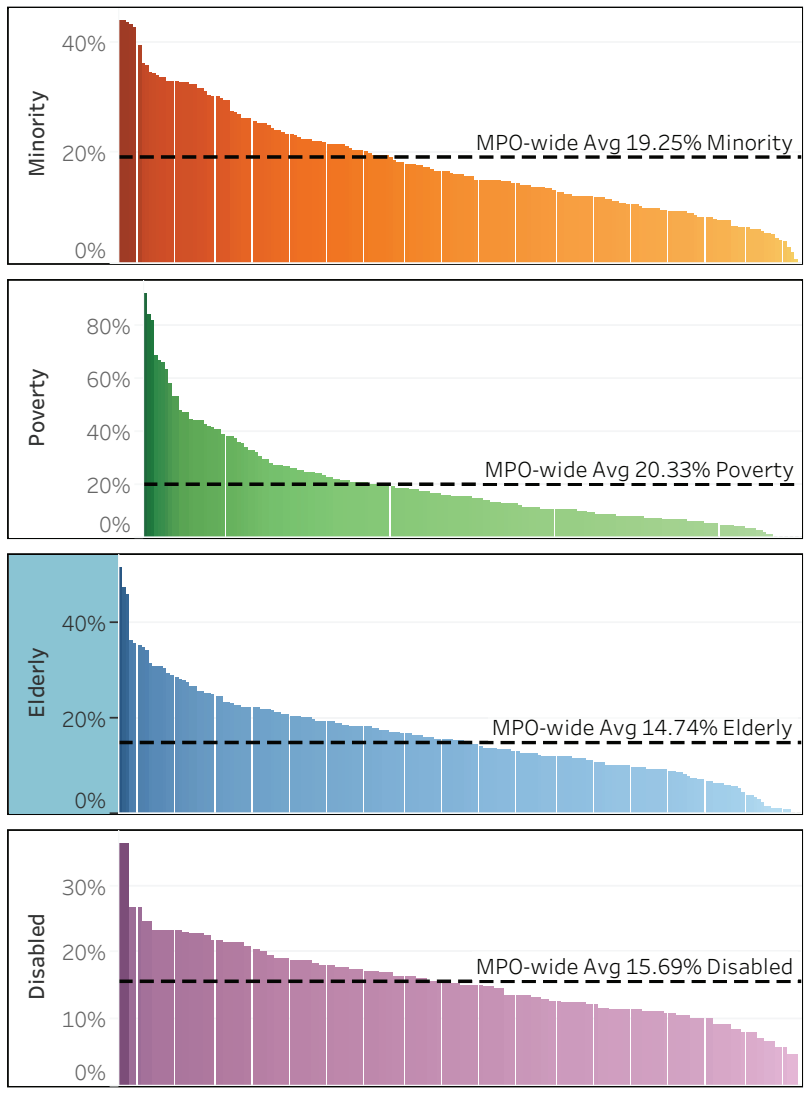


Figure 2. Communities of Concern map of the Eugene-Springfield area, obtained on Central Lane MPO website (Central Lane Metropolitan Planning Organization, n.d.).

PREVIOUS STUDIES IN EUGENE

EUGENE URBAN HEAT ISLAND

In 2017, Oliver Gaskell, an UO graduate student from the Planning, Public Policy & Management (PPPM) program, tried to understand the relationship between UHI effect and environmental justice communities based on temperature, environmental justice indicators, and land use data in his master project (Gaskell, 2018).

Gaskell had to collect the temperature data using point source data generated through the website called Weather Underground, which has 39 weather stations within the City of Eugene, as his research was done prior to the publication of Voelkel & Shandas' urban heat island map. For environmental justice indicators, he used the 5 out of 6 indicators. identified by the EPA. in his project. The indicators he used include percent low-income, percent minority, education level, individuals under 5, and individuals over 64.

The land use data were GIS layers collected from City of Eugene, LCOG, Oregon Spatial Data Library and Census TIGER products (Gaskell, 2018). They include, percentage tree cover (only include trees owned and maintained by the City of Eugene), percentage building cover, percentage land use density, percentage of commercial land use, building age, and census block groups.

His research identified UHI at block group levels (Figure 3). He also identified the hottest and coolest block groups on various days, and block groups with the most and least percentages of each environmental justice indicator and land use data attribute described above. Using the regression model, he then found that the major driver of UHI effect in Eugene is from medium and high-density land use due to 50% of impervious surfaces. He also compared the UHI map he created with the other environmental justice indicator maps he made to see whether these communities have any correlations with UHI.

As Gaskell noted, the percentage tree canopy cover in his research only includes trees that are owned and managed by the City of Eugene, thus the result might be influenced.

BUS RIDERSHIP, INCOME & EXTREME WEATHER EVENTS

A research done by Nichole Ngo in 2019 shows that bus ridership of the low-income neighborhoods is affected by the extreme and heavy rain events as they have very few alternatives for transportation. She found that bus ridership was increased by 2.7% on on days of heavy rain but dropped by 1.6% on hot days (Ngo, 2019). From this research, she suggests that residents in low-income neighborhoods are discouraged to travel during heavy rain or icy coniditions. In other words, they travel more by foot, by bike, or do not travel at all during hot days.


40 EUGENE STATION
$10
A MONTH
SPEED
LIMIT
30
STOP

CHAPTER 3

METHODOLOGY

METHODOLOGY

STEP 1: DATA COLLECTION & CALCULATIONS

The initial step of this project used GIS data and Communities of Concern map provided by the LCOG as well as urban heat island map provided by Voelkel & Shandas (2017) to narrow down 138 block groups to the top 25 Communities of Concern block groups. This process only includes block groups that have a concentration of 3 or more socio-economic factors on the Communities of Concern map. At the time of the initial phase, LCOG was able to provide the most updated 2018 communities of concern map data based on American Community Survey (ACS). For each of the 25 block groups, UHI coverage, canopy cover, and demographics in those block groups are calculated. In summary, the following 10 attributes of the GIS data were calculated or collected from each block group in order to gather the above-mentioned information:

1. percentage area affected by high temperature UHI zone
2. percentage tree canopy cover
3. household in poverty
4. disabled population
5. elderly population
6. minority population
7. unemployed population
8. household with no cars
9. population with limited English
10. population density

STEP 2: EXPERT SURVEY

After gathering all the data, the data were normalized by adjusting the values within each attribute to a scale from 0.00 to 1.00 for better comparison, where 0 is the least concerned and 1 is the most concerned. Meanwhile, I surveyed 5 experts and combined them with my own opinion to prioritize the attributes using the Garret's Ranking Technique. These experts come from a wide range of backgrounds, including both public and private sector, academia and non-profit organizations.

STEP 3: PRIORITIZATION OF UNDERSERVED COMMUNITIES

Combining all the data and calculated rankings of the attributes, the "neediness" rating is then calculated. The underserved communities are then prioritized based on the Neediness Rating.

STEP 4: ANALYZING AREA OF INTEREST & DESIGN RECOMMENDATIONS

A conceptual walkable green infrastructure network in all the 25 block groups is laid out in this step, Envisioned sections for each urban form type, and general design recommendations based on street types are also proposed. Four underserved block groups adjacent to 99W are selected for a more integrated design as these block groups cover the majority part of UHI, given that their prioritized rank for receiving the City's resources should remain the same. More importantly, these block groups cover a wide range of street types as well as the major route to other vulnerable communities in west Eugene. I analyzed their demographic and related the block groups to their surrounding built and natural environment, and proposed design recommendations on specific streets within the 4 selected block groups.

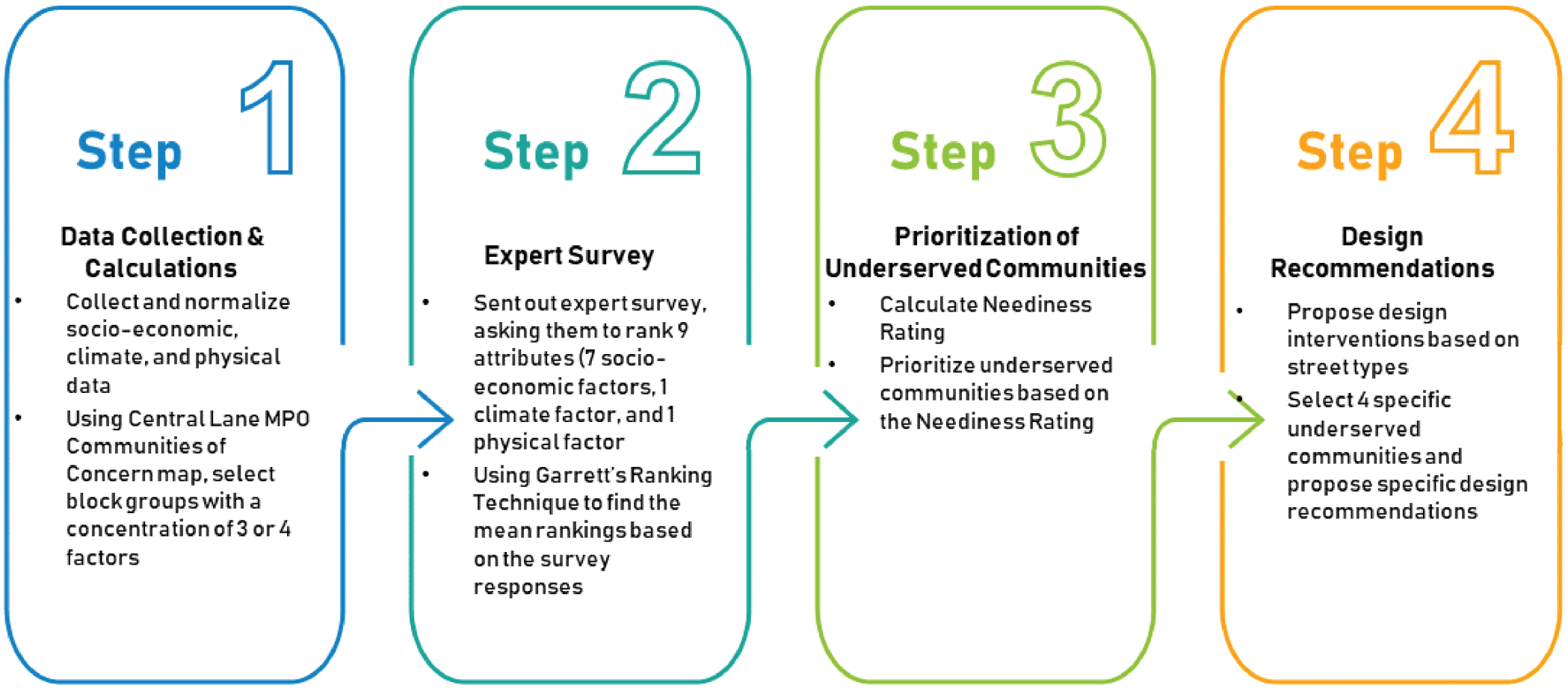


Figure 3. Process diagram by steps.

CHAPTER 4

IDENTIFYING UNDERSERVED COMMUNITIES

SELECTING THE NEEDINEST UNDERSERVED COMMUNITIES

THE 25 UNDERSERVED BLOCK GROUPS

There are 138 block groups within Eugene. To ensure the selected block groups are the most vulnerable communities. block groups that have a concentration of 3 or more socio-economic factors based on the Communities of Concern map are selected. Block groups that are outside of Eugene are excluded before the calculations of urban heat island area and tree canopy cover. This vastly narrow down selection from 138 total number of block groups to 25 major block groups within the City of Eugene (Figure 4).

EUGENE URBAN HEAT ISLAND & TREE CANOPY COVER

Eugene's UHI effect is most severe in the afternoon UHI map. Therefore, the afternoon map is used for the rest of the analysis(Figure 1). Heat is absorbed and trapped in the afternoon and released in the evening. As a result, creating thermal comfort streets using the afternoon map could reduce the heat trapped during the afternoon and so as to reduce the temperature at other times.

To effectively select the most needinest block groups for thermal comfort street retrofit, two other climate and biophysical data are included in the calculations. I calculated both the percentage area being affected by UHI with Voelkel & Shandas's UHI map and the percentage tree canopy cover with the 2009 vegetation map from LCOG for each of the 25 block groups

The two maps illustrate the negative correlation between UHI and tree canopy cover, in which the lower percentage the tree canopy cover is, the higher percentage area is being affected by UHI, vice versa (Figure 5, 6).

It is also important to note that even though some block groups are "greener" on the map, the highest percentage of the tree canopy cover amongst the 25 block groups is only 30.93% (Figure 6).

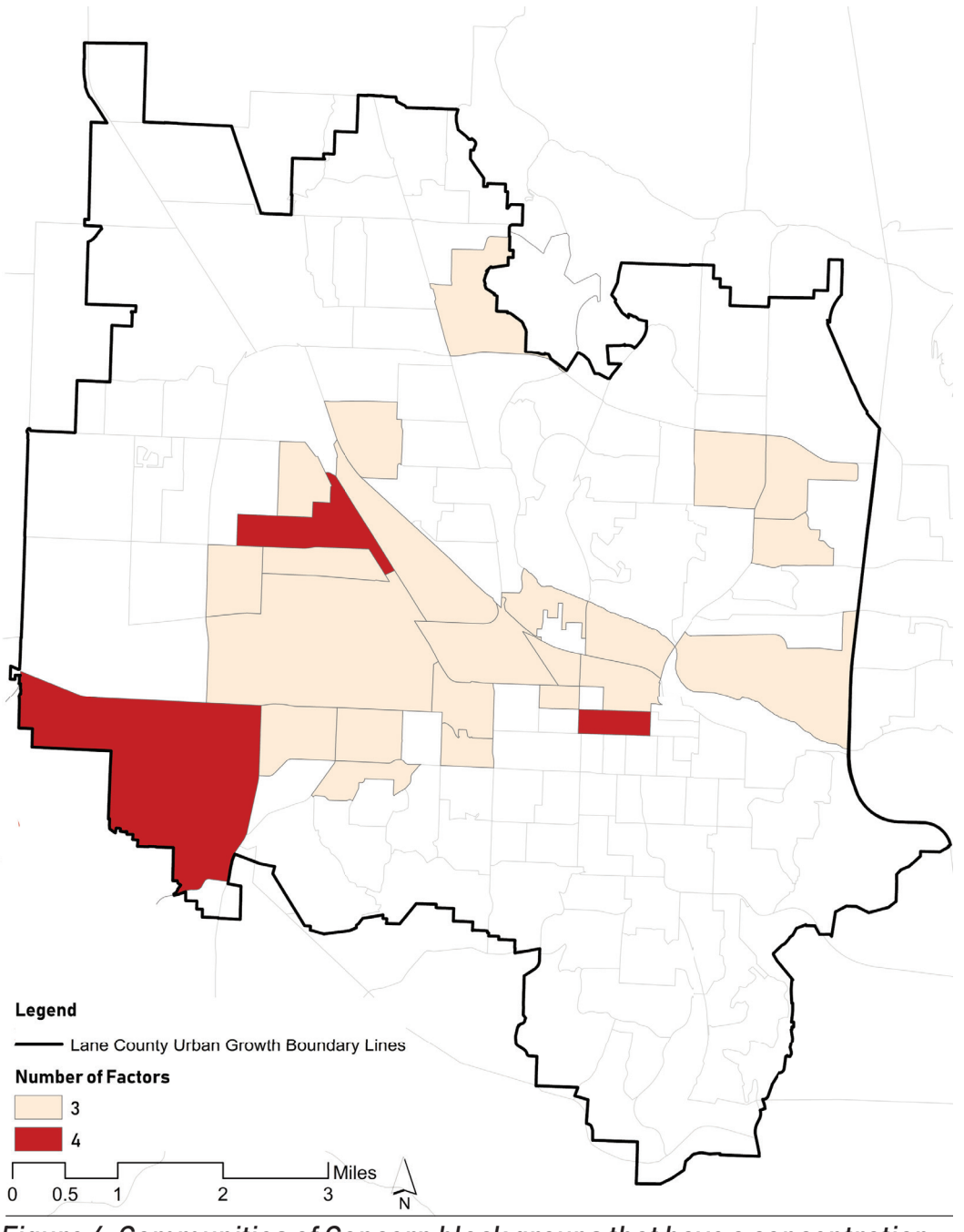


Figure 4. Communities of Concern block groups that have a concentration of 3 and 4 socio-economic factors based on Central Lane MPO Communities of Concern map. This is a 2013 aerial photo obtained from LCOG.

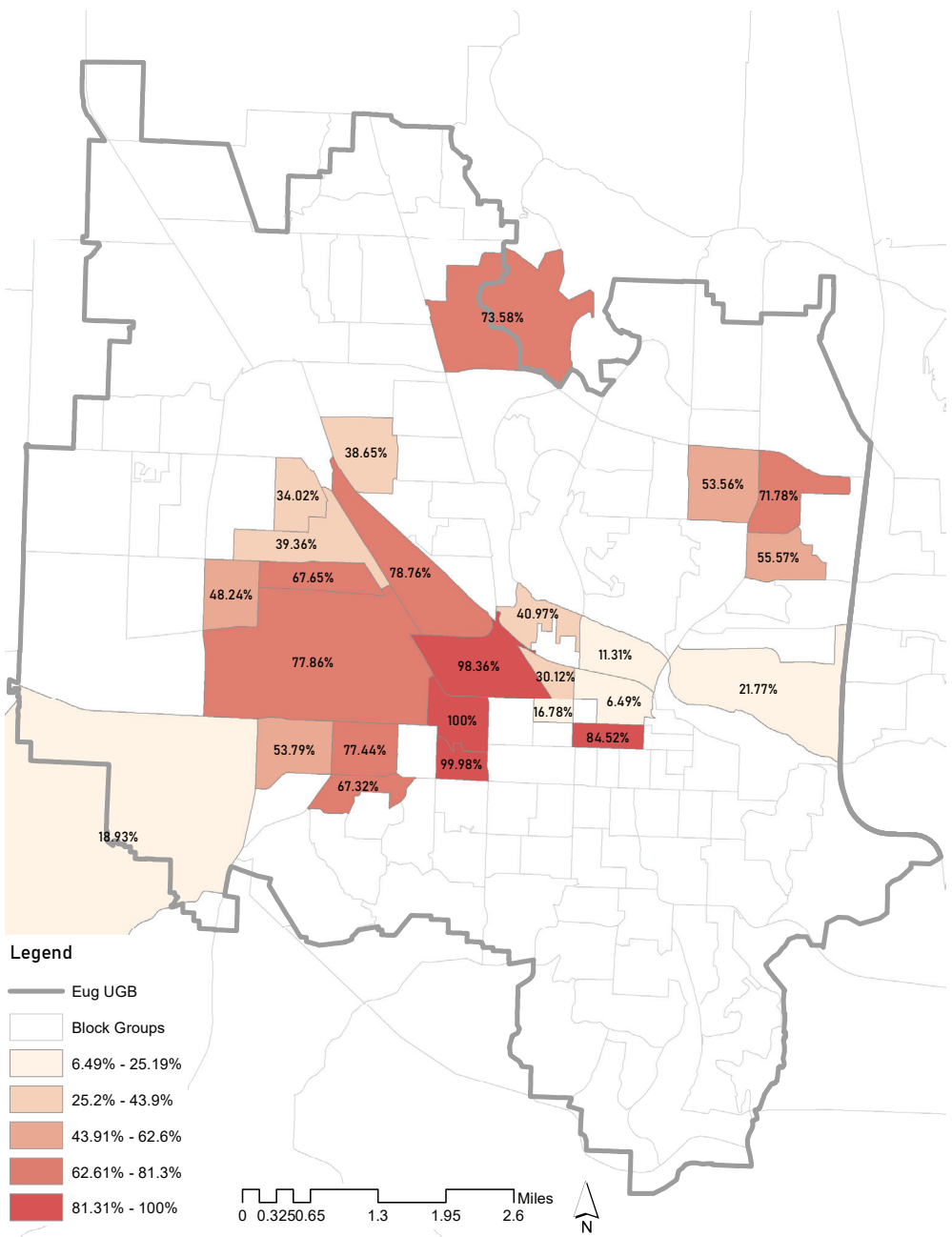


Figure 5. The percentage area affected by UHI within each of the 25 block groups was calculated using GIS.

