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Progress, Priorities, and Obstacles to Providing Adequate Shade and Lighting at Bus Stops in Los Angeles

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Progress, Priorities, and Obstacles to Providing Adequate Shade and Lighting at Bus Stops in Los Angeles

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Client: Kounkuey Design Initiative

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

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16. Abstract
In Los Angeles, bus shelters are a crucial source of relief from the heat and lighting after dark, but shelters are inadequately and inequitably distributed throughout the City. Although the City is making significant progress towards increasing the number of shelters and distributing them more equitably, there is limited understanding of how site constraints may limit shelter installation at priority locations or how other aspects of the built environment affect the distribution of adequate shade and nighttime lighting. To address these gaps, this project assessed the adequacy of shade and lighting at bus stops in Los Angeles, the alignment between the current locations of bus shelters and priority bus stops, and the magnitude and spatial distribution of site constraints that create obstacles to the installation of bus shelters. It combined an in-depth analysis of three neighborhoods (Sawtelle, Sun Valley, and Watts) that used original data collected during 202 nighttime site visits and a citywide analysis of all Metro, Big Blue Bus, and LADOT Transit bus stops in Los Angeles that used existing quantitative data. This research found that there are significant disparities in adequate shade and lighting across Los Angeles, and that the locations and types of bus shelters often exacerbate these disparities. Further, "higher-priority" stops where providing amenities is the most crucial are highly clustered in certain areas of the City. Finally, restrictions on installing bus shelters on narrow sidewalks or in residential areas may limit the installation of bus shelters at a significant number of high-priority bus stops.

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Disclaimer

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Executive Summary

Adequate shade and nighttime lighting at bus stops are critical to riders' comfort and safety. In Los Angeles, bus riders are already subject to uncomfortably hot temperatures, and the frequency of extreme heat days is predicted to skyrocket in coming decades. Simultaneously, high-quality lighting is vital to addressing riders' safety needs after dark. While stop conditions affect all riders, they are particularly essential to advancing gender-equity, especially for low-income riders and riders of color. Women and gender minorities spend more time waiting at bus stops, which increases their exposure to extreme heat, and they experience more fear, violence, and harassment while traveling, particularly while waiting at poorly lit stops.

Despite the critical importance of shade and lighting, stop amenities are inadequately and inequitably distributed throughout Los Angeles as a result of past policy and planning decisions. The Los Angeles Bureau of Streets Services (StreetsLA) has historically provided bus shelters through revenue-positive advertising contracts that have prioritized locations with high advertisement value rather than locations that provide the most value to riders. Further, installations have been subject to a lengthy and uncertain permitting process. Additionally, many bus stops are located on sidewalks that are not ADA-compliant or wide enough to accommodate a bus shelter. StreetsLA's new Sidewalk and Transit Amenities Program (STAP) and new shelter contract will address some of these issues by increasing the overall number of bus shelters and creating an equity-driven prioritization framework for their placement. However, STAP has not made substantial changes to address the effects of site constraints at bus stops, which may substantially limit the program's ability to allocate new shelters where they are most needed. Additionally, there is limited understanding of how other aspects of the built environment, like street trees and streetlights, affect the distribution of adequate shade and lighting.

To better understand these limitations, this project holistically assessed the adequacy of shade and lighting at bus stops in Los Angeles, the alignment between the current locations of bus shelters and the bus stops where providing amenities is the most important, and the magnitude and spatial distribution of site constraints that create obstacles to the installation of bus shelters. To do so, this project used existing quantitative data to conduct a citywide analysis of all LA Metro, Big Blue Bus, and LADOT Transit bus stops and integrated this with an analysis of data collected at over 200 stops through in-person, nighttime site visits in three study neighborhoods (Sawtelle, Sun Valley, and Watts).

Key Findings:

1. **Widespread inadequacies and inequities with bus stop lighting are overlooked by existing data.** Analyses of lighting using existing data are often limited to measuring proximity to streetlights, and bus stops are generally closer to streetlights in denser neighborhoods. However, proximity to streetlights is an insufficient proxy for the adequacy of lighting. Nighttime illuminance measurements taken during site visits revealed that stops in the highest-income site-visit neighborhood (Sawtelle) were substantially more likely to have adequate lighting, while stops in the lowest-income neighborhood (Watts) were substantially less likely to have adequate lighting. Inadequate lighting in Watts is primarily the byproduct of a lack of bus shelters equipped with lighting amenities, which are the most important determinant of measured lighting levels at bus stops, and insufficient illuminance cast by functioning

streetlights. These issues may be widespread in similar neighborhoods in South LA, whose comparatively high need would be masked by reasonably short distances to the nearest streetlight in these dense neighborhoods.