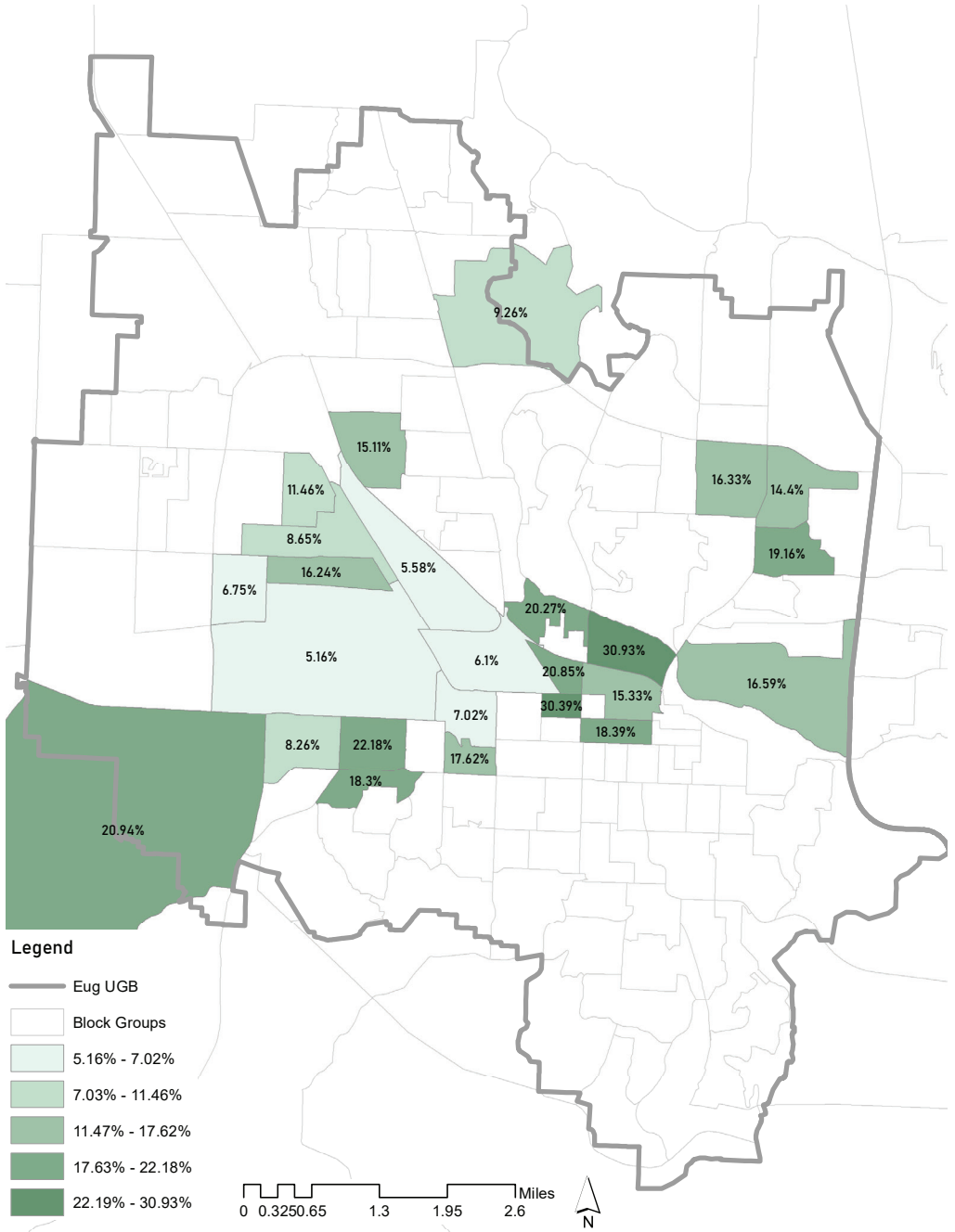


Figure 6. The percentage of tree canopy cover within each of the 25 block groups was calculated using GIS.

CHAPTER 5

RANKING THE UNDERSERVED COMMUNITIES

PRIORITIZING THE 25 BLOCK GROUPS USING GARRETT'S RANKING TECHNIQUE

The 25 block groups are prioritized using Garrett's Ranking Technique and other calculations. Initially, surveys were sent to ask experts to rank 1 as the least important and 9 as the most important attribute when prioritizing for underserved communities (Appendix A). The survey results were then converted to rank 1 as the most important and 9 as the least important in order to calculate using Garret's Ranking Technique (Appendix A).

Most surveyees ranked "area affected by UHI high temperature zone" as the most important factor, while "population with limited English" is the least concerned factor.

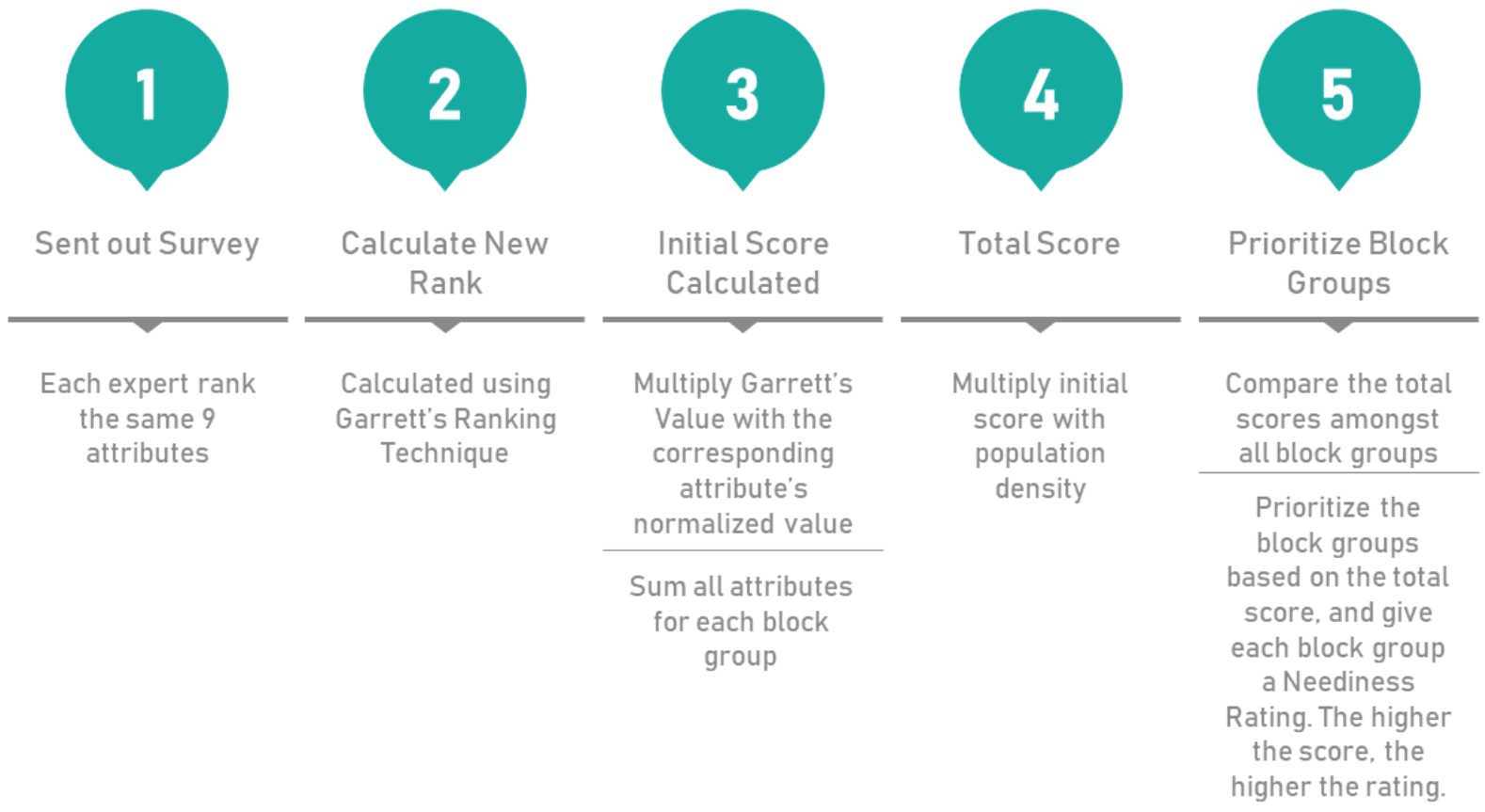


Figure 7. Process diagram for prioritization of the 25 block groups.

Attribute	Ranking
Area affected by UHI High Temperature Zone	1
Tree Canopy Cover	2
Elderly Population	3
Disabled Population	4
Household in Poverty	5
Household with No Cars	6
Unemployed Population	7
Minority Population	8
Population with Limited English	9

Table 1. Attribute rankings based on expert survey.

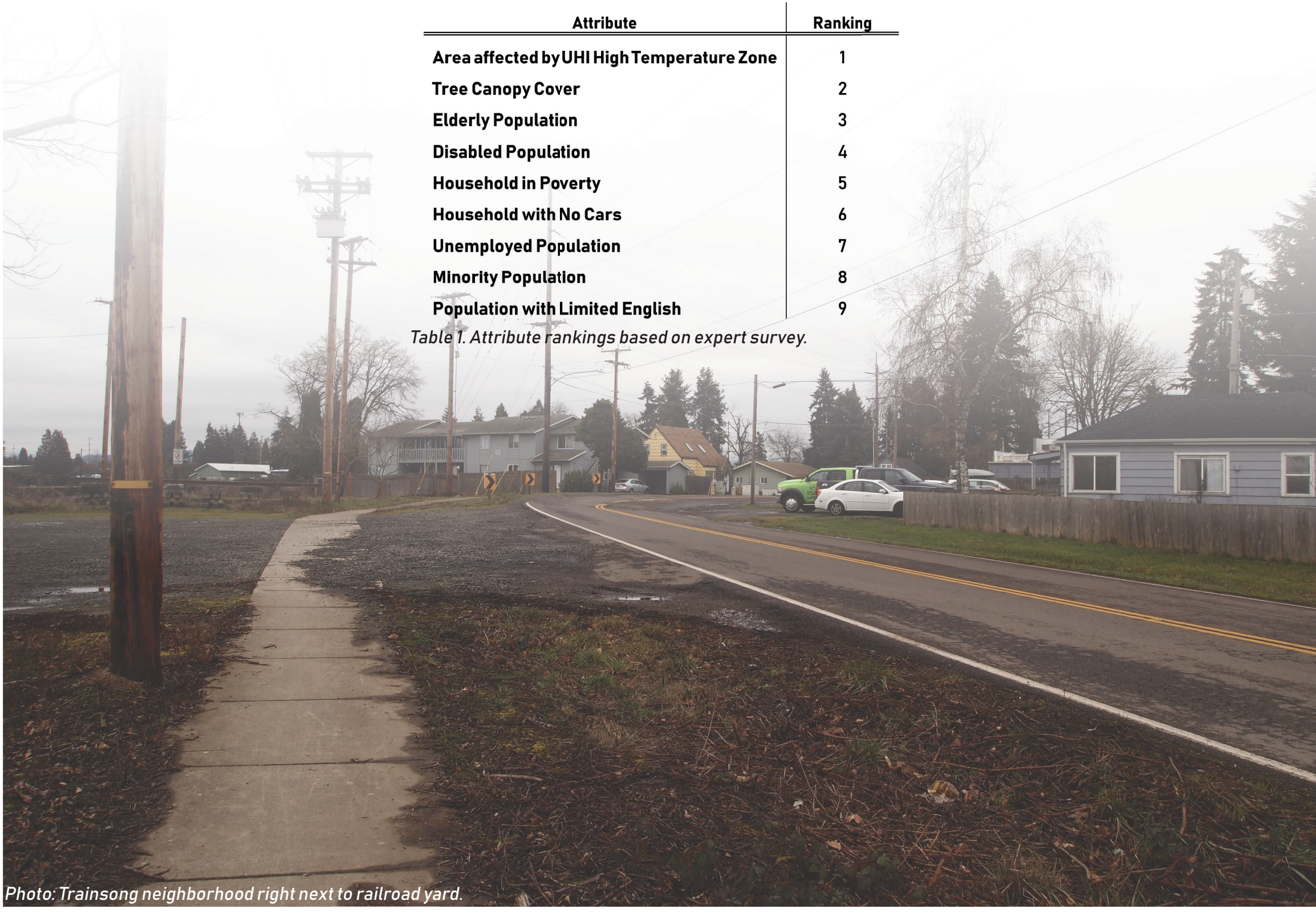


Photo: Trainsong neighborhood right next to railroad yard.

CALCULATION OF THE TOTAL SCORE & NEEDINESS RATING

Each normalized data is multiplied by the given weight of their corresponding new rank calculated from the Garrett's Ranking Technique for each attribute's score. The sum of all attributes within each block group is calculated for the initial score. The initial scores for each block group are then multiplied by the population density to calculate the total score in order to focus the prioritization on more populated neighborhoods. Finally, the neediness rating for each block group is arranged based on their score. The higher the score, the higher the rating is. Below is the equations used for the calculations:

Initial Score = Area Affected by UHI High Temperature Zone x 9
+ Tree Canopy Cover x 8
+ Elderly Population x 7
+ Disabled Population x 6
+ Household in Poverty x 5
+ Household with no Cars x 4
+ Unemployed Population x 3
+ Minority Population x 2
+ Population with Limited English x 1

Total Score = Initial Score x Population Density

Photo: Lark Park is located in a neighborhood in west Eugene, where most areas are zoned as industrial areas.

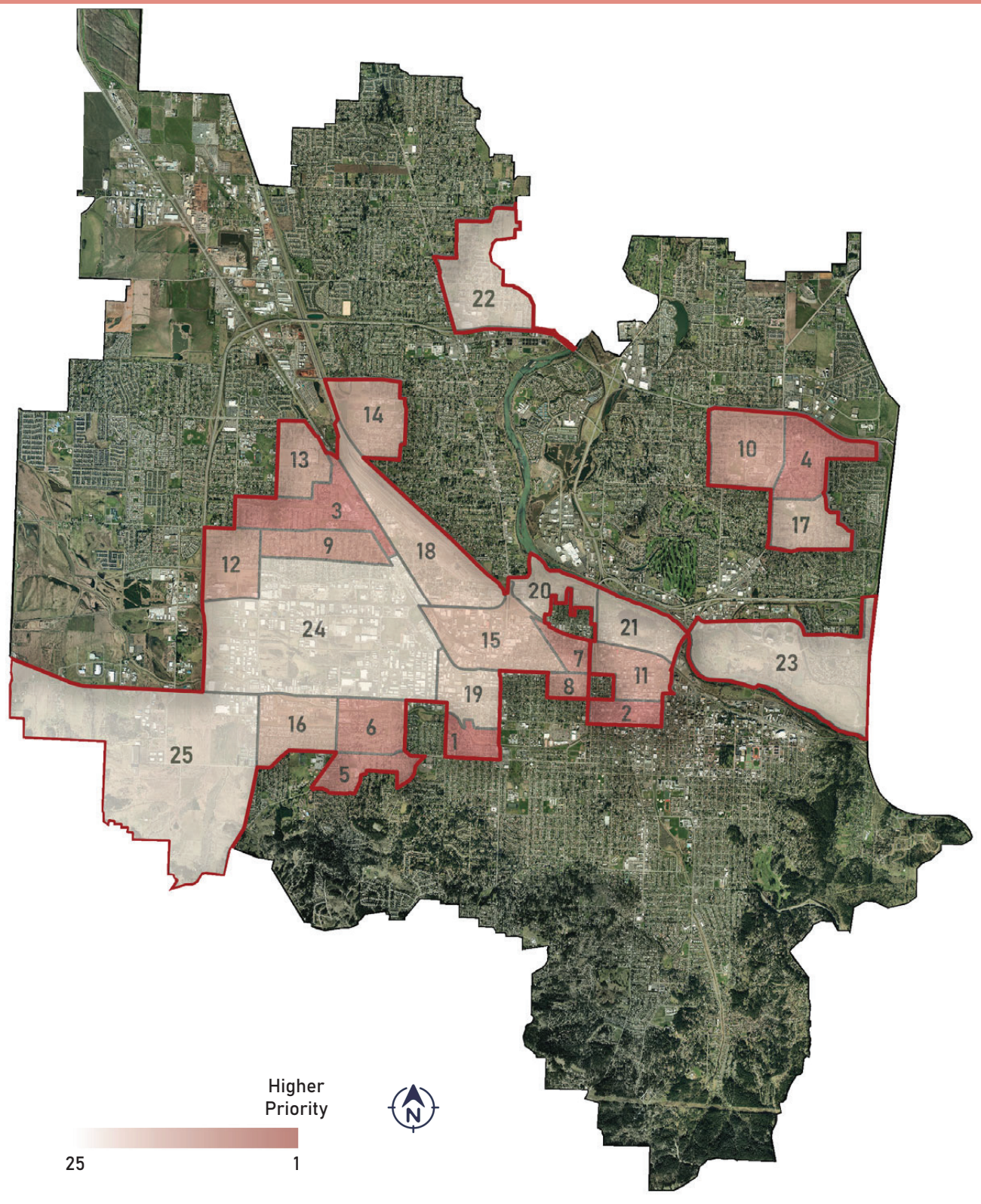


Figure 8. The 25 block groups are prioritized based on the calculations.

CHAPTER 6

IDENTIFYING POTENTIAL CITY-WIDE NETWORKS

CITY-WIDE ANALYSIS, EXISTING COOLING FACILITIES

By providing a better complete, thermal comfort pesdestrian and bike network, heat-related health risks could be largely reduced especially during summer, and people would be more willing to walk, bike and take public transportation. To plan for the 25 underserved communities, this chapter begins with the overall envisioned plans of what the 25 block groups would be like with better pedestrian and bike network and proposes standardized thermal comfort street intervention sections for different urban form types. The chapter then sums up with specific site analysis and designs the four selected block groups.

EXISTING TREE CANOPY COVER

Cooling facilities include libraries, communities centers, swimming pools, and spray play area (Lane County Government, 2017).

Over half of these facilities are outside the boundary of underserved communities. More importantly, cooling facilities within the underserved communities are too concentrated in a few block groups. Most underserved communities do not have existing cooling centers, especially along HWY 99 and west Eugene (Figure 13).

The City of Eugene should plan more cooling facilities in other underserved communities as well to cope with the demand.

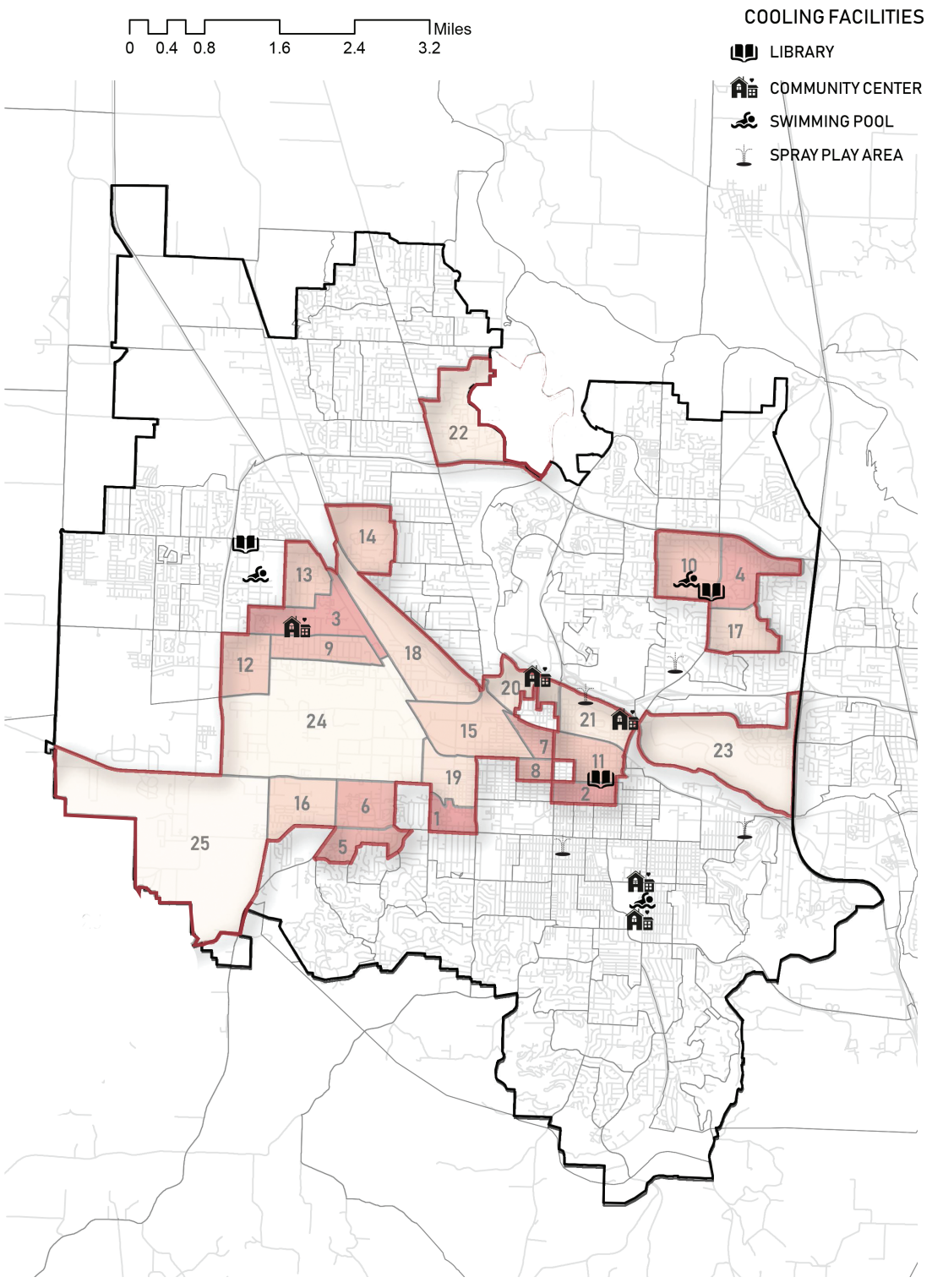


Figure 13. Cooling facilities' locations in relation to the 25 underserved communities.

Figure 14. The Bethel Branch Library (Waymaking, 2009).

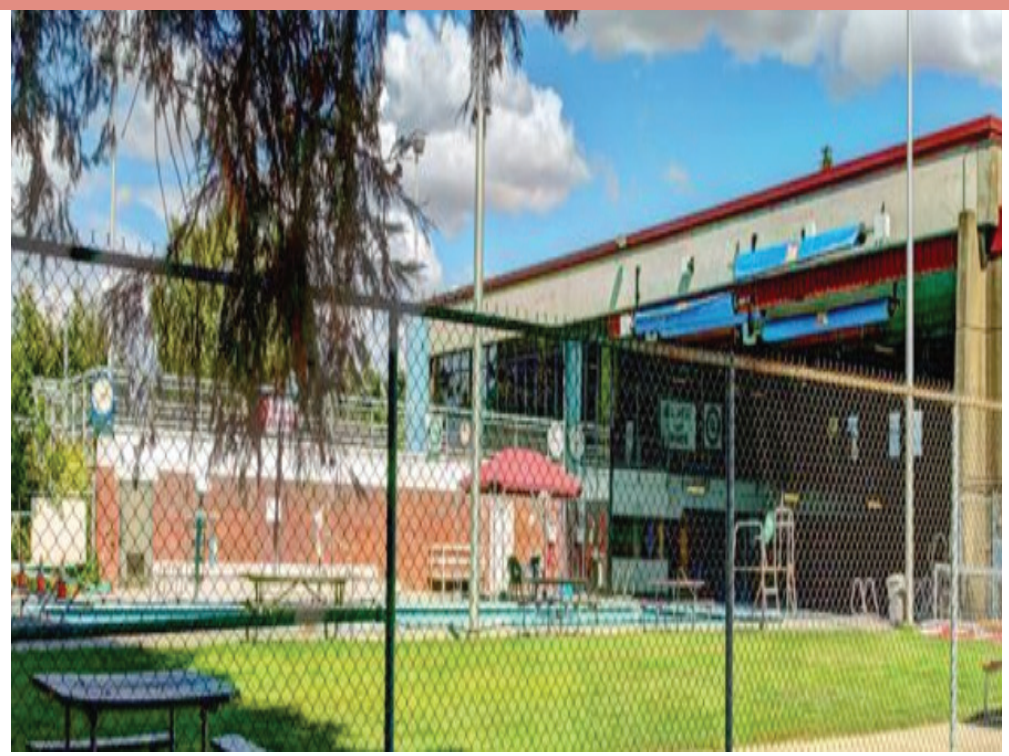


Figure 15. Echo Hollow Pool (City of Eugene, n.d.).

Figure 16. Petersen Barn Community Center (City of Eugene, n.d.).

Figure 17. Washington Park spray play area (City of Eugene, n.d.).

EXISTING BIKE NETWORK

EXISTING BIKE NETWORK RELATIVE TO BUS STOPS

To encourage people to use more public transport and walk more, understanding where the bus stops are located is crucial to providing thermal comfort streets. The connections from people's homes to the bus stops should provide comfortable experience. Existing bus stops are usually located right next to a bikeway. However, underserved communities are not having enough bikeways passing through their neighborhoods. In west, north, and northeast Eugene especially, bikeways are scarce and are not well-established even if they are present. In other words, the bus stops are usually further away from most underserved communities.

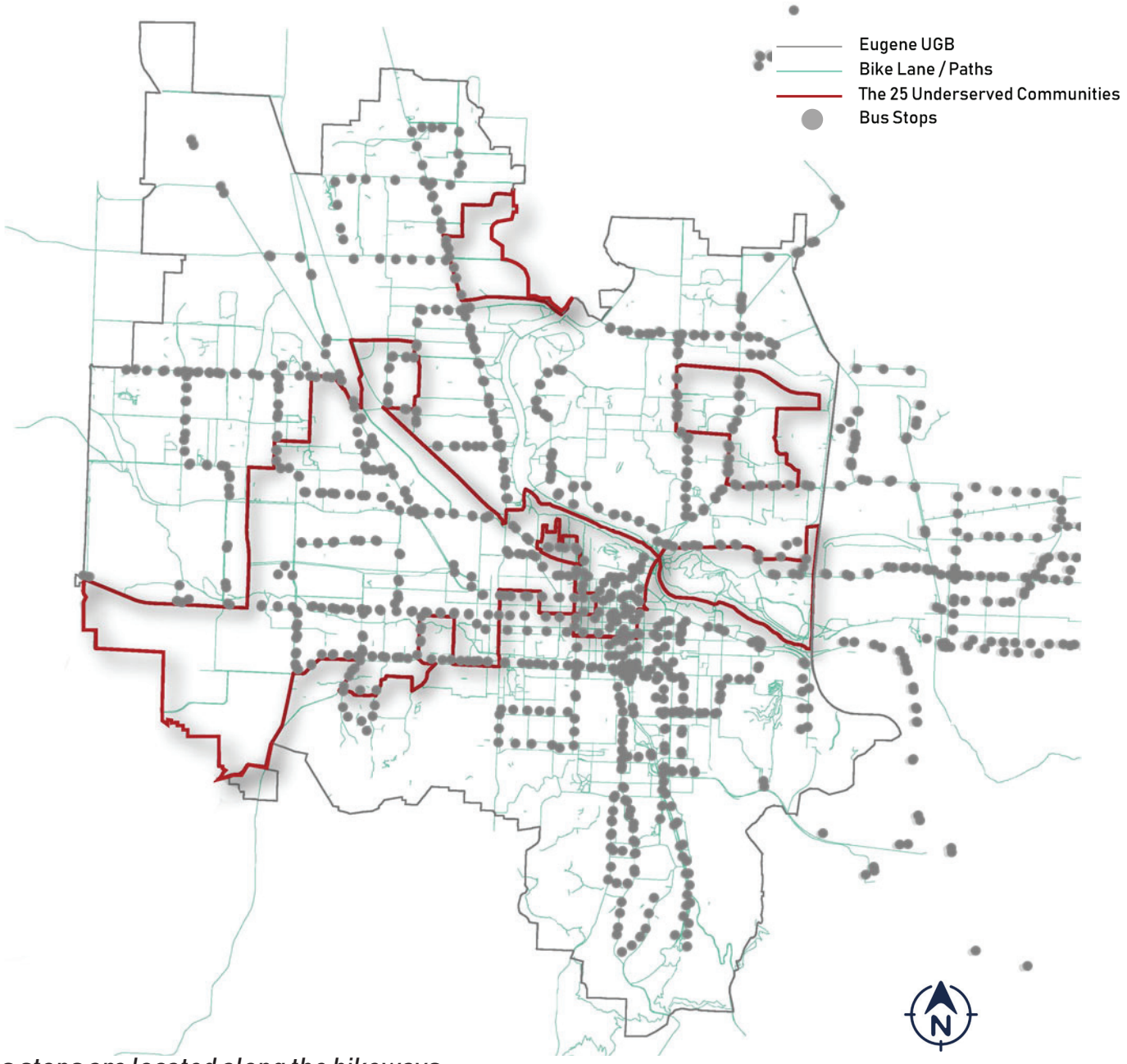


Figure 9. Most existing bus stops are located along the bikeways.

ENVISIONED BIKE NETWORK

ENVISIONED BIKE NETWORK

The envisioned network provides more bikeways for underserved communities linking to the existing bus stops. This provides more connections within and beyond each community, hence encourages residents to travel by bike and foot, especially for short-distance trips within the neighborhood.

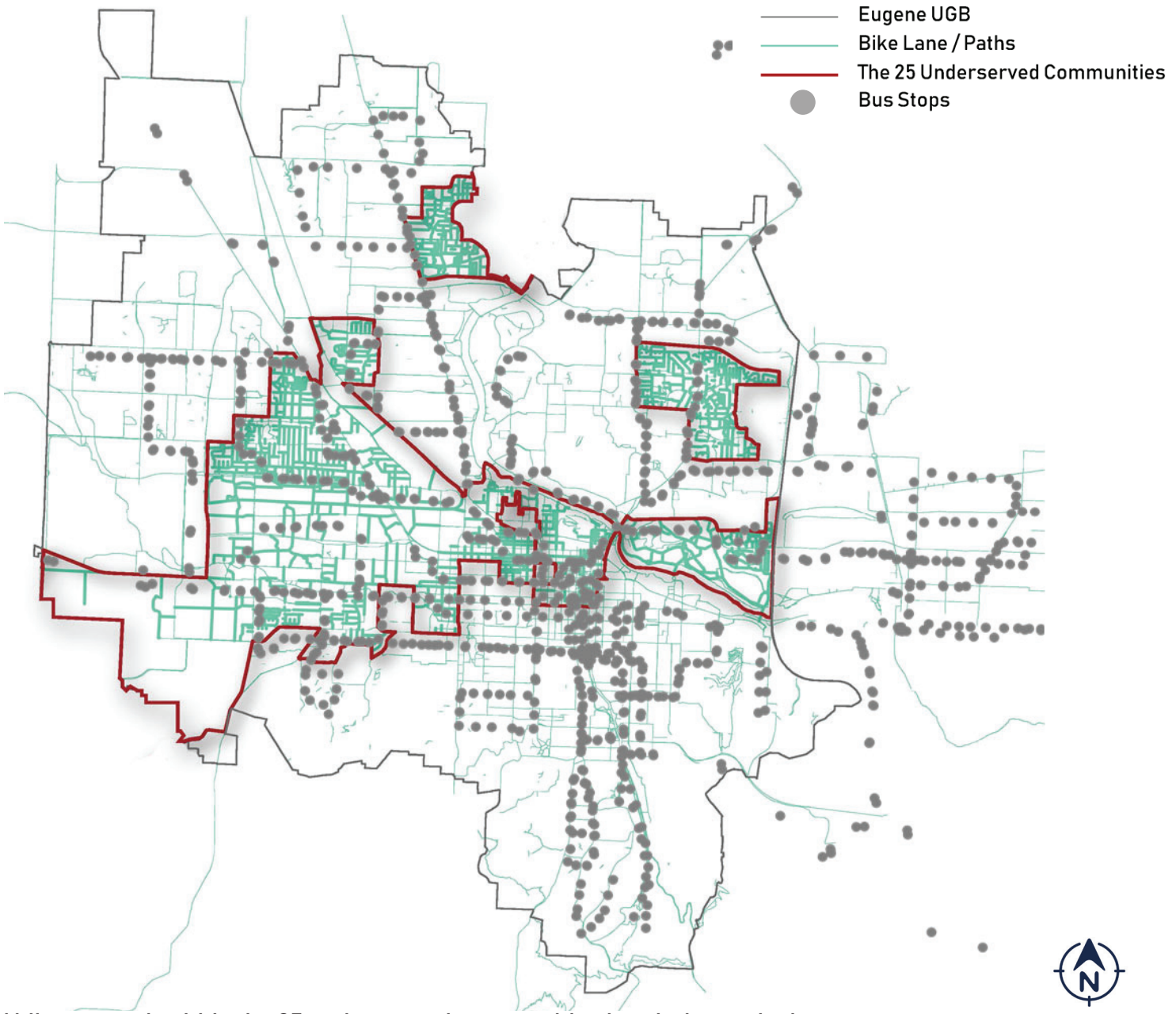


Figure 10. Envisioned bike network within the 25 underserved communities in relation to the bus stops..

EXISTING TREE CANOPY COVER

EXISTING TREE CANOPY COVER

Existing tree canopy cover within the underserved communities is limited compared to other communities within Eugene, especially in west Eugene. These are also areas where they lack cooling facilities.

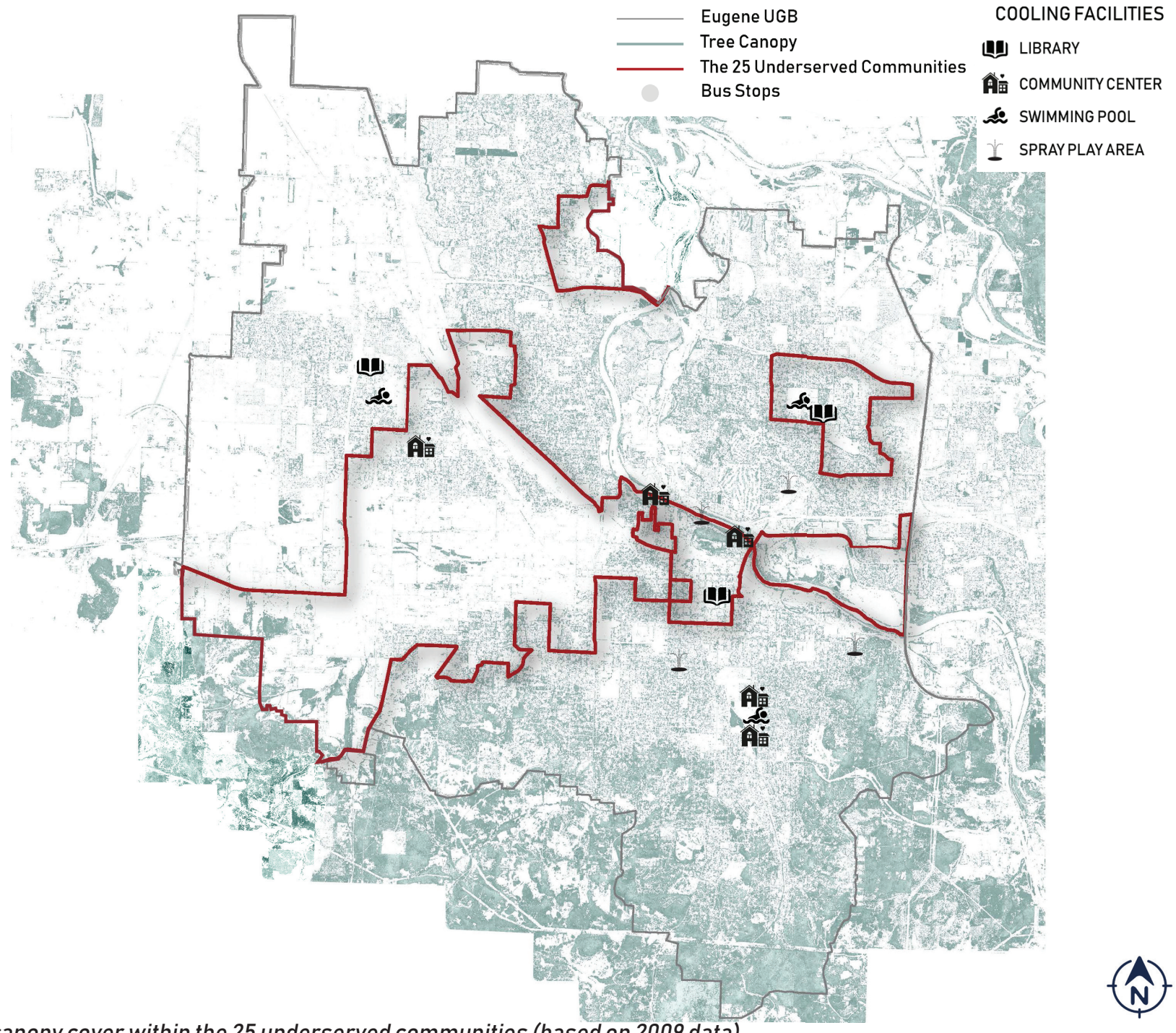


Figure 11. Existing tree canopy cover within the 25 underserved communities (based on 2009 data).

ENVISIONED TREE CANOPY COVER

ENVISIONED TREE CANOPY COVER

The envisioned network provides more tree canopy cover and cooling facilities for underserved communities. This provides more thermal comfort streets within and beyond each community, hence encourages residents to travel by bike and foot, especially for short-distance trips.