2. **Shade at bus stops is inadequate and inequitably distributed.** Most bus stops do not have shelters, and shelters are unevenly distributed. However, the presence of shelters does not tell the whole story when it comes to shade coverage. Shelters vary in terms of their size and features. Further, evidence from both the citywide analysis and site visits suggest that accounting for the presence of trees reveals larger disparities in shade availability, because neighborhoods with fewer shelters often have fewer trees near bus stops. These disparities may be the largest in the San Fernando Valley (the part of Los Angeles that experiences the most extreme heat), particularly in the Northeast area from Sun Valley to Sunland and Tujunga.
3. **The stops that most urgently need improved shade and lighting are clustered in specific areas of Los Angeles.** Although high priority stops are located throughout Los Angeles, an equity-driven prioritization framework highlights that shelters are particularly important in two distinct geographic areas. Shelters are particularly important in the Eastside, eastern half of Central LA, and South LA, where many bus stops are high ridership, near important destinations, and located in areas with high percentages of residents of color and low-income households. Shelters are also especially important in the area of the San Fernando Valley from Van Nuys to the western edge of the City, where many bus stops have infrequent service and are exposed to the most extreme heat. The mismatch between stop priority and current shelter locations exhibits such a strong spatial pattern that a small number of council districts (Districts 3, 6, 9, 12, and 14) contain the majority of higher-priority stops without shelters.
4. **Land-use restrictions and sidewalk widths pose significant obstacles to installing shelters at priority locations.** Restrictions on installing bus shelters in residential areas may prevent shelter installation at up to 19% of higher-priority bus stops without shelters, and narrow sidewalks may prevent the installation of standard advertising shelters at up to 53% of these stops. These restrictions limit shelter installation at many higher-priority stops in low-income neighborhoods. However, these obstacles alone do not explain why many lower-income neighborhoods have higher rates of unsheltered higher-priority stops, which is likely in part a result of how advertising revenue has historically dictated the locations of bus amenities. In contrast, site constraints are the most likely to inhibit efforts to remedy inequities in shelter availability at higher-priority bus stops in more suburban neighborhoods in the San Fernando Valley, including Northridge and Reseda.
5. **New and updated data on shade and lighting are necessary for guiding equity-focused policy and planning.** Existing quantitative data frequently fail to measure the most pertinent aspects of adequate shade and lighting (such as illuminance levels) or are too outdated to be useful (such as with existing tree canopy data). Accurate data that reflect bus riders' experiences are vital to understanding current conditions and prioritizing improvements where they are most needed.

This report ends with recommendations for addressing these design, political, and data limitations that will enhance efforts to provide the shade and nighttime lighting necessary for a gender-equitable transportation system.

Introduction

In many cities, including Los Angeles, public transit mediates many residents' ability to get to the places that they want or need to go. Despite this vital role, transit often fails to meet the mobility needs of women and people of color, who nevertheless comprise transit's core ridership (American Public Transportation Association, 2007). Public transit systems, travel data, and planning models and methodologies were historically designed around the commutes of white men. Planners largely ignored travel related to unpaid labor and assumed that women would adopt men's commute behaviors as they entered the workforce, despite evidence that gender-based differences in mobility are largely resilient to changes in employment trends (Rosenbloom, 1978). These practices, which largely continue to this day, have resulted in a dearth of access to opportunities for women and gender minorities that is particularly pronounced in low-income communities and communities of color.

Women and gender minorities' unique mobility needs have remained so persistent because they represent manifestations of broader systems of inequality, and these needs are particularly salient for women with other intersecting marginalized identities. Despite the narrowing of gender-based differences in paid work, women continue to bear responsibility for most care-related labor, including household shopping and dependents' transportation (Lachance-Grzela & Bouchard, 2010; Román & Gracia, 2022). For example, children in the United States are almost three times as likely to travel to school with their mothers than with their fathers (N. C. McDonald, 2008). Gender gaps in labor have endured as a result of the interplay between household-level disparities in power and broader societal inequities and gender norms, and are therefore felt more strongly by women with other intersecting marginalized identities (Lachance-Grzela & Bouchard, 2010). Gender-based inequalities in care-related labor disproportionately affect Latinx and Asian women, particularly Latinx immigrant women (Kolpashnikova & Kan, 2020; Wight et al., 2013), and women with lower socio-economic statuses spend more time on these tasks in part because they are less able to afford ways of outsourcing this work (Schneider & Hastings, 2017). These care-related responsibilities shape women's travel needs by increasing their need to make short trips around their neighborhoods, to travel outside of peak commute hours, and to "trip-chain" to accomplish other household tasks like grocery trips as stops along their commute or as part of multi-stop journeys (Rosenbloom, 1978). Despite this, transit systems are often centered around serving peak-hour commute trips from residential areas to employment districts as directly as possible, with both route designs and service frequencies that prioritize these trips. These system designs force women to endure more frequent transfers and longer wait times as they are faced with systems that were not built to serve their travel (Los Angeles County Metropolitan Transportation Authority, 2019; Los Angeles Department of Transportation, 2021).

Additionally, women and gender minorities' mobility is disproportionately constrained by the threat of violence, particularly gender-based violence, while making trips with public transit. Women and gender minorities are substantially more likely to face violence and harassment while using public transit, and nonbinary and transgender riders are particularly exposed to gender-based violence and harassment (Loukaitou-Sideris et al., 2020; Lubitow et al., 2017). Research has consistently shown that women and gender minorities' safety needs are the strongest while getting to and waiting at transit stops, particularly after dark (Wallace et al., 1999; Reed et al., 2000; Loukaitou-Sideris, 2014; Loukaitou-

Sideris et al., 2020). However, conditions during these trip phases have received substantially less attention in transit research and planning than conditions in transit vehicles (Iseki & Taylor, 2010). As a result, many transit stops, and the journeys to and from them, remain unsafe and inhospitable sites that inhibit riders' mobility and sense of safety.

The legacy of transit systems that ignore gender-based differences in mobility and slow progress towards rectifying inequities reflect power dynamics that minimize the needs of women and gender minorities. However, progress towards gender-equitable transit systems has also been constrained by a lack of locally-specific information on the needs of these riders. In Los Angeles, there is a growing effort to begin addressing these knowledge gaps through new research, which has included the completion of two landmark studies commissioned by local transportation agencies.

In 2019, the Los Angeles County Metropolitan Transportation Authority (Metro) published *Understanding How Women Travel*, a groundbreaking effort to understand Los Angeles women's unique travel burdens. The study combined conventional research methods, including analysis of existing datasets, a new survey, and focus groups, with innovative research methods designed to provide additional qualitative insights and reflect the perspectives of groups of riders who are frequently underrepresented in traditional research, such as unhoused women, women with disabilities, and immigrant women. These new research methods included conducting ethnographic observations of women riding transit, holding workshops facilitated in partnership with local community-based organizations, and collecting data through pop-up engagements in transit stations.

Understanding How Women Travel generated a deep foundation of knowledge related to gender-based inequities in the Los Angeles region's transit system. The study confirmed the inequities present in the broader literature. It found that women in Los Angeles are more likely than men to travel with dependents and to travel midday when transit service is less frequent. It also found that women have safety concerns about using public transit that constrain their mobility by causing them to engage in adaptive behaviors or avoid traveling, particularly at night. The report made a variety of recommendations regarding potential changes to staffing, service levels, fare policies, design, and future investments that could alleviate women's unique travel burdens. Improved shade and lighting at bus stops were noted as key improvements necessary to ensure that women are safe and comfortable while using transit.

The Los Angeles Department of Transportation (LADOT) commissioned the *Changing Lanes* study to build on this work by focusing on three study neighborhoods to generate more detailed insights and make recommendations towards remedying existing gender inequities in the transportation system in the City of Los Angeles. Sawtelle, Sun Valley, and Watts were chosen as the study neighborhoods (see **Figures 1** and **2** in the Data and Methodology section for maps of the locations of these neighborhoods and the bus stops within them). These neighborhoods were selected to represent different neighborhood typologies by capturing variety across geographic region, income, and the presence of important destinations; and to prioritize areas with more residents of color and women workers living in households without access to a car. To develop a deep and community-engaged understanding of the transportation experiences of women in these neighborhoods, the study analyzed existing data sources and collected new data through surveys, travel interviews, and focus groups that were guided by and implemented with help from a cohort of working group members from each neighborhood.