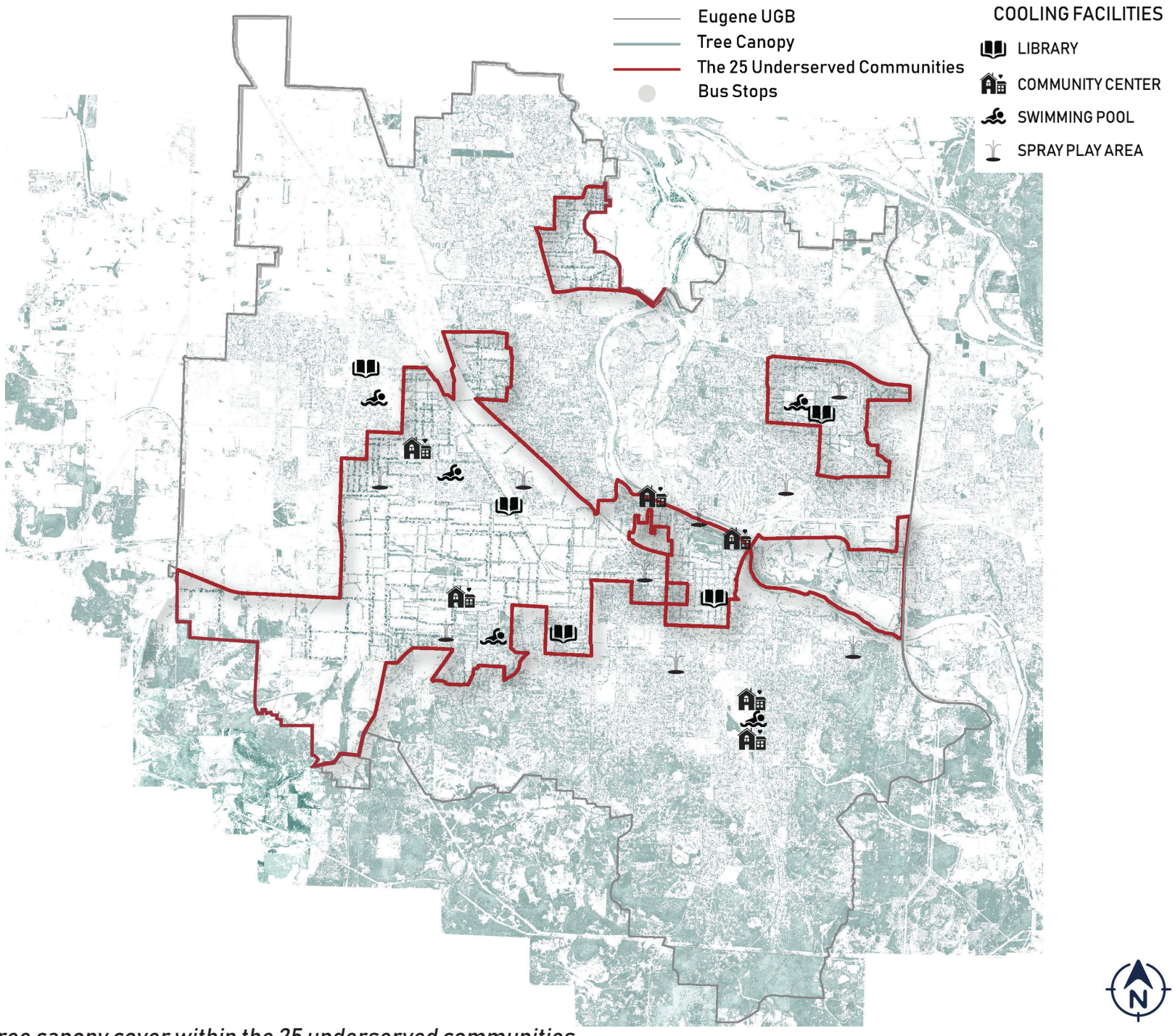


Figure 12. Envisioned tree canopy cover within the 25 underserved communities.

CHAPTER 7

URBAN FORM & STREET TYPOLOGY.

URBAN FORM TYPOLOGY

Different configurations of urban forms produce varying streetscapes, Some design interventions are more appropriate on streets in urban settings, while some are more appropriate in a more open-suburban area. For this reason, understanding a spectrum of urban forms within the underserved communities could help select the most efficient types of design interventions. This chapter summarizes the different urban form types developed within the 25 underserved communities and proposes design interventions for different street types within each urban form type.

URBAN FORM TYPOLOGY SPECTRUM

There are nine urban form types identified for this project. Due to the time limitation, the range of urban form types are only representing types within the 25 underserved communities.

The nine urban form types are (Figure 18):

1. mixed-use urban core
2. open urban
3. urban industrial
4. urban transition
5. compact suburban
6. open suburban
7. suburban industrial
8. railroad yard neighborhood
9. rural transition

MIXED-USE URBAN CORE

Mixed-use urban core is the center of urban area, where it integrates residential, commercial, cultural, institutional, and/or entertainment uses and provides pedestrian connections. It is usually characterized by multi-storey buildings and highly walkable streets with close proximity of most amenities.

OPEN URBAN

Open urban area is an urban area with wider streets and more open spaces such as parks and sport facilities.

URBAN INDUSTRIAL

Urban industrial contains manufacturing or other industrial sites within the urban area. The streets are usually wider with very few street trees for easier access of large commercial trucking.

URBAN TRANSITION

Urban transition is an area where narrow urban roads begin transitioning to highway or freeway. It is still within urban area but has not reached suburban area yet.

COMPACT SUBURBAN

Compact suburban area is suburban area that are becoming more compact and urban. Most part of it are usually just residential area with quiet streets.

OPEN SUBURBAN

Open suburban is a suburban area with wider streets and more open spaces such as parks and natural areas.

SUBURBAN INDUSTRIAL

Suburban industrial contains manufacturing or other industrial sites within the suburban area. The streets are usually poorly paved and wide with almost no street trees for easier access of large commercial trucking.

RAILROAD YARD NEIGHBORHOOD

Railroad yard neighborhood is area where residential area is developed right next to a huge railroad yard.

RURAL TRANSITION

Rural transition is on the edge of the suburban area. It includes agricultural areas and rural residential areas within the urban growth boundary. Roads in rural transition begin transitioning from paved to gravel.

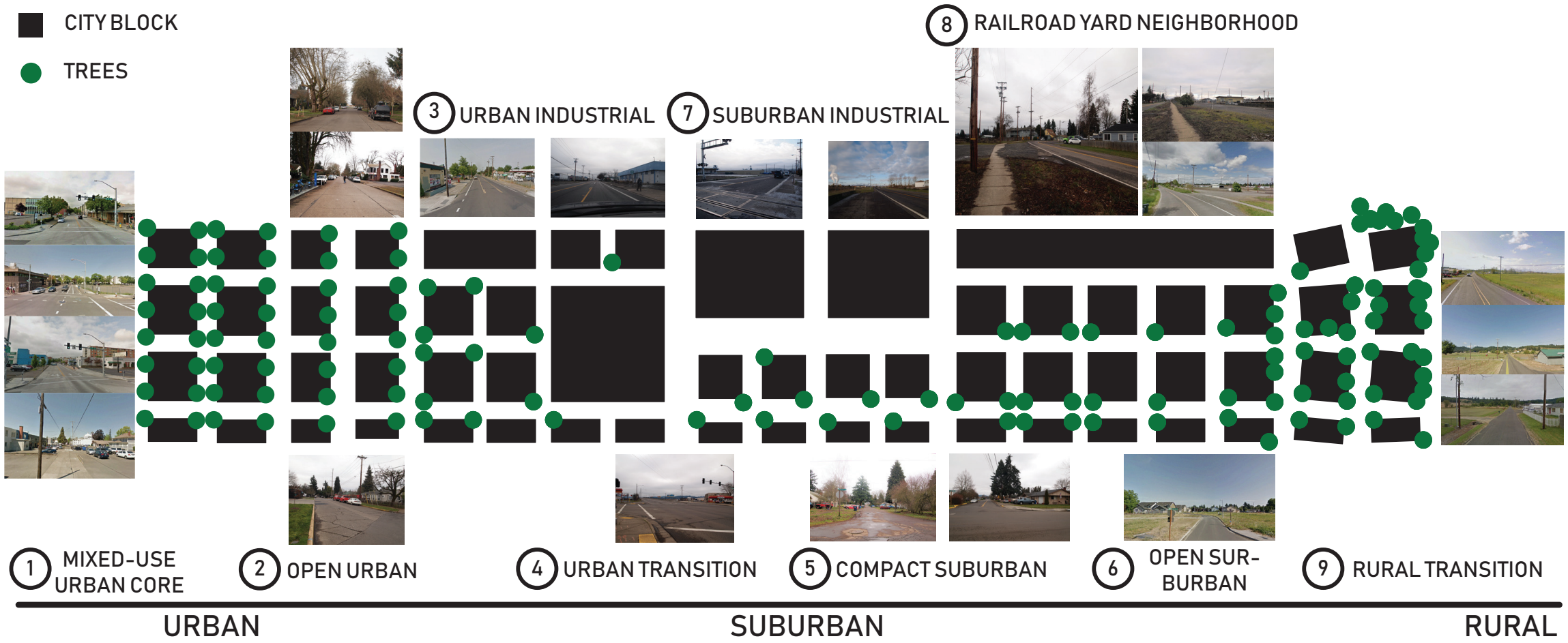


Figure 18. Urban form types amongst the 25 underserved communities.

URBAN FORM TYPOLOGY OF THE 25 UNDERSERVED COMMUNITIES

Each of the 25 block groups is assigned an urban form type based on observation. The table below shows a summary of the 4 selected underserved communities and their corresponding neediness rating, urban form typology, and primary vulnerable group (Table 2).

The primary vulnerable group is included to help guide the design process and choose the appriopriate type of design interventions for specific vulnerable groups.

A summary table showing all the 25 block groups can be found in Appendix B.

Block Group ID	Neediness Rating	Urban Types	Primary Vulnerable Group
410390043001	3	Compact Suburban	Household in Poverty
410390042003	7	Urban Transition	Disabled
410390042002	15	Urban Industrial	Household in Poverty
410390042001	18	Railroad Yard Neighborhood	Disabled

Table 2. This table shows the four selected block group's neediness rating, urban form type, and its primary vulnerable group.

STREET TYPOLOGY

Different configurations of urban forms produce varying streetscapes, Some design interventions are more appropriate on streets in urban settings, while some are more appropriate in a more open-suburban area. For this reason, understanding a spectrum of urban forms within the underserved communities could help select the most efficient types of design interventions. The following sections summarize the different urban form typologies developed within the 25 underserved communities and proposes design interventions for different street typologies within each urban form typology.

Each of the urban form type contains various combination of street conigurations. There are 12 different street types, modified from Eugene's Design Standards & Guidelines for Eugene Streets, Sidewalks, Bikeways & Access Ways (City of Eugene, 2018). This project subdivided alley into commercial alley and residential alley.

Urban Form Types (representing a range of urban form types within the 25 prioritized Block Groups)	Walkable / Bikable Street Types (Using Eugene Complete Street Design Guide as reference)									
	Commercial Main Street	Multi-way Boulevard	Commercial Suburban	Mixed-Use Neighborhood	Residential Connector	Share Street	Urban Industrial	Suburban Industrial	Commercial Alley	Residential Alley
Mixed-Use Urban Core	■			■	■	■			■	■
Urban Transition		■		■	■				■	■
Open Urban					■					
Urban Industrial							■			
Compact Suburban		■		■	■	■				■
Open Suburban			■		■					■
Suburban Industrial			■					■		
Railroad Yard Neighborhood		■			■	■				
Rural Transition			■							

Table 3. Each urban form types contains various combination of street typologies.

DESIGN INTERVENTION SUGGESTIONS

Four major design strategies should be used to create thermal comfort streets:

1. creating shade through greening and shade structure
2. using light color cool pavement
3. installing cooling devices
4. creating other co-benefits with stormwater, energy saving renewable energy

There are different types of design interventions that have been used in other cities from common solutions such as tree plantings, permeable pavement, to stormwater management solutions such bioswales, and rain gardens, or to newer solutions such as mist garden, cool pavement, kenetic pavement, and solar fans. Below are a list of design interventions that the City could adopt:

1. Fabric Structures / Other Overhead Structures
2. Shelters
3. Tree Tunnels
4. Vegetated Tunnels
5. Trees
6. Bioswales
7. Stormwater Planters
8. Planter Strips
9. Rain Gardens
10. Green Roof
11. Vegetated Walls
12. Permeable Pavement
13. Cool Pavement
14. Kinetic Pavement
15. Detention Pond
16. Fountain
17. Drinking Fountain
18. Mist Garden
19. Cooling Sprays
20. Water Walls
21. Misting Fan
22. Spray Play
23. Solar Fan
24. Solar Panels
25. Solar Roads
26. Solar Streetlights

The appropriate types of design interventions are summarized in a table by the UHI effects they are mitigating in different urban form settings (Appendix C).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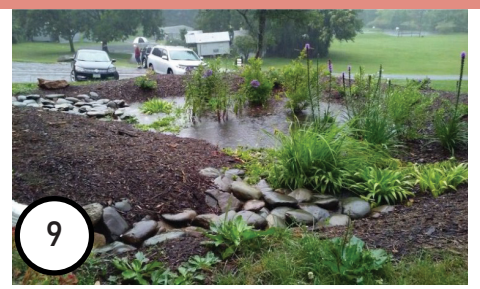
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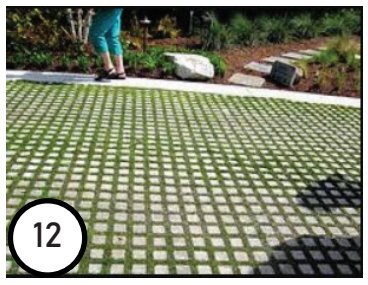
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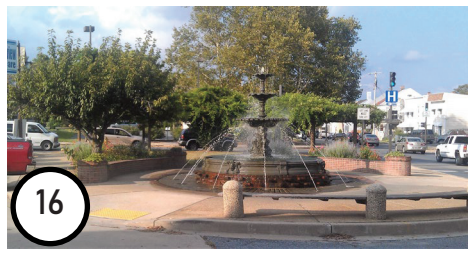
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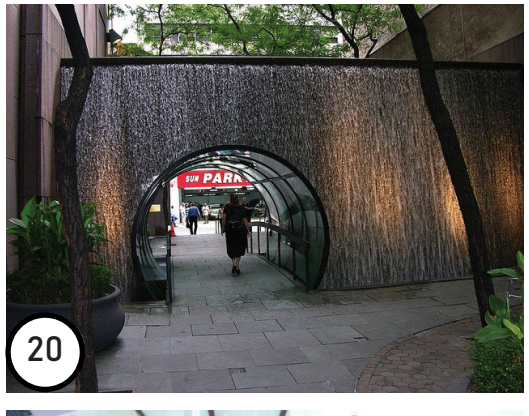
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STREET TYPOLOGY ILLUSTRATIONS

This section of the chapter illustrates generic thermal comfort street design interventions for different street types that could be adopted across Eugene. These street types include commercial main street, multiway boulevard, commercial suburban, commercial alley, mixed-use neighborhood, residential alley, residential connector, and shared street. These street type classification are modified from the Eugene's Draft Complete Street Design Standards, with the separate classification for commercial and residential alley (City of Eugene, 2018).

COMMERCIAL MAIN STREET

Commercial main streets are the major streets in mixed-use urban core. The lowest stories of the buildings are usually for commercial use.

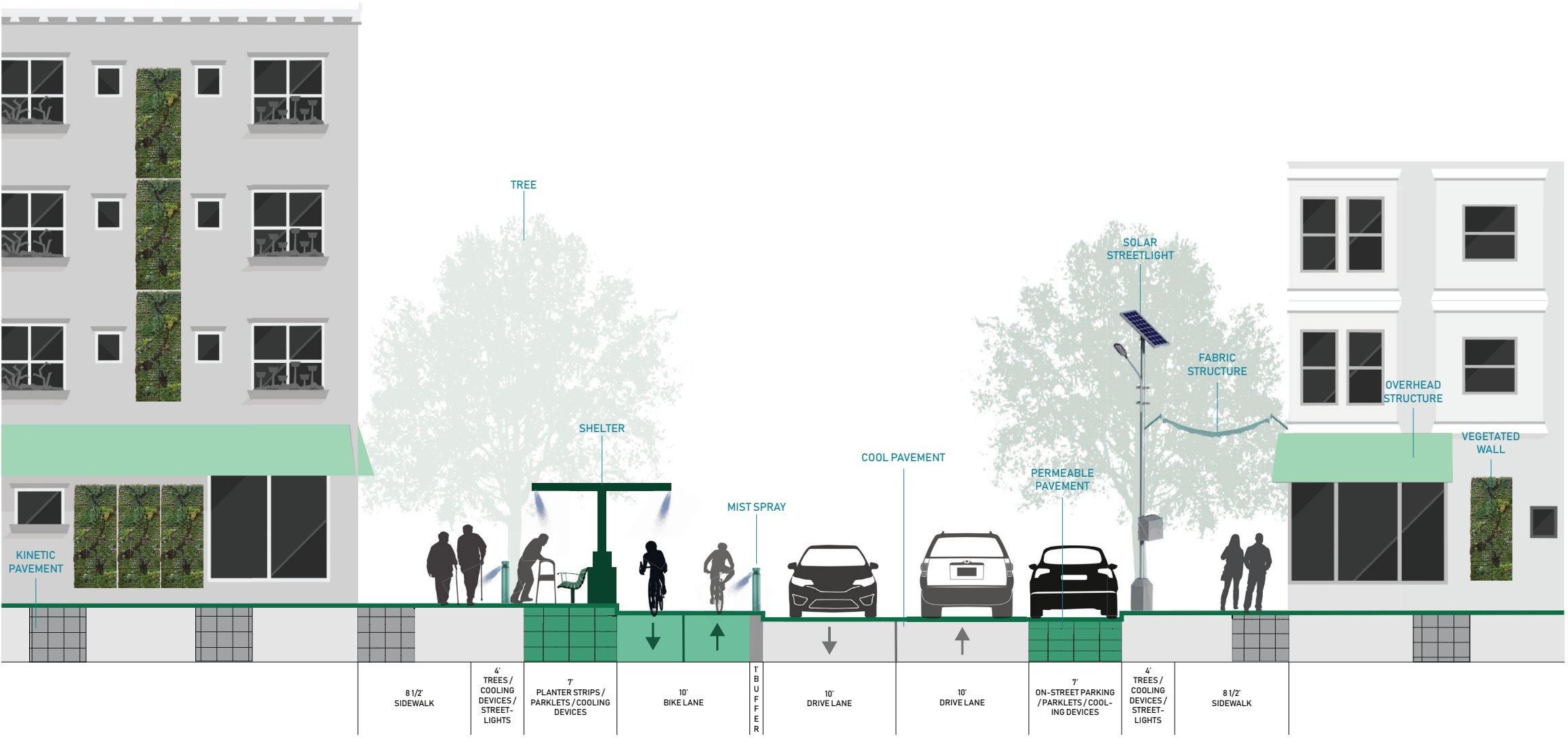


Figure 19. Sample section of a commercial main street.

MULTI-WAY BOULEVARD

Multi-way boulevard marks the transition from urban commercial areas to suburban commercial areas. It has characteristics of both commercial main streets and commercial suburban streets. This street type is generally wider than other commercial street types and provides major access and connection to the surrounding areas.