Published in 2021, *Changing Lanes* echoed many of the *Understanding How Women Travel* findings related to the barriers that disproportionately limit the mobility of women and the way in which other forms of inequality compound gender inequities. For example, higher-income women can afford strategies that allow them to overcome gender-related barriers that lower-income women cannot as easily circumvent. The report also called for the bus stop improvements recommended by *Understanding How Women Travel*, including improved shade and lighting. The report also made a variety of specific recommendations related to closing the data gap, stressing that gender equity has been constrained by inadequate data that has failed to measure aspects of the transportation system that are important to women. In particular, the report called for the collection of a variety of data on infrastructure conditions particularly important to women and gender minorities, including sidewalk quality and widths, intensity of and distance between streetlights, and the presence of street trees, seating, and other street furniture.

This project continues to build on the work of *Understanding How Women Travel* and *Changing Lanes*. While both studies found that shade and lighting at bus stops are critical to supporting women's mobility, these vital amenities are inadequately and inequitably distributed throughout Los Angeles as a result of past policy and planning decisions. In Los Angeles, like in many places, bus stops are within the jurisdiction of local municipalities, and transit agencies, including LA Metro, play a minimal role in bus stop conditions beyond choosing stops' locations. Within the City of Los Angeles, bus shelters and other street furniture are the responsibility of the Los Angeles Bureau of Streets Services (StreetsLA). StreetsLA has historically placed bus shelters through a revenue-positive advertising contract that has prioritized locations with high advertisement value rather than locations that provide the most value to riders. Further, installations have been subject to a lengthy and uncertain permitting process. Finally, a sizable number of bus stops are located on sidewalks that are not ADA compliant and are not wide enough to accommodate a bus shelter. StreetsLA's new Sidewalk and Transit Amenities Program (STAP) and new shelter contract will address some of these issues by increasing the overall number of bus shelters and creating an equity-driven prioritization framework for their placement. Additionally, some bus stops will be brought into ADA compliance through sidewalk repairs when shelters are installed on currently non-compliant sites. Notably, there has been less research and public discussion of the effects of site constraints at bus stops, which may substantially limit STAP's ability to allocate new shelters where they are most needed.

Additionally, attention to bus stop amenities has generally been restricted to addressing the distribution of transit-specific street furniture, particularly bus shelters. This focus fails to acknowledge the role of other sidewalk elements, including street trees and streetlights, which also impact riders' safety and comfort at bus stops. For example, street trees can complement, or act as substitutes for, bus shelters, by increasing shade at bus stops and reducing riders' exposure to heat while waiting for the bus. However, street trees can also decrease illuminance by blocking light from nearby sources and can obstruct bus riders' lines of sight. Additionally, the quality of nighttime lighting at bus stops is significantly influenced by the conditions of surrounding streetlights, including illumination levels and maintenance issues. Accounting for these other factors is particularly critical to understanding disparities in access to adequate shade and lighting at bus stops because stops may be affected by the broader inequities that permeate almost every aspect of public space. For example, disparities in tree canopy coverage could result in bus stops in lower-income communities or communities of color having less access to shade from trees. Similarly, streetlight maintenance work is prioritized based on 311 requests in Los Angeles, which could result in more widespread, prolonged maintenance issues with the streetlights surrounding bus stops in these communities, which are often less likely to report their needs through 311 systems (Kontokosta et al., 2017).

This project begins to fill these knowledge gaps by holistically assessing the distribution of adequate shade and lighting at bus stops in Los Angeles and investigating the magnitude and spatial distribution of the limitations imposed by site constraints. To do so, this project investigated three key questions: 1) what is the current spatial distribution of adequate shade and lighting in the City of Los Angeles, 2) to what extent are the locations of existing bus shelters aligned with the locations of "higher-priority" bus stops where providing basic amenities is most important, and 3) what is the magnitude and spatial distribution of site constraints that may pose obstacles to the installation of bus shelters at unsheltered higher-priority stops?

The remainder of this report begins with an overview of the literature related to the importance of shade and lighting at bus stops and equity issues in their distribution. Next, this report provides a brief overview of the data and methodology used to conduct this research through two levels of analysis: 1) a citywide analysis of all LA Metro, Big Blue Bus, and LADOT Transit bus stops that used existing quantitative data, and 2) an in-depth analysis of three neighborhoods (Sawtelle, Sun Valley, and Watts) that incorporated additional data collected during 202 nighttime site visits. This report then describes the results of these analyses. Finally, this report concludes with policy and planning recommendations related to improving access to shade and lighting and to improving data quality so that improvements can be effectively prioritized.

Literature Review

Shade at Bus Stops

Importance of Shade at Bus Stops

Shade at bus stops is vital to providing safety and comfort for bus riders in environments increasingly plagued by high temperatures. In hot climates like Phoenix, Arizona, surveys have found that most transit riders are uncomfortably hot while waiting for the bus (Dzyuban et al., 2022). This issue is prevalent in Los Angeles, where a lack of shade at bus stops is an important source of discomfort for women using transit (Los Angeles County Metropolitan Transportation Authority, 2019; Los Angeles Department of Transportation, 2021).

Exposure to extreme heat is also an important public health and equity issue. Extreme heat can result in heat-related death; cause heat-related illnesses, including heat stroke, heat cramps, heat syncope, and heat exhaustion; and exacerbate preexisting health conditions including cardiovascular and respiratory diseases (Berko, 2014). Extreme heat currently causes about 1,300 deaths per year in the United States (Centers for Disease Control and Prevention, 2023). Additionally, the burdens of extreme heat disproportionately fall on people with other marginalized identities. Young children, older adults, people of color, people who are unhoused, people with disabilities, and low-income people are all more vulnerable to extreme heat (Berko, 2014; United States Environmental Protection Agency, 2006).

Climate change is intensifying the risks of extreme heat, by increasing both the frequency and intensity of extreme heat events (United States Environmental Protection Agency, 2006). This is a particularly urgent problem in Los Angeles, where the frequency of extreme heat days is predicted to skyrocket in coming decades. A recent report found that the number of days per year exceeding 93.9°F in Los Angeles County is expected to triple from 7 to 21 by 2053 (First Street Foundation, 2022). Sun et al. (2015) similarly found that the average number of days exceeding 95°F in Downtown Los Angeles will balloon from 6 days to 22 days by mid-century and 54 days by the end of the century, and that most areas of the Greater Los Angeles region will experience increases of 60-90 extreme heat days per year by the end of the century.

In the transit context, Metro's *Understanding How Women Travel* study and LADOT's *Changing Lanes* study both found that extreme heat at bus stops is a critical gender-equity issue that disproportionately affects women. Women are more likely to travel midday, when transit service can be less frequent, and are more likely to make trips that require transfers, both of which contribute to women spending more time waiting at bus stops (Los Angeles County Metropolitan Transportation Authority, 2019; Los Angeles Department of Transportation, 2021). Women are also more likely to be traveling with young children or older dependents (Los Angeles County Metropolitan Transportation Authority, 2019; Los Angeles Department of Transportation, 2021), groups of riders who are more vulnerable to extreme heat (Berko, 2014).

Adequate shade at bus stops can mitigate the effects of extreme heat. Since thermal comfort (someone's subjective assessment of the heat environment) is highly influenced by absorbed radiation, shade can significantly increase an individual's thermal comfort by reducing their exposure to sunlight

(Emetere, 2022; Lee et al., 2018). Substantial research has demonstrated that trees can significantly increase thermal comfort both directly, by providing shade from solar radiation, and indirectly, by cooling the atmosphere through evapotranspiration and reducing an area's heat absorption and retention (Coutts et al., 2016; Lee et al., 2018; Knight et al., 2021; Rahman et al., 2021). While there has been less research measuring the effects of bus shelters on thermal comfort, one such study by Dzyuban et al. (2022) measured environmental conditions at sun-exposed and shaded areas at bus stops and found that bus shelters significantly reduced physiological equivalent temperature (PET) at bus stops by an average of about 20°C.

By increasing safety and comfort, shade at bus stops can have a variety of downstream effects, including decreasing riders' perceptions of how long they spend waiting for the bus. Fan et al. (2016) compared transit riders' self-reported wait times collected in an on-board survey to observed wait times determined by reviewing video footage of each passengers' actual wait and found that bus shelters decreased riders' perceptions of wait times, after controlling for their actual wait times and other passenger and trip characteristics. They also found that "basic amenities" were sufficient to provide these benefits, as there was little difference in the effect of "basic" or "premium" shelters. A study by Lagune-Reutler et al. (2016) that largely replicated this methodology similarly found that the presence of mature trees reduced riders' perceptions of wait times, after controlling for actual wait times and other passenger and trip characteristics.