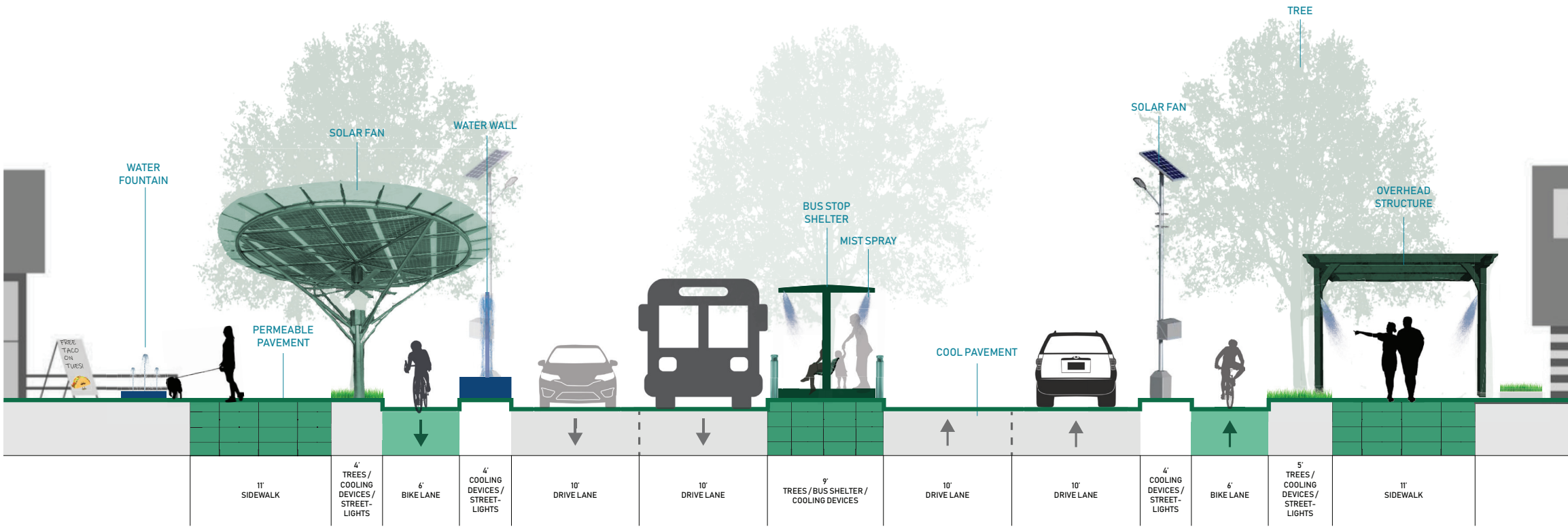


Figure 20. Sample section of a multi-way boulevard.

COMMERCIAL SUBURBAN

Commercial suburban provides access to larger and industrial businesses. These streets connect to highway and are wider than other street types. Thus, it offers more access to public transportation.

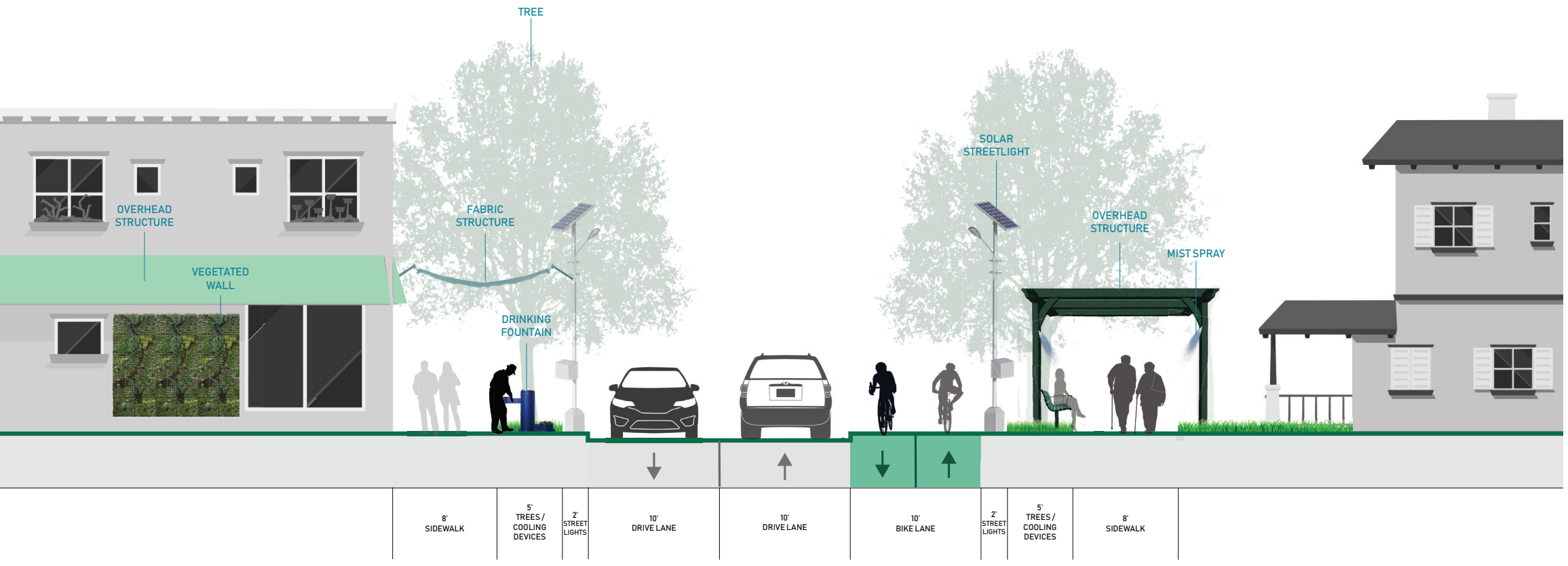


Figure 21. Sample section of a commercial suburban street.

MIXED-USE NEIGHBORHOOD

Mixed-use neighborhood streets allow for both commercial and residential uses. Buildings are mostly multi-storey. This type of street is more pedestrian-focused and provides easy access to various modes of transportation.

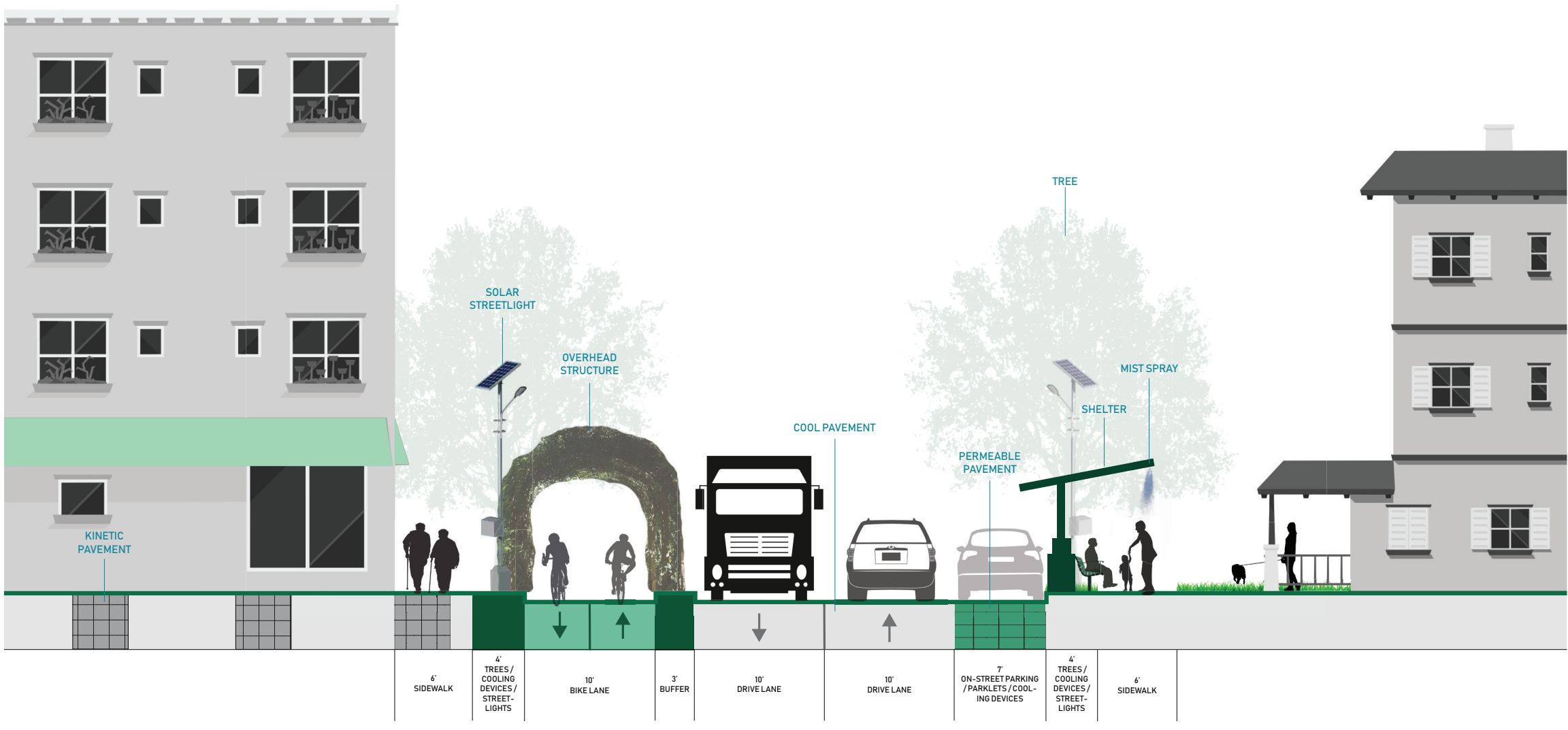


Figure 22. Sample section of a mixed-use neighborhood.

COMMERCIAL ALLEY

Commercial alleys are alleyways between commercial stores or buildings. These alleys provide pedestrians connections and shortcuts around the surrounding areas. Commercial activities should be encouraged to keep commercial alleys vibrant and safe to travel through.

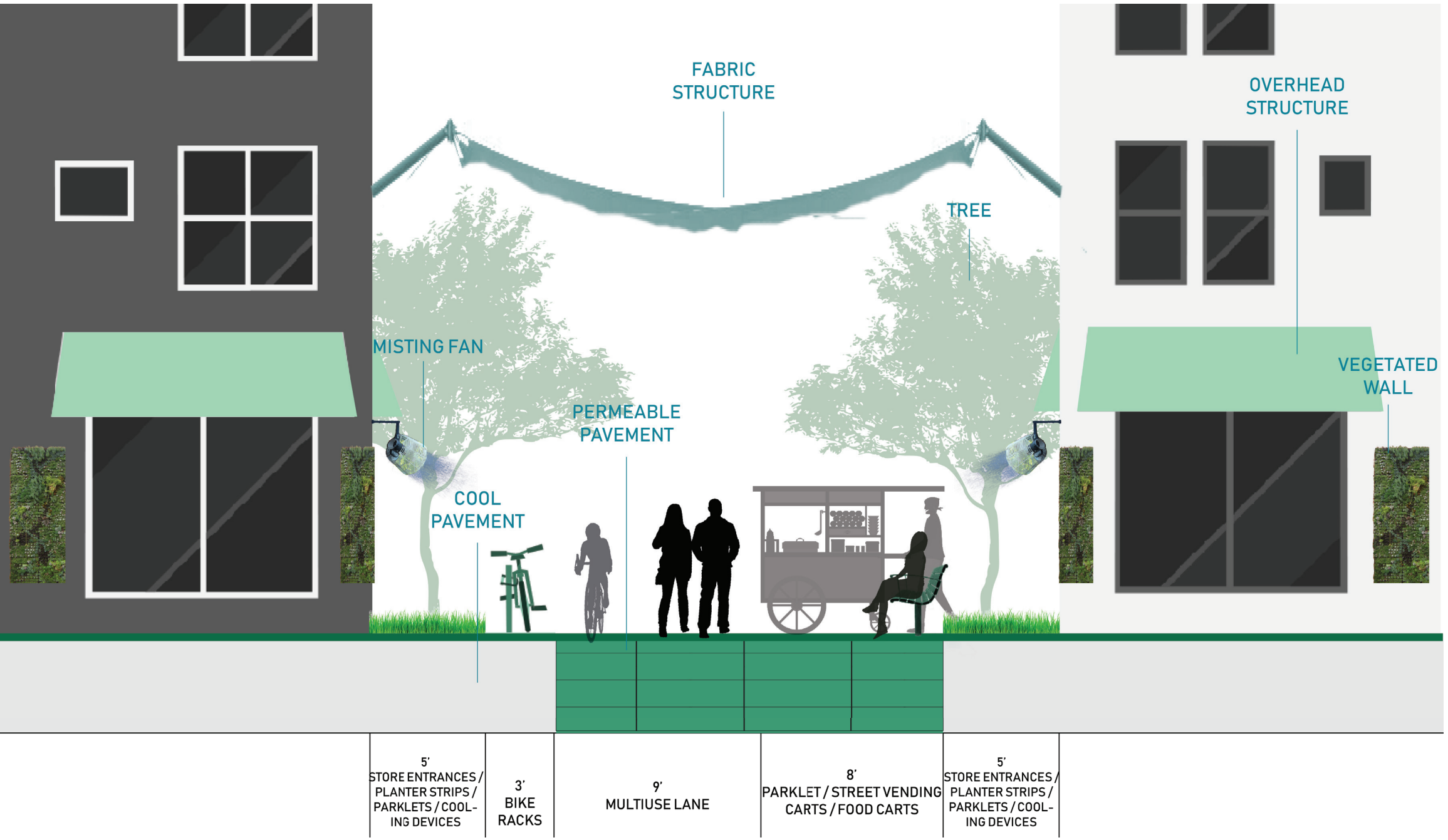


Figure 23. Sample section of a commercial alley.

RESIDENTIAL ALLEY

Residential alleys are alleyways between residential buildings. These alleys provide pedestrians connections and shortcuts around the surrounding areas, as well as social space for the neighborhood.

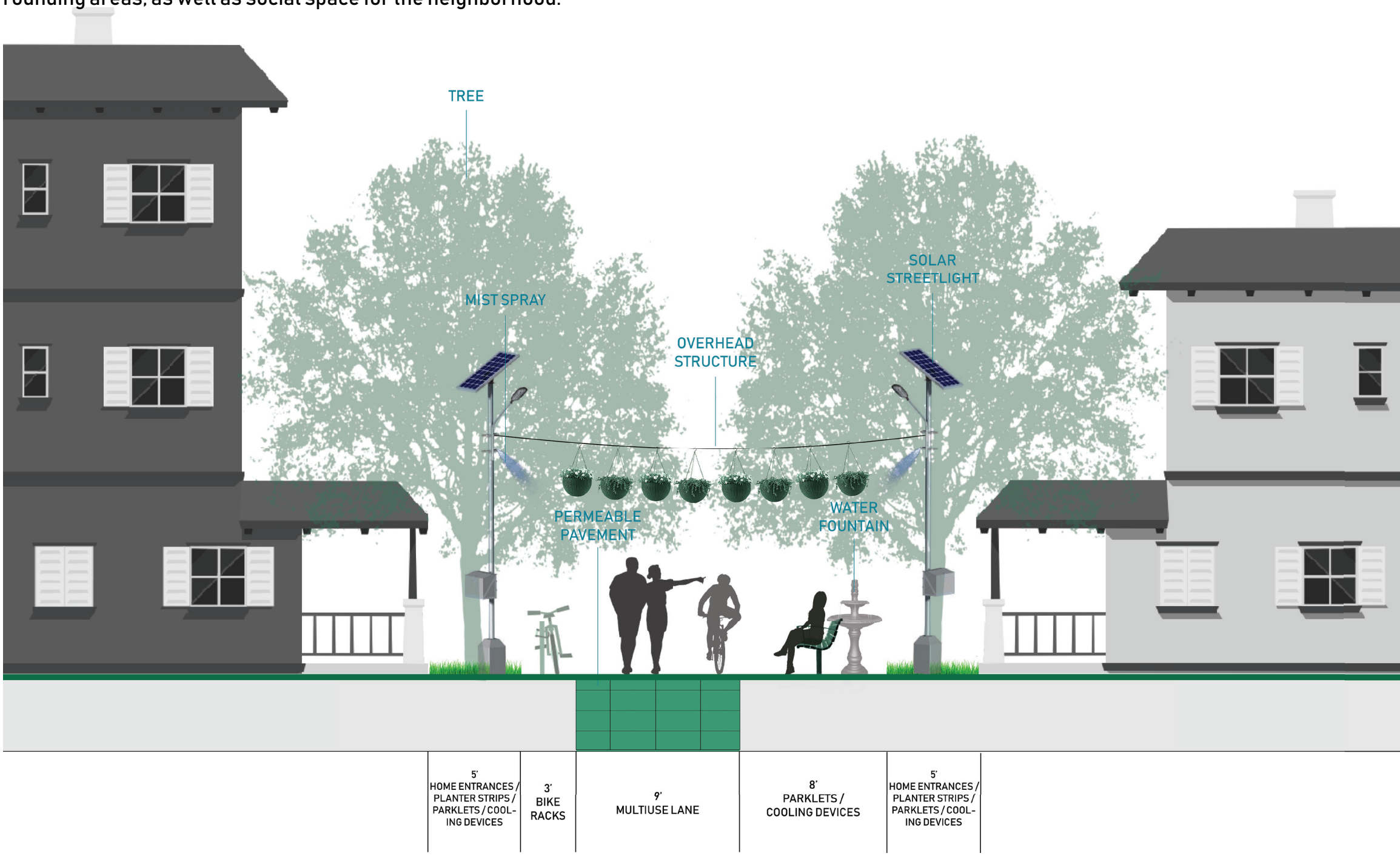


Figure 24. Sample section of a residential alley.

RESIDENTIAL CONNECTOR

Residential connectors are streets that divert major traffic roads to other neighborhoods. Residential connectors should act as an extended front yard for the homes that are on the same street.

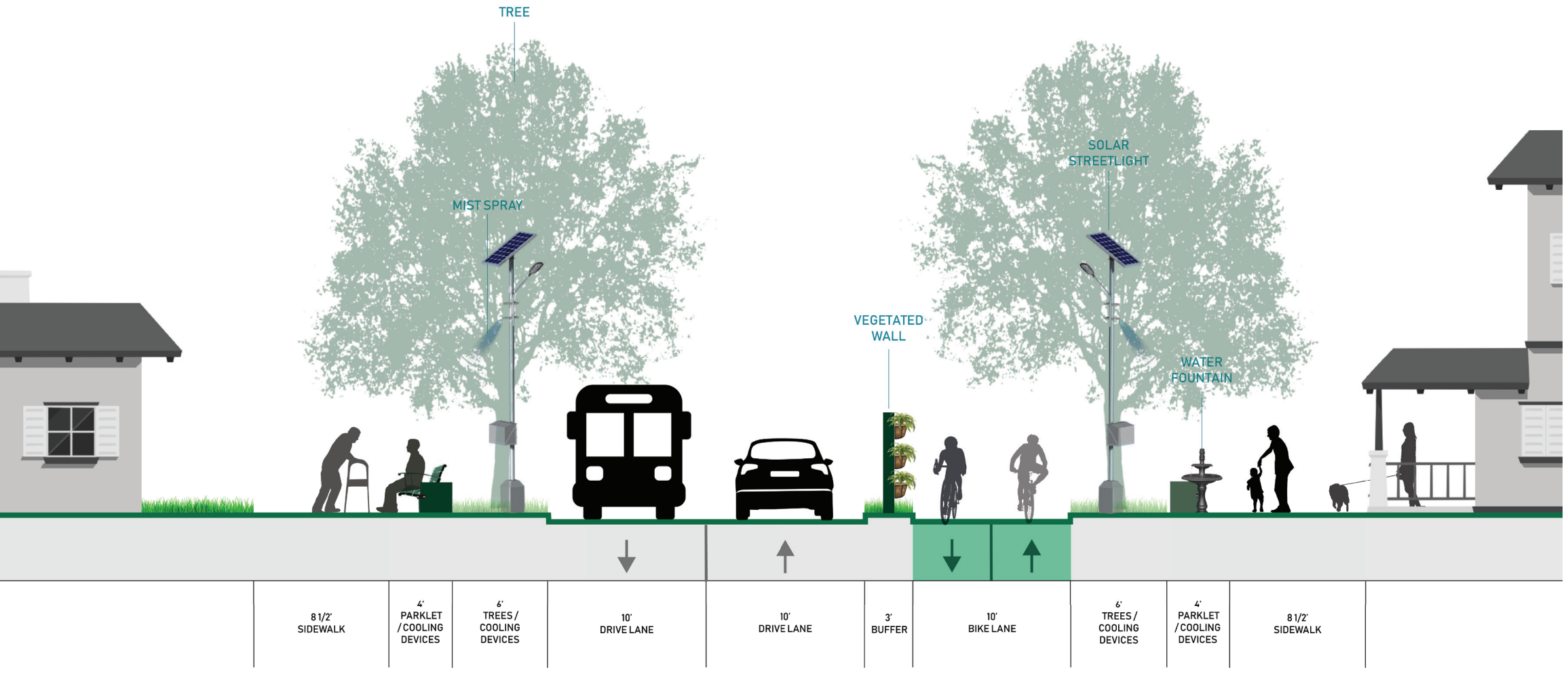


Figure 25. Sample section of a residential connector.