By providing these benefits, shade at bus stops may even be able to increase ridership. Kim et al. (2020) leveraged the natural experiment created when the Utah Transit Authority (UTA) upgraded a set of bus stops in Salt Lake County to compare ridership changes at upgraded stops to other control stops within the system and found that increases in bus ridership were 141% higher at stops that had received improvements. Although the authors caution that some of the increase in ridership could have been caused by riders switching from unimproved to improved stops, they note that this switching effect still adds empirical evidence to the argument that amenities do affect riders' travel behavior choices.

Recent studies have also specifically sought to test whether shade can increase ridership by mediating the effect of extreme weather. Miao et al. (2019) found that incidences of extreme weather (defined as extreme high temperatures, extreme low temperatures, and extreme rainfall) all decreased bus ridership in Salt Lake City, Utah. However, the presence of a shelter was able to reduce these ridership decreases on weekdays. While the moderating effects of shelters were relatively small, effects were stronger at bus stops with lower service frequencies (and thereby longer potential wait times). Lanza and Durand (2021) also found that higher temperatures decreased bus boarding, but found that bus shelters produced no moderating effect and that the level of tree canopy coverage around bus stops had only a modest moderating effect on the ridership impacts of high temperatures in Austin, Texas. The authors posit that these modest results could be the result of Austin bus riders' difficulty in accessing alternative modes of transportation or could be an artifact of the way that Capital Metropolitan Transit Authority places shelters. Since the transit agency places shelters at high ridership stops or stops adjacent to key destinations (like hospitals), shelters could be disproportionately located in denser areas that experience higher microclimate temperatures due to urban heat island effects. However, these differences in temperature were not accounted for in the study, which could have obscured shelters' potential heat-moderating effects.

Although the empirical research linking shade to travel behavior decisions is inconclusive, ample research has demonstrated the dangers of extreme heat and the ability of shade to increase thermal comfort. Therefore, providing riders who are reliant on transit for their mobility with shaded areas to wait for the bus is vital to their safety and comfort.

Distribution of Shade at Bus Stops

Dedicated bus shelters are the most direct way of providing riders with shade at bus stops, but bus shelter delivery models vary substantially from city to city. A recent TransitCenter report conducted case studies of transit amenity delivery in five major urban areas in the United States (Buchanan & Hovenkotter, 2018). Different types of local agencies are primarily responsible for providing bus amenities, including bus shelters, benches, and trash cans, in different urban areas. In some places like New York City and Los Angeles, most of the responsibility falls on local municipal governments, while in other places like Portland, Oregon and the Twin Cities, Minnesota, most of the responsibility is designated to the local transit agencies. The review also found that there is substantial variation between urban areas regarding how the locations of bus shelters are determined and how amenity programs are funded. Some areas, including Portland, consistently allocate a substantial amount of funding for bus shelters in their annual capital budgets, while other areas, like Los Angeles and New York, provide amenities including bus shelters through revenue-neutral or revenue-positive advertising contracts, which has historically biased shelter placement towards areas with the most advertising revenue potential over locations where shelters can provide the most value to riders.

Since bus shelters are not consistently funded like other parts of transit systems, local agencies and municipalities are left to figure out how to fund and deliver bus shelters. As a result, the adequacy and equity of the distribution of bus shelters is likely to vary both across and within cities. However, there has been little research assessing the basic distribution of bus shelters, or how different models of bus amenity delivery affect equity in their distribution. Comparing the findings of the little research that does exist highlights how the equitability of the distribution of bus shelters varies across urban areas. Lanza and Durand (2021) found that race, ethnicity, and poverty level in the surrounding census tract did not have a statistically significant effect on whether a bus stop would have a shelter in Austin, Texas, after controlling for service frequency, the density of bus stops, and the total population. This equitable distribution could be a result of Austin's transit agency, Capital Metro's, ridership-driven framework for shelter placements, which is in part possible because Capital Metro provides bus amenities through a non-advertising contract funded through its Capital Improvement Plan (Capital Metropolitan Transportation Authority, 2023). In contrast, Moran (2022) found that only 31% of bus stops in San Francisco, California had bus shelters, and that there were clear spatial inequities, where bus stops in the northern half of the city were substantially more likely to have shelters than those in the southern half. Moran further found that the odds that a bus stop would have a shelter increased by nearly 1% for every 1% increase in the percentage of white residents in the census tract in which the stop was located. This difference could in part be driven by the result of San Francisco Muni's reliance on a revenue-positive advertising contract for the provision of bus amenities (City and County of San Francisco, 2022).