SHARED STREET

Shared streets are usually narrower streets in low density residential area. In this type of street, no vehicles should be allowed other than autonomous vehicles. Bike and e-scooters would share the same road.

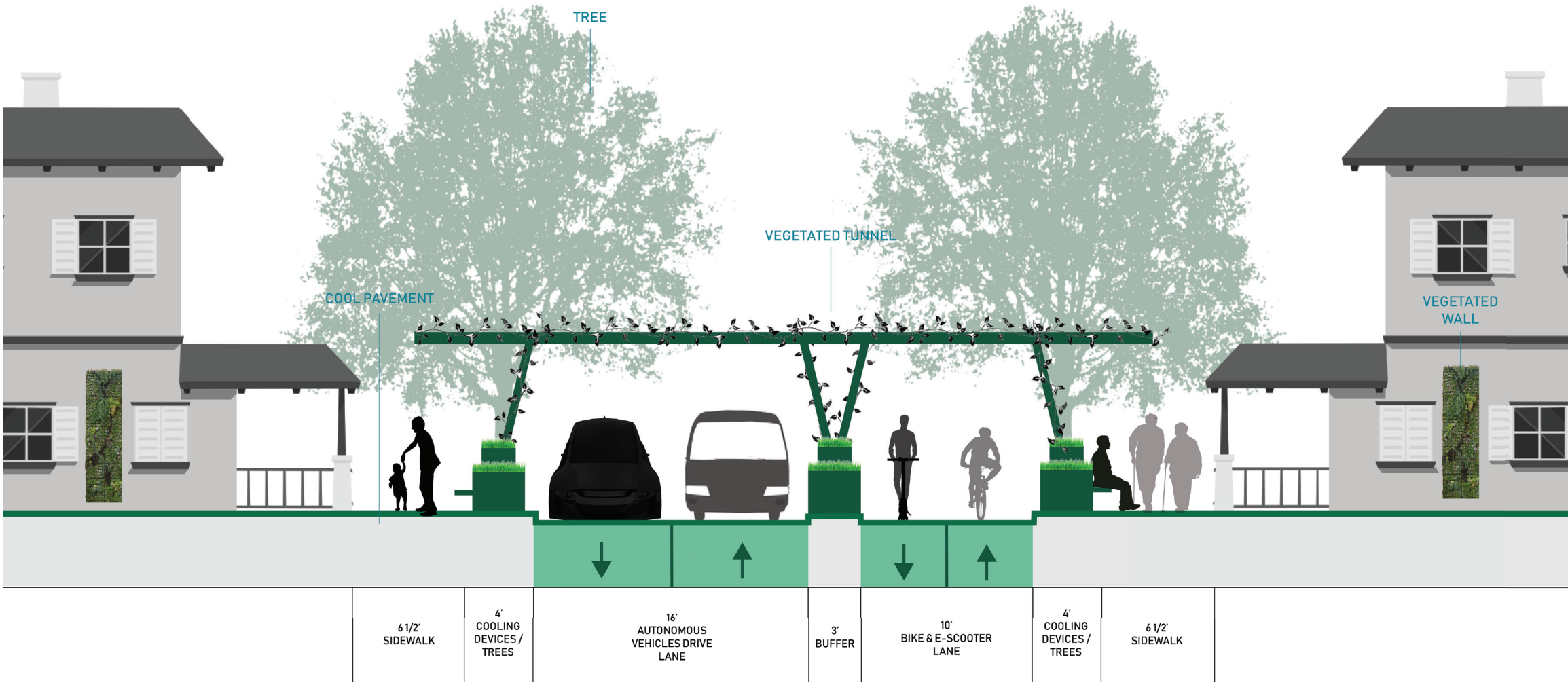


Figure 26. Sample section of a shared street.

URBAN INDUSTRIAL

Streets within the urban industrial area should provide bikeshare station with bike lanes connected to other communities. Cool pavement is often used with roadside shelters to provide cooling effect and shade.

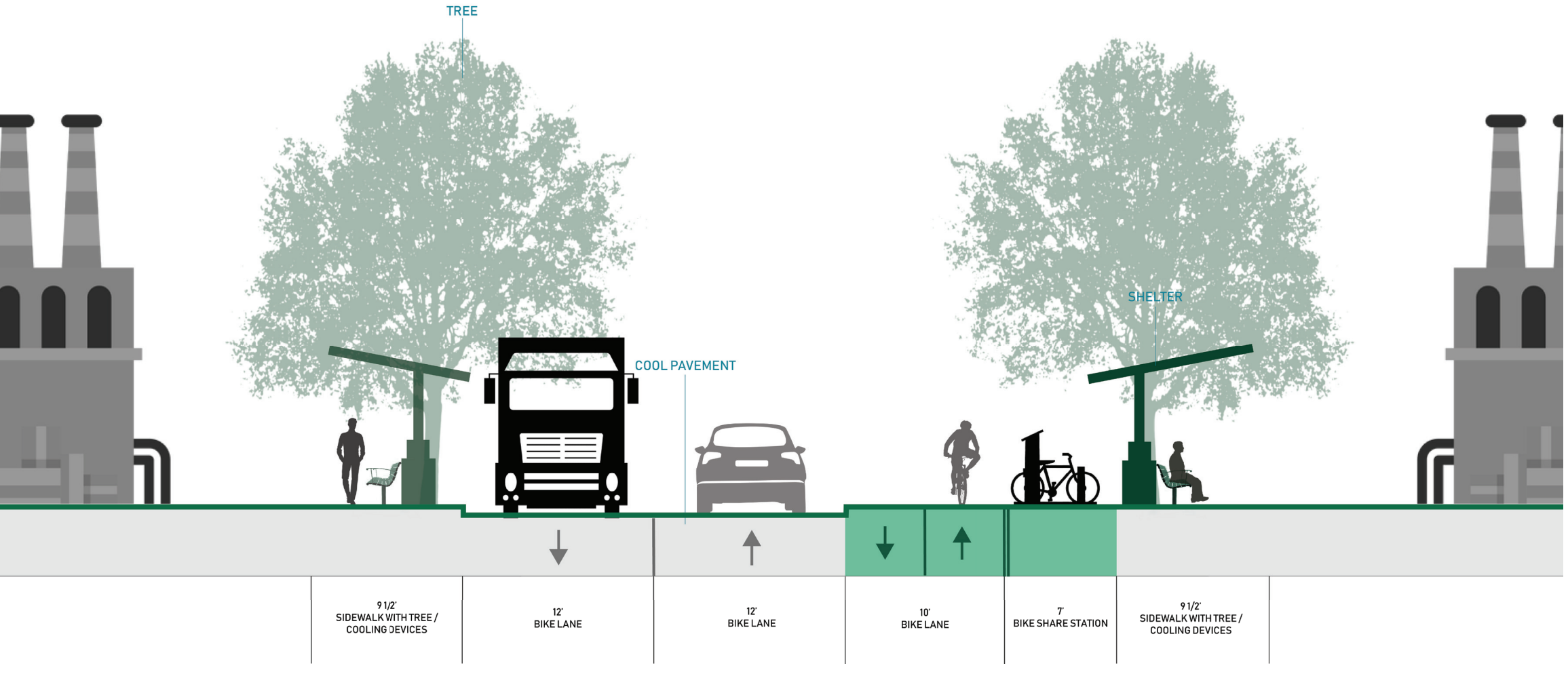


Figure 27. Sample section of a urban industrial street.

SUBURBAN INDUSTRIAL

Streets on suburban industrial areas should be designed in the same way as urban industrial but without bikeshare stations to save costs.

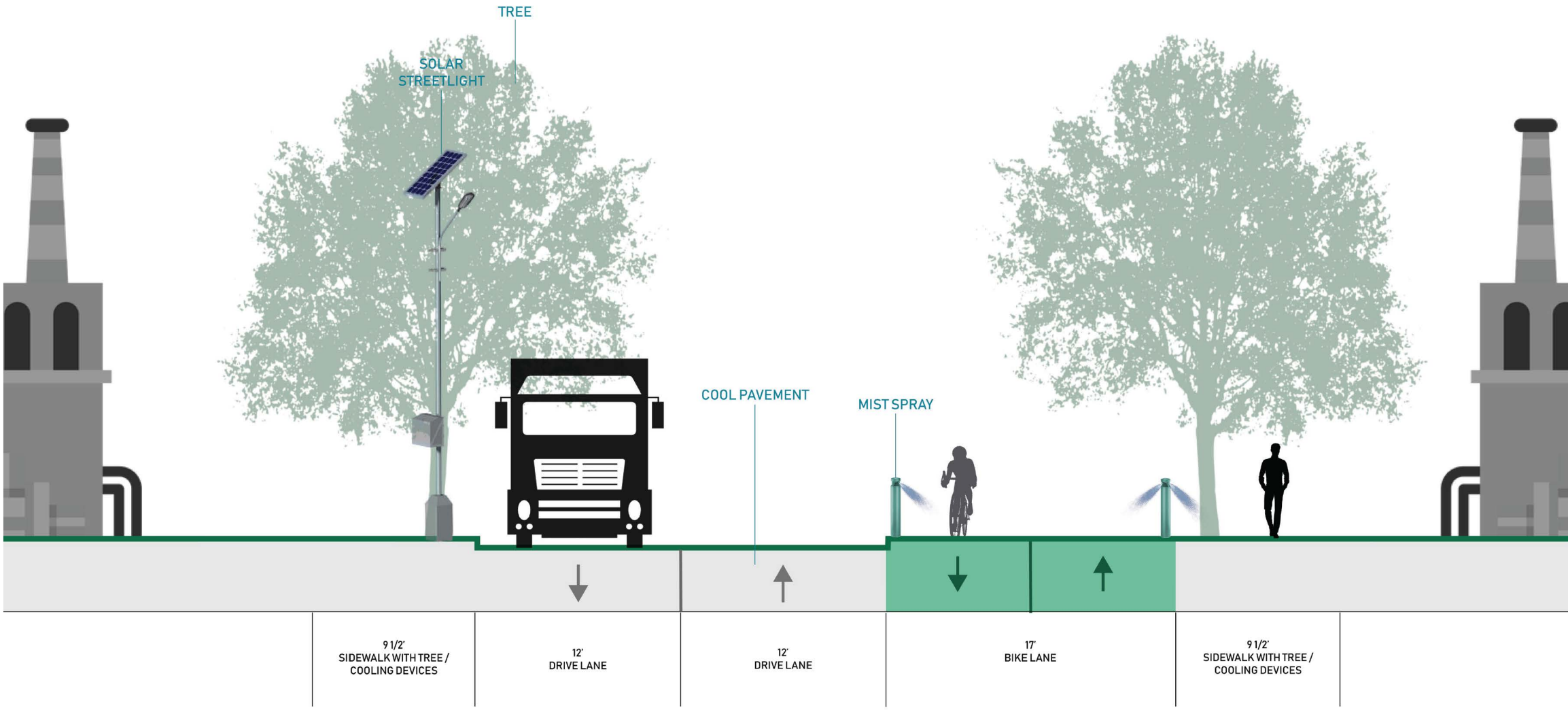
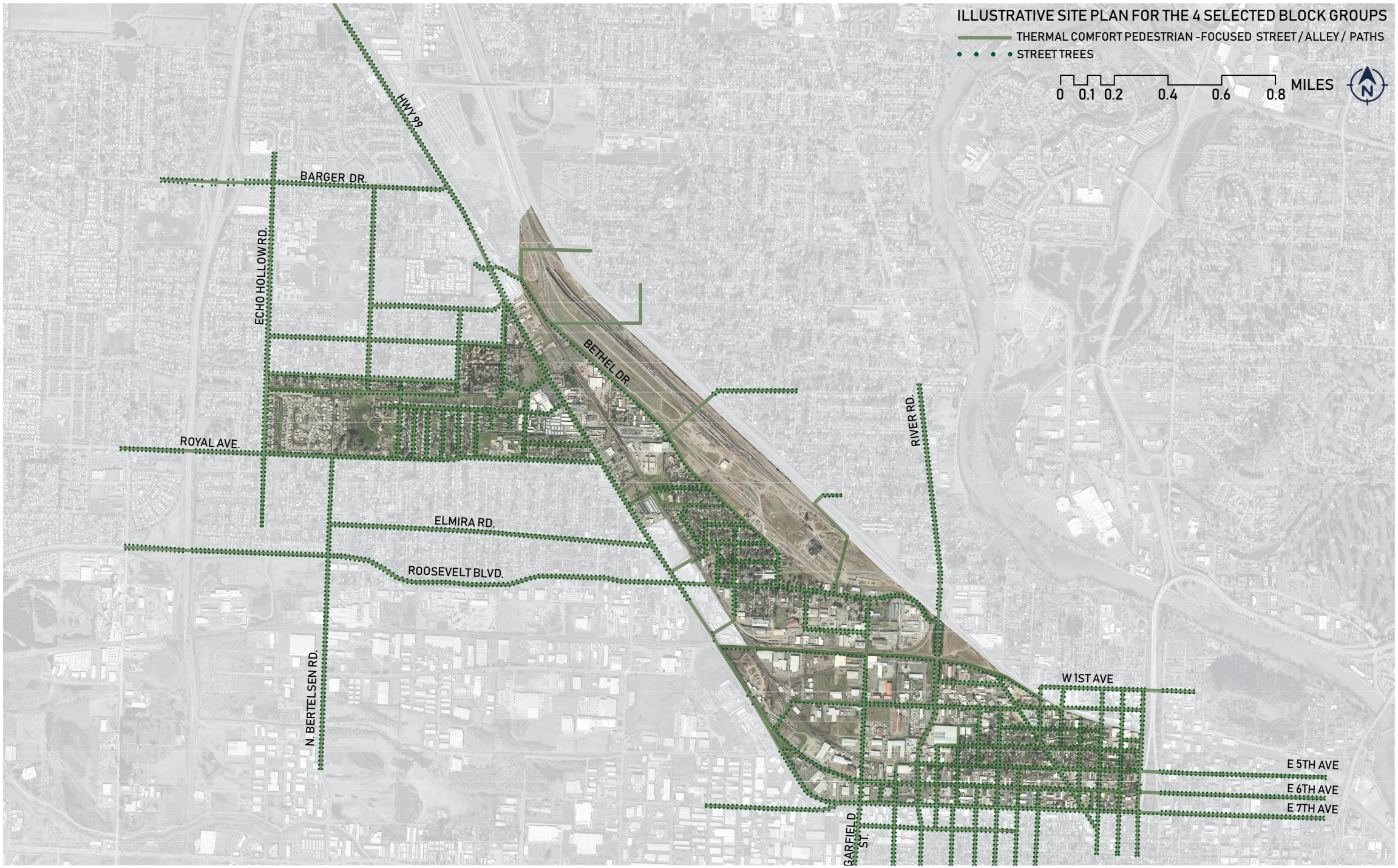


Figure 28. Sample section of a suburban industrial street.

CHAPTER 8

SELECTING AREAS FOR DESIGN DEMONSTRATION


ILLUSTRATIVE SITE PLAN FOR THE 4 SELECTED BLOCK GROUPS
THERMAL COMFORT PEDESTRIAN -FOCUSED STREET / ALLEY / PATHS
STREET TREES
0 0.1 0.2 0.4 0.6 0.8 MILES
N
HWY 99
BARGER DR.
ECHO HOLLOW RD.
BETHEL DR.
ROYAL AVE.
RIVER RD.
ELMIRA RD.
ROOSEVELT BLVD.
N. BERTELSEN RD.
W 1ST AVE
E 5TH AVE
E 6TH AVE
E 7TH AVE

THE FOUR SELECTED BLOCK GROUPS

The four block groups selected for design are adjacent to 99W. These block groups are selected based on their proximity to each other in order to propose a more integrated design, given that their priority for receiving the City's resources remain the same.

These block groups cover the majority of the street types in Eugene that could be replicated to other urban form types. Furthermore, they cover the major routes linking to other underserved communities. Thus, designing these block groups together could provide an important structure that could extend to the rest of Eugene.

Photo: Intersection at Roosevelt Blvd & HWY 99.

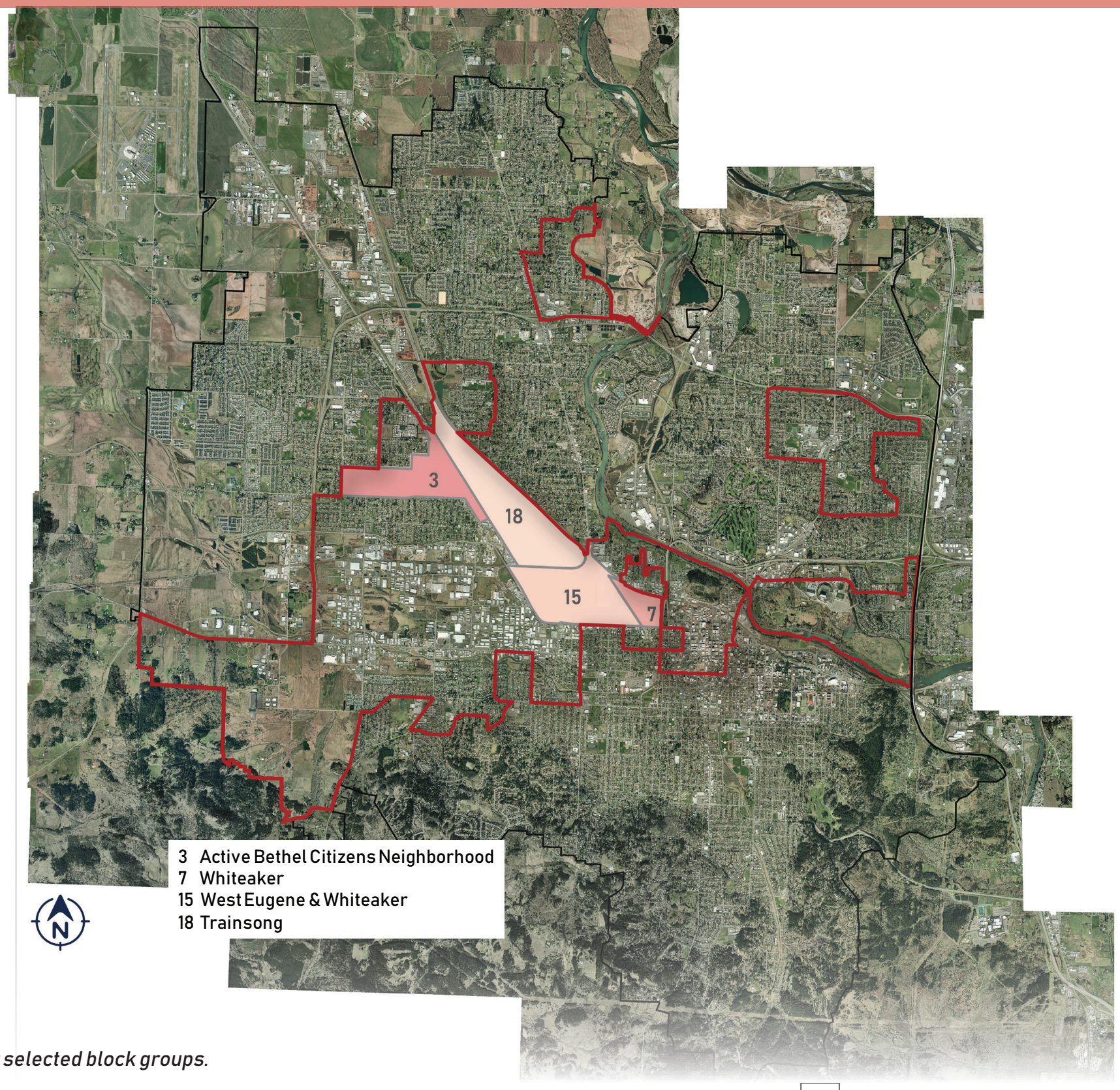


Figure 29. The four selected block groups.