Specific to Los Angeles, Law and Taylor (2001) found that the system for determining bus shelter placements in Los Angeles in 2001 was primarily driven by advertising revenue potential. Ensuring geographic equity across City Council Districts was the second largest factor in determining bus shelter placements, and ridership had the smallest impact on shelter locations. They found that this system had resulted in only 20% of total time riders spent waiting for the bus occurring at bus stops with shelters, even though the exact same number of shelters could be used to cover 50% of riders' time if distributed at the highest-ridership stops in each City Council District without regard for advertising potential, and could cover 52% of riders' time if they were distributed at the highest ridership stops without taking into account advertising potential or geographic equity. More recently, Brozen et al. (2023) looked at the current distribution of bus shelters at stops served by LA Metro, and found that only 26% of stops across the county had shelters. Although they did not find a relationship between the percentage of stops with shelters and areas' designations as disadvantaged communities (DACs), they did find large variations in the percentage of stops with shelter by city and by Council District within the City of LA. Together, these studies demonstrate that the way that the City has historically placed bus shelters has resulted in the majority of stops and time that riders spend waiting at stops occurring at locations without shelters to provide vital protection from the sun.

While most research about the distribution of shade at bus stops is focused on bus shelters, street trees can also play a vital role in providing shade for riders. Transportation research may pay insufficient attention to shade from trees because their provision generally falls outside of the domain of transportation agencies. However, accounting for trees is important because bus stops in low-income communities and communities of color may be less likely to receive shade from nearby trees due to broader inequities in urban tree canopy coverage (Landry & Chakraborty, 2009; Pham et al., 2012; Nesbitt et al., 2019).

Most research has found that tree canopy coverage is lower in lower-income communities and communities of color, although results vary between studies of different cities. To understand broader trends and account for the differences in results, a team of researchers conducted two companion meta-analyses of 67 quantitative, original studies examining the relationship between race or income and urban tree canopy coverage. Gerrish and Watkins (2018) found that higher-income areas have more tree canopy coverage, and incorporating stronger methodological design into studies dampened but did not eliminate the statistical significance of this effect. Watkins and Gerrish (2018) also found that areas with more people of color have less tree canopy coverage, but that the effects of race were reduced or eliminated by methodological choices like controlling for income and accounting for spatial autocorrelation, suggesting that racial inequalities are largely mediated by income. However, they also found that racial inequalities are larger when studies focus on public land (rather than private land), indicating that inequities are primarily the result of inequities in public tree provision. Racial inequalities were also higher in arid cities where trees are more difficult and costly to maintain.

These inequities exacerbate differences in temperatures across urban areas, contributing to more extreme heat in lower-income communities and communities of color. McDonald et al. (2024) estimated the change in air temperatures due to tree canopy in census blocks across the United States and found that lower levels of tree canopy in census blocks primarily inhabited by people of color contributed to higher temperatures in these areas, thereby increasing heat-related mortality and morbidity. Despite the urgency of addressing disparities, inequitable urban canopy coverage may also be difficult to overcome due to broader inequities in the built environment. Danford et al. (2014) explored whether tree planting efforts in Boston could eliminate inequities in the tree canopy coverage by estimating the maximum potential tree canopy coverage that could be added to impervious areas, pervious areas, and street segments. They found that lower-income areas of Boston had lower urban tree coverage, that equity-focused tree planting initiatives could not fully eliminate these inequities, and that planting trees wherever was ecologically feasible would result in less equity than a more limited equity-driven tree distribution. Disparities in urban tree coverage were so hard to overcome because lower-income areas were more likely to have built environmental characteristics that could accommodate fewer trees (such as less open space and more land area devoted to impervious surfaces like parking lots).

Specific to Los Angeles, Schwarz et al. (2015) found that census blocks and census tracts in Los Angeles with higher incomes, more Asian residents, and fewer Black and Latinx residents all had higher urban tree coverage, although these effects generally disappeared after controlling for other demographic variables and spatial autocorrelation. Bloch (2019) explains that grants targeted at remedying these inequities by planting trees in low-income communities of color in Los Angeles have run into persistent challenges with planting trees with larger canopies in areas like South LA, due to broader built environmental characteristics like narrow sidewalks and overhead powerlines. Taken together, the literature indicates that although disparities may be mediated by other factors, low-income communities and communities of color nonetheless live in areas that currently have less shade from trees and may be less likely to be able to accommodate the planting of new shade-producing trees. These disparities in urban tree canopy coverage may translate to persistent disparities in tree canopy shade at bus stops.