BLOCK GROUP NEEDINESS RANKING #3: ACTIVE BETHEL CITIZENS NEIGHBORHOOD

PROFILE

Neediness Ranking : #3
Block Group FIPS Code : 410390043001
Urban Form Typology : Compact Suburban
Primary Vulnerable Group : Household in Poverty

NEIGHBORHOOD BACKGROUND & CHARACTERISTICS

This block group is located within the Active Bethel Citizens (ABC) neighborhood. It is a suburban neighborhood and is the largest neighborhood in Eugene (City of Eugene City Manager's Office, 2017). The entire neighborhood has most of the population identified themselves as white, while almost 15% of the population identified themselves as non-white, other race alone or with two or more races. Most residents identified their ancestry as others including Hispanics and Asians (33.8%), German (16.7%), and Irish (10.8%) (Statistical Altas, 2019).

The neighborhood is experiencing aging population. As of 2010, most of the people are aged between 30 to 69 years old, with a comparatively low population at age 5 or under to 29 (City of Eugene Neighborhood Services, 2011). There are 15% veteran population within the neighborhood (City of Eugene Neighborhood Services, 2011). Most children and adolescence are attending elementary and high school, and the highest level of education the majority of the entire population completed is high school, GED, or alternative (City of Eugene Neighborhood Services, 2011).

There are more owners (65%) than renters (35%) at this neighborhood (City of Eugene Neighborhood Services, 2011). The neighborhood consists of mostly single person household and husband-wife family household with no children under 18 years old (City of Eugene Neighborhood Services, 2011).

In the Bethel neighborhood, there are 15.8% of the working population is employed in administrative jobs, 11.7% is employed in sales and related occupations, 9.2% in management positions, and 8.1% in production jobs (Statistical Altas, 2019).
A total of 42% of the ABC neighborhood experienced at least twelve months of poverty from 2005 to 2009.The selected block

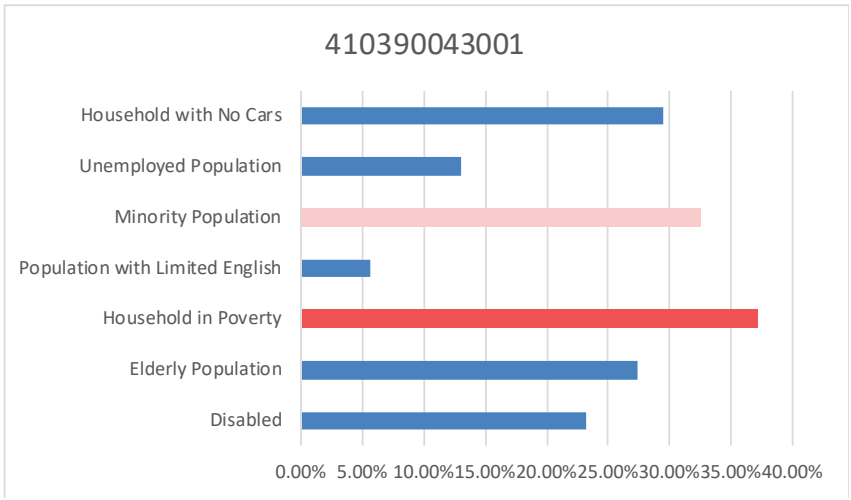


Figure 30. Vulnerable groups within the neighborhood.

group particularly, with neediness ranking #3, has a Per Capita of the block group of $14,470, a median household income of $21,540, and a median family income of $42,845 (City of Eugene Neighborhood Services, 2011). All of which are relatively low compared to other block groups within the ABC neighborhood.

Most residents of the ABC neighborhood (89%) commute to work by driving alone or carpooled using car, truck, van. Only 4% would travel by bus or trolley bus, 2% by bicycle, and 1% by foot (City of Eugene Neighborhood Services, 2011).

The ABC neighborhood are mostly zoned as low-density residential, and exclusive farm use (City of Eugene Neighborhood Services, 2011). Most lands are used as single-family housing, agriculture, and roads (City of Eugene Neighborhood Services, 2011). Only 10.5% of the land are developed as parks (City of Eugene Neighborhood Services, 2011). However, over 11% of the land are still vacant (City of Eugene Neighborhood Services, 2011).

Major amenities and restaurants are located along Hwy 99. Two major franchise grocery stores are Winco Foods and Albertsons, both are relatively close to the Randy Pape Beltline. A number of schools and churches are relatively close to the neighborhood. Many people think that the neighborhood is relaxed, quiet and private, while some reported homeless and theft issues within the neighborhood (Trulia, 2019).

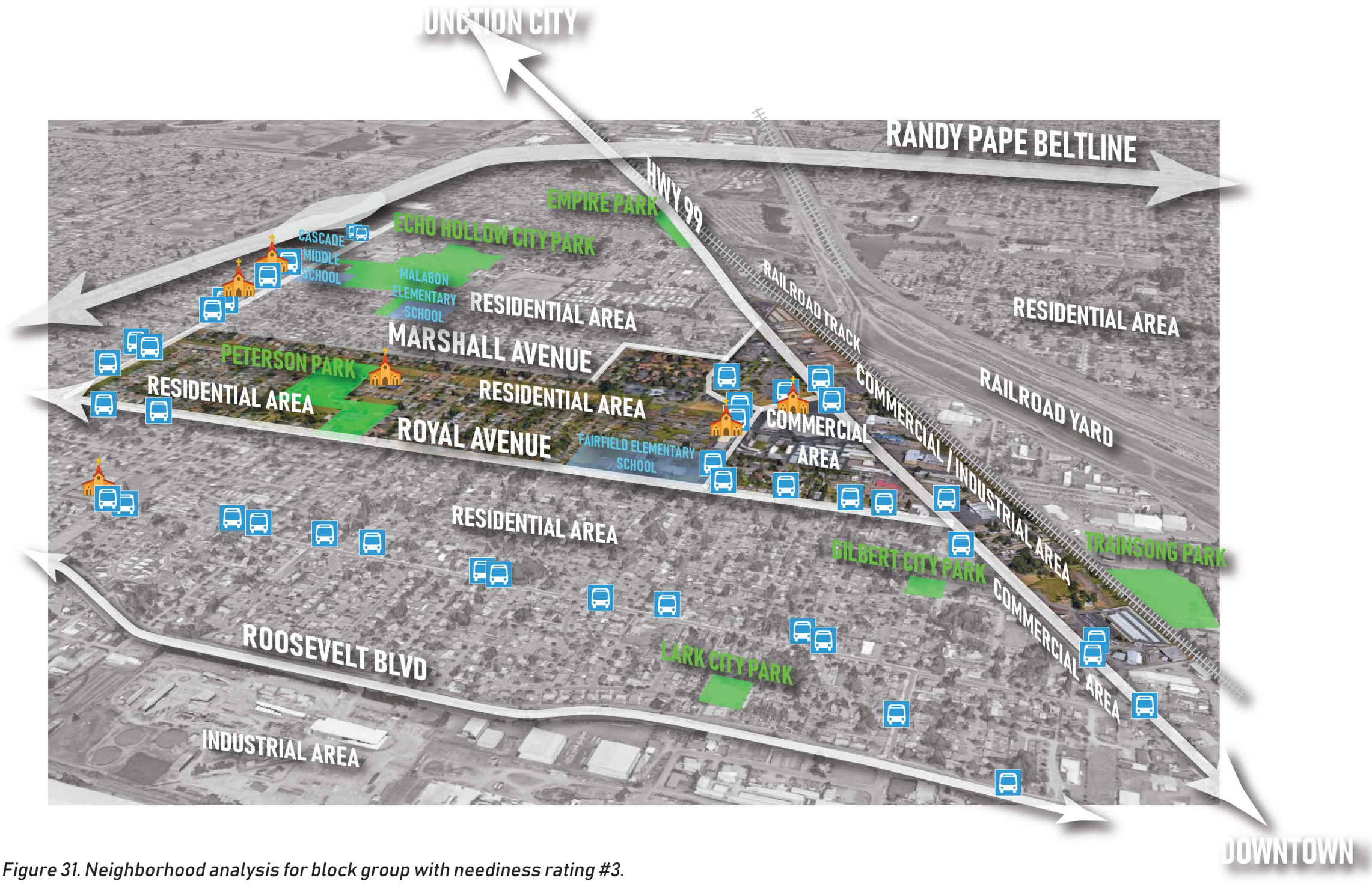


Figure 31. Neighborhood analysis for block group with neediness rating #3.

Figure 32. Existing condition of Richard Ave.

Figure 33. Proposed condition of Richard Ave with better connection to Hwy 99.

BLOCK GROUP NEEDINESS RANKING #7: WHITEAKER COMMUNITY COUNCIL

PROFILE

Neediness Ranking : #7
Block Group FIPS Code : 410390042003
Urban Form Typology : Urban Transition
Primary Vulnerable Group : Disabled

NEIGHBORHOOD BACKGROUND & CHARACTERISTICS

The #7 block group is situated completely within Whiteaker Community Council. The entire neighborhood has most of the population identified themselves as white alone (City of Eugene Neighborhood Services, 2011). Most residents identified their ancestry as others including Hispanics and Asians (33.7%), and German (21.3%) (Statistical Altas, 2019).

The neighborhood is experiencing aging population. As of 2010, most of the people are aged between 30 to 49 years old, with a comparatively low population at age 18 to 29 and very low population of age 17 or under (City of Eugene Neighborhood Services, 2011). There are 9% veteran population within the neighborhood (City of Eugene Neighborhood Services, 2011). Most children and adolescence completed college undergraduate program (City of Eugene Neighborhood Services, 2011).

There are more renters (82%) than owners (18%) at this neighborhood (City of Eugene Neighborhood Services, 2011). The neighborhood consists of mostly single person household and 2-or-more-person non-family households (City of Eugene Neighborhood Services, 2011).

There are 12.1% of the working population is employed in sales and related jobs and 9.5% is employed in food service (Statistical Altas, 2019).

A total of 58% of the Whiteaker neighborhood experienced at least twelve months of poverty from 2005 to 2009 (City of Eugene Neighborhood Services, 2011). It has a per capita of the block group of $18,431, a median household income of $25,603, and a median family income of $34,375 (City of Eugene Neighborhood Services, 2011). All of which are relatively low compared to the surrounding neighborhood.

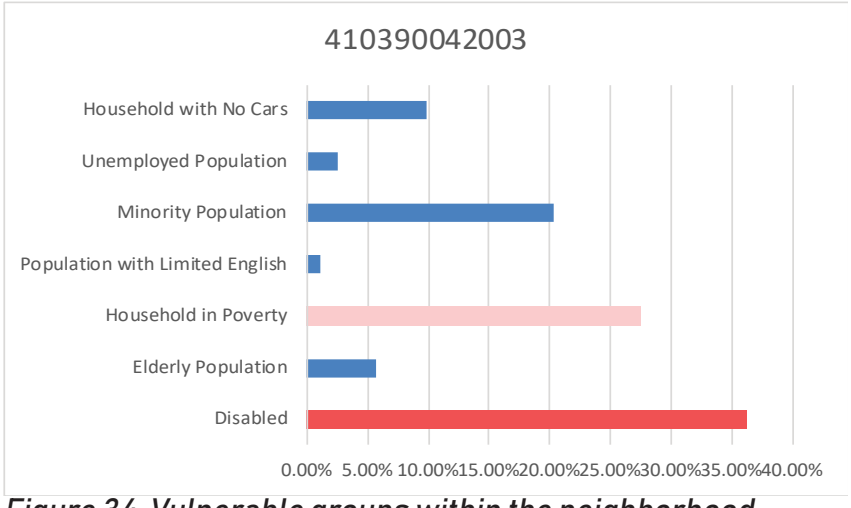


Figure 34. Vulnerable groups within the neighborhood.

Most residents (49%) commute to work by driving alone or carpooled using car, truck, van, with 20% by bicycle, and 11% by foot (City of Eugene Neighborhood Services, 2011).

The Whiteaker neighborhood are mostly zoned as public land and low-density residential (City of Eugene Neighborhood Services, 2011). Most lands are used as residential, parks and roads (City of Eugene Neighborhood Services, 2011). Only 10.5% of the land are developed as parks (City of Eugene Neighborhood Services, 2011).

The neighborhood is surrounded by industrial and big box commercial businesses. The residential area has some tree canopy cover, however, there is not much tree canopy cover in the industrial and big box commercial areas, making the neighborhood seemed disconnected from the surrounding amenities.

Figure 35. Neighborhood analysis for block group with neediness rating #7.

Figure 36. Existing condition of Blair Blvd.

Figure 37. Proposed condition of Richard Ave providing more sitting areas and ADA access.

Figure 38. Existing condition of Richard Ave.

Figure 39. Proposed condition of Richard Ave provides more sittings and shade.

BLOCK GROUP NEEDINESS RANKING #15: WEST EUGENE & WHITEAKER NEIGHBORHOOD

PROFILE

Neediness Ranking : #15
Block Group FIPS Code : 410390042002
Urban Form Typology : Urban Industrial
Primary Vulnerable Group : Household in Poverty

NEIGHBORHOOD BACKGROUND & CHARACTERISTICS

Half of this block group is located in the east end of the West Eugene Community Organization neighborhood, the industrial area within the boundary of West Eugene Community Organization, and the major residential area located in Whiteaker Community Council neighborhood.

The block group #15 neighborhood is a small, urban neighborhood transiting from the surburban area (City of Eugene City Manager's Office, 2017). This west-central Eugene neighborhood has most of the population identified themselves as hite alone (City of Eugene Neighborhood Services, 2011). The ancestry of the residents is diverse. Most residents identified their ancestry as others including Hispanics and Asians (34.9%), German (19.8%), Irish (11.8%), and English (8.5%) (Statistical Atlas, 2019).

The West Eugene neighborhood is experiencing severe aging population. As of 2010, most of the people are aged between 40 to 59 years old, with a comparatively low population (9.1% male, 4% female in total) at age 25 or under to 39 (City of Eugene Neighborhood Services, 2011).

There are more renters (67%) than owners (33%) at this neighborhood (City of Eugene Neighborhood Services, 2011). The neighborhood consists of mostly single person household and 2-or-more-person non-family households (City of Eugene Neighborhood Services, 2011).

There are 12.1% of the working population is employed in dministrative jobs and 9.5% is employed in ales and related occupation (Statistical Altas, 2019).

In the neighborhood that falls within Whiteaker Community Council, it has a per capita of the block group of $13,223, a median household income of $25,677, and a median family income of $50,250 (City of Eugene Neighborhood Services, 2011).

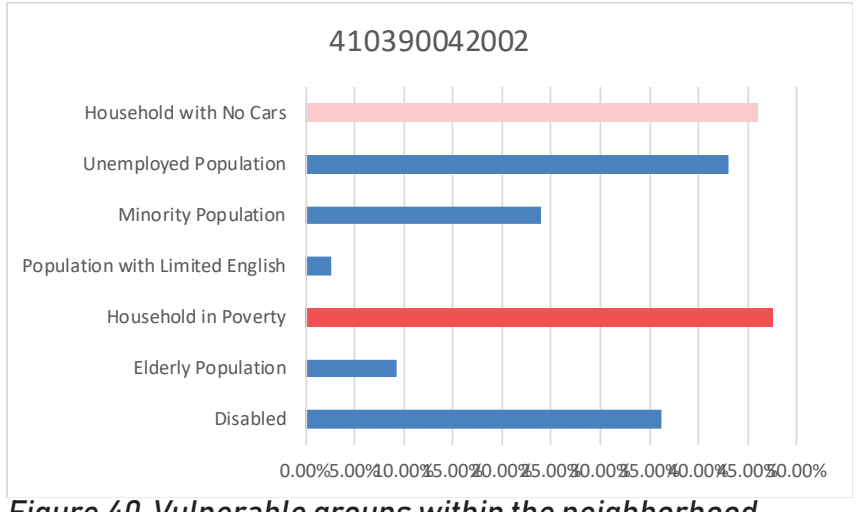


Figure 40. Vulnerable groups within the neighborhood.

Most residents (49%) commute to work by driving alone or carpooled using car, truck, van, with 20% by bicycle, and 11% by foot (City of Eugene Neighborhood Services, 2011).

The Whiteaker neighborhood are mostly zoned as public land and low-density residential (City of Eugene Neighborhood Services, 2011). Most lands are used as residential, parks and roads (City of Eugene Neighborhood Services, 2011). Only 10.5% of the land are developed as parks (City of Eugene Neighborhood Services, 2011).

The neighborhood is surrounded by industrial and big box commercial businesses. The residential area has some tree canopy cover, however, there is not much tree canopy cover in the industrial and big box commercial areas, making the neighborhood seemed disconnected from the surrounding amenities.

Figure 41. Neighborhood analysis for block group with neediness rating #15.

Figure 42. Existing condition of Hwy 99.

Figure 43. Proposed condition of Hwy 99 to provide better connections with shade.

BLOCK GROUP NEEDINESS RANKING #18: WHITEAKER NEIGHBORHOOD

PROFILE

Neediness Ranking : #18
Block Group FIPS Code : 410390042001
Urban Form Typology : Railroad Yard Neighborhood
Primary Vulnerable Group : Disabled

NEIGHBORHOOD BACKGROUND & CHARACTERISTICS

This block group is located within the Trainsong neighbors. It is a very small suburban area with a large railroad yard on the east side of the neighborhood (City of Eugene City Manager's Office, 2017). The neighborhood has most of the population identified themselves as white, while almost 22% of the population identified themselves as non-white or with two or more races. Most residents identified their ancestry as others including Hispanics and Asians (37.6%) and German (20.9%)(Statistical Atlas, 2019).

The neighborhood is experiencing severe aging population. As of 2010, most of the people are aged between 30 to 69 years old, with a comparatively low population at age 25 to 29 (City of Eugene Neighborhood Services, 2011). There are 18% veteran population within the neighborhood (City of Eugene Neighborhood Services, 2011). The highest level of education most people completed is high school, GED, or alternative (City of Eugene Neighborhood Services, 2011).

There are more renters (71%) than owners (29%) at this neighborhood (City of Eugene Neighborhood Services, 2011). The neighborhood consists of mostly single person household and 2-or-more-person non-family households (City of Eugene Neighborhood Services, 2011).

In the Trainsong neighborhood, there are 10.9% of the working population is employed in administrative jobs and 10.6% is employed in food service occupations (Statistical Atlas, 2019).

A total of 28% of the neighborhood experienced at least twelve months of poverty from 2005 to 2009.The selected block group particularly, with neediness ranking #18, has a Per Capita of the block group of $14,515, a median household income of $30,882,

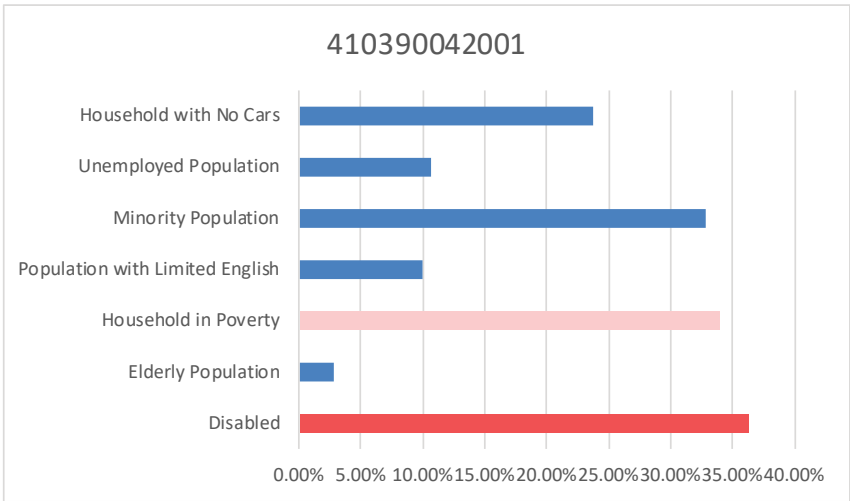


Figure 44. Vulnerable groups within the neighborhood.

and a median family income of $29,833 (City of Eugene Neighborhood Services, 2011). All of which are relatively low compared to other block groups within Eugene.

Most residents (69%) commute to work by driving alone or carpooled using car, truck, van. There are 12% who would travel by bus or trolley bus, 6% by bicycle, and 4% by foot (City of Eugene Neighborhood Services, 2011).

The neighborhood are mostly zoned as industrial, community commercials, and low-density to limited high-density residential (City of Eugene Neighborhood Services, 2011). Most lands are used as railroad, roads, residential, and industrial (City of Eugene Neighborhood Services, 2011).

The neighborhood practices perma-culture. Major amenities and restaurants are located along Hwy 99. There is a local grocery store within the neighborhood, and another one in the Bethel area. There is no school within this neighborhood, but a number of schools are located in the adjacent Bethel neighborhood. The neighborhood is lack of sidewalks, with a railroad track on the west side of the neighborhood preventing the residents walk directly to the community stores along Hwy 99. The only sidewalks linked to Hwy 99 are on Roosevelt Blvd and the north end of Bethel Drive. Moderate level of crimes is reported at the stores near Roosevelt Blvd and Hwy 99 (Trulia, 2019).

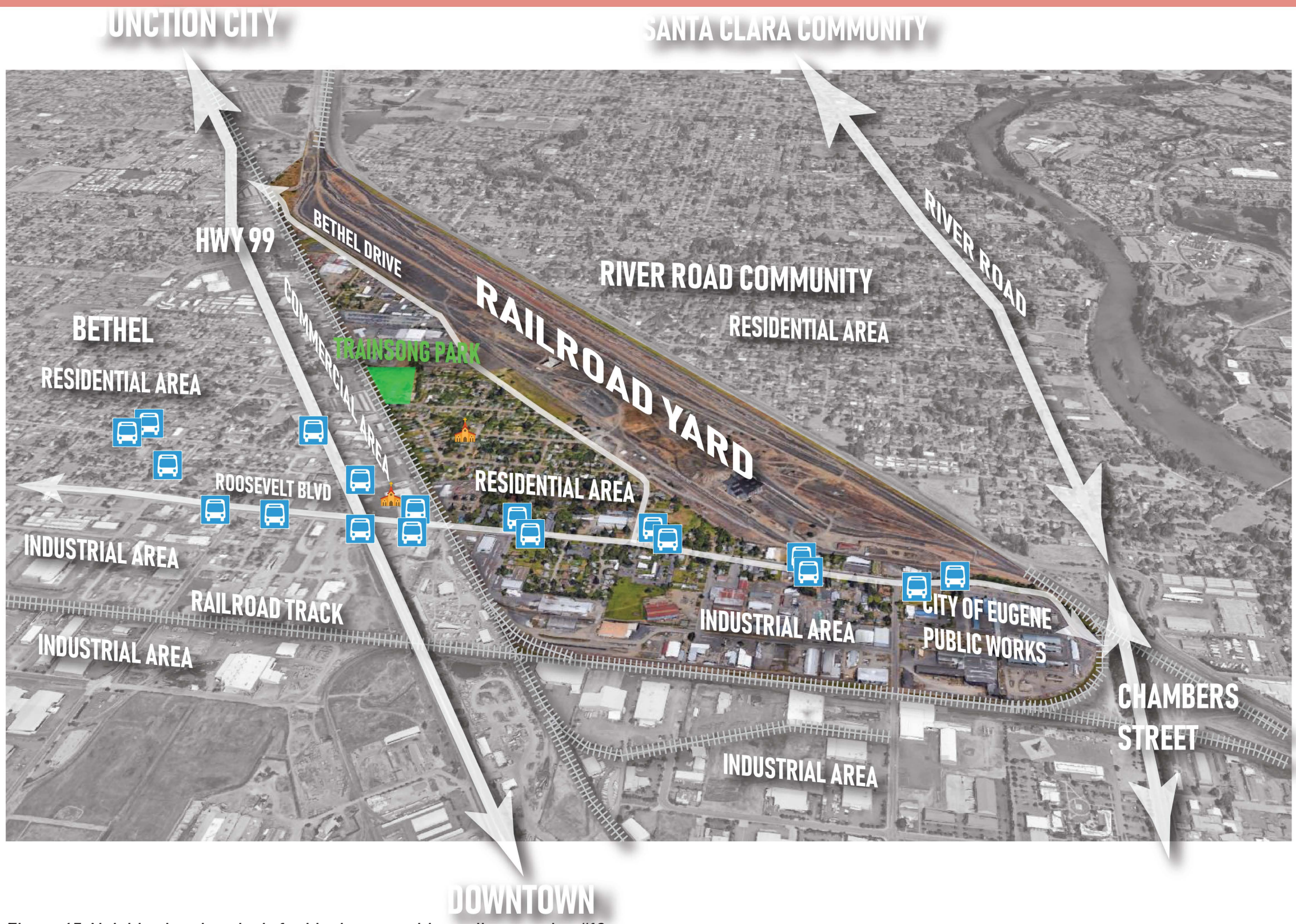


Figure 45. Neighborhood analysis for block group with neediness rating #18.

Figure 45. Existing condition of Haig. St.

Figure 46. Proposed condition of Haig. St. with community garden features.

SUMMARY & RECOMMENDATIONS FOR IMPLEMENTATIONS

SUMMARY

Creating thermal comfort streets in cities is an inevitable step to adapting to climate change. As extreme heat events become more intense and frequent, the environment and our lives are being threatened. In vulnerable communities particularly, they are underserved with tree canopy cover on their walk and bike networks. This factor alone exposes community members to much higher risks of heat-related illnesses and caused many to death every year. Furthermore, it contributes to even more intense UHI as they choose to travel by car over by foot or by bike.

For these reasons, this project helps the City of Eugene to prioritize its resources to create thermal comfort streets in underserved communities efficiently. Thermal comfort street design interventions provide the major benefits of improving human health & comfort. The design also produces co-benefits of reducing energy consumption, filter and reduce emissions of air pollutants & greenhouse gases, improve water quality, and improve human health & comfort.

A city-wide thermal comfort street network and street design recommendations are proposed in this project and could be applicable to the underserved communities as well as to the rest of Eugene. To illustrate the thermal comfort street design ideas, four block groups are selected for more in-depth analysis and are provided specific design solutions.

THE FOUR DESIGN STRATEGIES

There are four design strategies that should be applied when creating thermal comfort streets:

1. create shade through greening and shade structures
2. use light color pavement
3. install cooling devices
4. provide other co-benefits with stormwater energy saving, and renewable energy

FUNDING

There are three funding opportunities available to the city for climate change related projects.

1. Smart Growth Grants is funded by the EPA. It supports activities that improve the quality of development and protect human health and the environment (EPA, 2018).
2. Environmental Justice Grants is funded by the EPA. It support and empower communities that are developing and implementing solutions that significantly address environmental and/or public health issues at the local level (EPA, 2017).
3. Surface transportation funding programs are funded by the Department of Transportation Federal Highway Administration. Its funding covers a wide range of pedestrian and bike related projects (Federal Highway Administration, 2018).

These fundings could help the City to install more effective design interventions rather than just planting trees.

SHORT-TERM & LONG-TERM GOALS

In a short run, the city should reserve funds for the underserved communities accordingly based on the neediness rating. Site analysis, planning and design should be done to the top prioritized communities first. If fundings are limited, streets with north-east orientation within the community should receive fundings first for thermal comfort street implementation as these streets often receive more sunlights. Bike network should be interconnected with other surrounding communities. Permeable pavement could be used to reduce surface runoff.

In a long run, the city should rezone the city to allow for more mixed-use neighborhoods to reduce the prioximity between residentials, commercials and other amenities essential to daily lives. Rezoning could also narrow the gap between the high and low income households, hence, more opportunities to create better quality thermal comfort streets. The city should also require industrial buildings to be more high-tech and environmentally friendly in order to reduce the environmental impacts they create.

APPENDIX A

Attributes	My Response	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Tree Canopy Cover	8	8	5	9	8	8
Area affected by UHI High Temperature Zone	9	9	4	8	9	9
Disabled Population	5	6	8	3	5	7
Elderly Population	6	7	7	4	6	6
Household in Poverty	4	4	9	7	2	5
Population with Limited English	1	3	1	2	4	2
Minority Population	2	2	2	1	7	1
Unemployed Population	3	1	3	6	3	3
Household with No Cars	7	5	6	5	1	4

*Table A-1. Survey was sent out asking experts to rank the most and least important attributes when it comes to prioritizing for underserved communities. **1 = Least Important, 9 = Most important.*

Attributes	My Response	Response 1	Response 2	Response 3	Response 4	Response 5
Tree Canopy Cover	2	2	5	1	2	2
Area affected by UHI High Temperature Zone	1	1	6	2	1	1
Disabled Population	5	4	2	7	5	3
Elderly Population	4	3	3	6	4	4
Household in Poverty	6	6	1	3	8	5
Population with Limited English	9	7	9	8	6	8
Minority Population	8	8	8	9	3	9
Unemployed Population	7	9	7	4	7	7
Household with No Cars	3	5	4	5	9	6

Table A-2. Responses have to be rearranged in order to calculate using Garret's Ranking Technique.
*** 1 = Most important, 8 = Least important.*

Rank	$100 (R_{ij} - 0.5)/ N_j$	Percent Position	Garret Value
1	100 (1-0.5)/9	5.56	81
2	100 (2-0.5)/9	16.67	69
3	100 (3-0.5)/9	27.78	62
4	100 (4-0.5)/9	38.89	56
5	100 (5-0.5)/9	50.00	50
6	100 (6-0.5)/9	61.11	44
7	100 (7-0.5)/9	72.22	38
8	100 (8-0.5)/9	83.33	31
9	100 (9-0.5)/9	94.44	19

Table A-3. Garret Values are calculated using the formula 100(Rij - 0.5)/Nj, where Rij = Rank given for the ith variable by jth respondents, Nj = Number of variable ranked by jth respondents.

Attributes	Frequency of Rank							
	1	2	3	4	5	6	7	8
Tree Canopy Cover	1	4	0	0	1	0	0	0
Area affected by UHI High Temperature Zone	4	1	0	0	0	1	0	0
Disabled Population	0	1	1	1	2	0	1	0
Elderly Population	0	0	2	3	0	1	0	0
Household in Poverty	1	0	1	0	1	2	0	1
Population with Limited English	0	0	0	0	0	1	1	2
Minority Population	0	0	1	0	0	0	0	3
Unemployed Population	0	0	0	1	0	0	4	0
Household with No Cars	0	0	1	1	2	1	0	0

Table A-4. Garret Values are calculated using the formula 100(Rij - 0.5)/Nj, where Rij = Rank given for the ith variable by jth respondents, Nj = Number of variable ranked by jth respondents.

Attributes	Frequency of Rank x Percent Position									Total	Average Score (Total/6)	New Rank	Weight
	1	2	3	4	5	6	7	8	9				
Tree Canopy Cover	81	276	0	0	50	0	0	0	0	407	67.83	2	8
Area affected by UHI High Temperature Zone	324	69	0	0	0	44	0	0	0	437	72.83	1	9
Disabled Population	0	69	62	56	100	0	38	0	0	325	54.17	4	6
Elderly Population	0	0	124	168	0	44	0	0	0	336	56.00	3	7
Household in Poverty	81	0	62	0	50	88	0	31	0	312	52.00	5	5
Population with Limited English	0	0	0	0	0	44	38	62	38	182	30.33	9	1
Minority Population	0	0	62	0	0	0	0	93	38	193	32.17	8	2
Unemployed Population	0	0	0	56	0	0	152	0	19	227	37.83	7	3
Household with No Cars	0	0	62	56	100	44	0	0	19	281	46.83	6	4

Table A-5. Frequency of rank is multiplied by the Garret's Value to calculate the new rank. Weights are then assigned based on the rank.

Attribute	Weight
Area affected by UHI High Temperature Zone	9
Tree Canopy Cover	8
Elderly Population	7
Disabled Population	6
Household in Poverty	5
Household with No Cars	4
Unemployed Population	3
Minority Population	2
Population with Limited English	1

Table A-6. Weights that are used to calculate the total score for "Neediness" Rating.

Block Group ID	Tree Canopy Cover	Area affected by UHI High Temperature Zone	Disabled Population	Elderly Population	Household in Poverty	Population with Limited English	Minority Population	Unemployed Population	Household with No Cars	Score (Addition of all Normalized Data x corresponding weights)	Population Density (per sq. mi)	Total Score (Score x Density)	Neediness Rating
410390010022	0.39	0.13	0.21	0.52	0.62	0.00	0.38	0.14	0.36	14.86990365	0.00	0	25
410390023011	0.84	0.72	0.47	0.35	0.34	0.04	0.25	0.14	0.27	22.23723352	0.16	3.564650454	22
410390026002	0.76	0.29	0.30	0.34	0.00	0.29	0.71	0.00	0.00	14.54304964	0.40	5.809965629	13
410390027002	0.61	0.34	0.36	0.31	0.51	0.15	0.28	0.15	0.19	16.80421648	0.35	5.807579886	14
410390029021	0.57	0.50	0.33	0.64	0.23	0.16	0.40	0.07	0.51	19.83837515	0.45	8.84159781	10
410390031012	0.46	0.52	0.26	0.41	0.04	0.24	0.33	0.31	0.14	15.37340454	0.36	5.541442686	17
410390031013	0.64	0.70	0.26	0.39	0.34	0.25	0.07	0.09	0.33	19.36340109	0.61	11.81476127	4
410390031024	0.56	0.16	0.00	0.32	0.70	1.00	0.98	0.20	0.47	17.1171784	0.17	2.853054126	23
410390039001	0.61	0.00	0.42	0.22	0.75	0.12	0.76	0.21	0.89	18.47860447	0.40	7.357794294	11
410390039002	0.49	0.83	0.42	0.35	0.91	0.12	0.45	0.31	0.95	26.65941924	0.66	17.64055553	2
410390040001	0.00	0.05	0.40	1.00	0.72	0.08	0.00	0.17	1.00	18.1112973	0.21	3.764698963	21
410390040003	0.41	0.37	0.40	0.27	0.29	0.22	0.40	0.42	0.26	15.70404268	0.26	4.095067249	20
410390042001	0.98	0.77	1.00	0.04	0.54	0.51	0.70	0.25	0.45	28.23910756	0.19	5.48998162	18
410390042002	0.96	0.98	1.00	0.17	0.80	0.14	0.45	1.00	0.88	35.31186954	0.16	5.647497304	15
410390042003	0.39	0.25	1.00	0.10	0.41	0.05	0.34	0.06	0.19	15.84806691	0.67	10.60678151	7
410390043001	0.86	0.35	0.48	0.57	0.60	0.29	0.70	0.30	0.56	24.76796339	0.50	12.46828173	3
410390043002	1.00	0.76	0.48	0.13	0.51	0.46	1.00	0.27	0.20	25.2892151	0.05	1.222425903	24
410390043003	0.94	0.45	0.48	0.00	0.38	0.16	0.48	0.19	0.07	18.29170443	0.38	6.984957554	12
410390043004	0.57	0.65	0.48	0.31	0.19	0.23	0.69	0.27	0.10	19.28465051	0.46	8.86884553	9
410390044011	0.34	0.76	0.31	0.13	0.34	0.49	0.69	0.21	0.22	17.35795085	0.63	10.98311729	6
410390044012	0.88	0.51	0.31	0.39	0.26	0.13	0.37	0.36	0.04	19.55093578	0.29	5.637365322	16
410390044014	0.49	0.65	0.31	0.64	0.27	0.00	0.37	0.12	0.85	21.94703292	0.51	11.26225248	5
410390044032	0.52	1.00	0.26	0.00	0.50	0.18	0.38	0.12	0.09	18.83469666	1.00	18.83469666	1
410390044033	0.93	1.00	0.26	0.45	1.00	0.12	0.24	0.40	0.28	29.0982255	0.17	4.879796354	19
410390045021	0.02	0.11	0.00	0.31	0.30	0.47	0.43	0.70	0.57	10.55577146	0.87	9.133829496	8

Table A-7. Neediness rating calculations using the total score equation.

APPENDIX B

Block Group ID	Neediness Rating	Urban Types	Primary Vulnerable Group
410390044032	1	Open Suburban	Household in Poverty
410390039002	2	Mixed-Use Urban Core	Household in Poverty
410390043001	3	Compact Suburban	Household in Poverty
410390031013	4	Compact Suburban	Household in Poverty
410390044014	5	Compact Suburban	Household with no Cars
410390044011	6	Compact Suburban	Minority Population
410390042003	7	Urban Transition	Disabled
410390045021	8	Urban Transition	Household with no Cars
410390043004	9	Compact Suburban	Minority Population
410390029021	10	Compact Suburban	Elderly Population
410390039001	11	Mixed-Use Urban Core	Household with no Cars
410390043003	12	Open Suburban	Household in Poverty
410390026002	13	Open Suburban	Minority Population
410390027002	14	Open Suburban	Household in Poverty
410390042002	15	Urban Industrial	Household in Poverty
410390044012	16	Suburban Industrial	Minority Population
410390031012	17	Compact Suburban	Elderly Population
410390042001	18	Railroad Yard Neighborhood	Disabled
410390044033	19	Urban Industrial	Household in Poverty
410390040003	20	Open Urban	Minority Population
410390040001	21	Open Urban	Household with no Cars
410390023011	22	Open Suburban	Household in Poverty
410390031024	23	Open Suburban	Household in Poverty
410390043002	24	Suburban Industrial	Minority Population
410390010022	25	Rural Transition	Household in Poverty

Table B-1. Summary of the 25 block groups and their corresponding urban form types and primary vulnerable groups.

APPENDIX C

Street Design Interventions	Design Solutions by Urban Form Types (Considering Costs & Effectiveness)								
	Mixed-Use Urban Core	Urban Transition	Open Urban	Compact Suburban	Open Suburban	Urban Industrial	Suburban Industrial	Railroad Yard Neighborhood	Rural Transition
VEGETATION									
Trees									
Bioswales									
Stormwater Planters									
Planter Strips									
Rain Gardens									
Green Roofs									
Vegetated Walls									
PAVEMENT TYPES									
Permeable Pavement									
Cool Pavement									
Kinetic Pavement									
WATER FEATURES									
Detention Pond									
Fountain									
Water Fountain									
Mist Garden									
Mist Sprays									
Water Walls									
Misting Fan									
Spray Play									

Street Design Interventions	Design Solutions by Urban Form Types (Considering Costs & Effectiveness)								
	Mixed-Use Urban Core	Urban Transition	Open Urban	Compact Suburban	Open Suburban	Urban Industrial	Suburban Industrial	Railroad Yard Neighborhood	Rural Transition
SOLAR HARVESTING									
Solar Streetlights									
Solar Fans									
Solar Panels									
Solar Roads									
MANMADE SHADE STRUCTURE									
Fabric Structures									
Overhead Structures									
Shelters									
Tree Tunnels									
Vegetated Tunnels									

Table C-1. Design solutions by urban form types.

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