Lighting at Bus Stops

Importance of Lighting at Bus Stops

Substantial research has demonstrated that women and gender minorities' travel behavior is constrained by fear of experiencing harm while traveling. Through a series of in-depth interviews, Loukaitou-Sideris (2014) found that women frequently modify their travel behavior due to safety concerns, often resulting in the avoidance of public transit and avoidance of traveling after dark. An effort to quantify this behavior found that 75% of women who had experienced frightening incidents while traveling, and 61% of women who hadn't, reported avoiding certain stops, routes, or destinations due to safety concerns (Stark & Meschik, 2018). In another study, 86% of women who responded to a survey of transit pass holders enrolled at one of three universities in Los Angeles reported that they feel the need to take precautions against crime while using public transit buses, with 52% of women reporting traveling only during the daytime and 51% reporting waiting for transit only at well-lit places (Loukaitou-Sideris et al., 2020). Concerns about safety also disproportionately affect transit riders who have other intersecting marginalized identities – people of color, LGBTQIA+ people, people with disabilities, and older or younger people may experience more fear while traveling, and income levels mediate women's ability to avoid unsafe trips by switching to a more expensive mode (Ding et al., 2020; Los Angeles Department of Transportation, 2021). As such, characteristics of the transit system that prevent women from feeling safe prevent equitable access to mobility.

Adequate lighting at transit stops has a significant effect on women's feelings of safety while using public transit after dark. Loukaitou-Sideris (2014) found through qualitative interviews that adequate lighting is extremely important to women feeling safe in transit environments. While lighting is often thought of in the context of personal security, these qualitative interviews also highlighted the holistic importance of lighting as it relates to safety. For example, representatives of an organization that advocates for older women noted lack of adequate lighting as among the hazards that increase the risk that older women will trip and fall.

Quantitative survey research has confirmed that transit riders, particularly women, report that increased lighting at stops would make them feel safer, that women are more likely to notice lighting improvements, and that riders who notice lighting improvements actually do feel safer at transit stops. Reed et al. (2000) surveyed bus riders in Michigan about potential transit safety enhancements and found that of the possible interventions included in the survey, respondents reported that emergency phones and increased lighting at bus stops were the two safety enhancements that would most improve their feelings of security, and women were significantly more likely than men to say that increased lighting would make them feel safer. Additionally, when Wallace et al. (1999) evaluated a series of enhanced safety and security measures in Ann Arbor, Michigan, they found that riders reported that the increased lighting at bus transfer centers made them feel safer, that women and lower-income riders were more likely to have noticed the increased lighting, and that riders who had noticed the increased lighting reported higher perceptions of safety. These results emphasize that women may be more sensitive to increases in lighting not only because they have heightened safety concerns, but also because they are more likely to notice differences in lighting levels.

Adequate lighting has also been shown to reduce potential harm to bus riders. Researchers have argued that improved lighting can reduce crime by improving visibility, increasing the number of other people in public space, and demonstrating investment in communities, and a systematic review of the research concluded that improved street lighting does successfully reduce crime (Welsh & Farrington, 2008). This finding holds within bus stop environments. A survey of transit pass holders enrolled at one of three universities in Los Angeles found that respondents who reported that the bus stops that they used were poorly illuminated were more likely to have experienced sexual harassment while using the bus (Loukaitou-Sideris et al., 2020).

Distribution of Lighting at Bus Stops

Despite the volume of research establishing the importance of lighting at bus stops, no peer-reviewed literature analyzing the distribution of adequate lighting at bus stops could be found. This research gap has likely resulted from a variety of factors, including a lack of available data on lighting quality and a lack of research interest within the field of transportation since street lighting falls outside the domain of most transportation agencies.

While literature on the distribution of adequate lighting does not exist, existing research suggests that there may be racial and socioeconomic disparities that are difficult to assess with currently available data. While the City of Los Angeles publishes data on streetlight locations that can be used to calculate streetlight densities and the approximate distances between bus stops and the nearest streetlight, these calculations mask inequities with lighting as a result of these streetlights being broken or poorly-lit. *Changing Lanes* found that although streetlight densities were the highest in Watts, the lowest-income of the three Los Angeles neighborhoods studied, residents of the neighborhood reported that the lighting is inadequate and that the lights may be underpowered or dimmed (Los Angeles Department of Transportation, 2021).

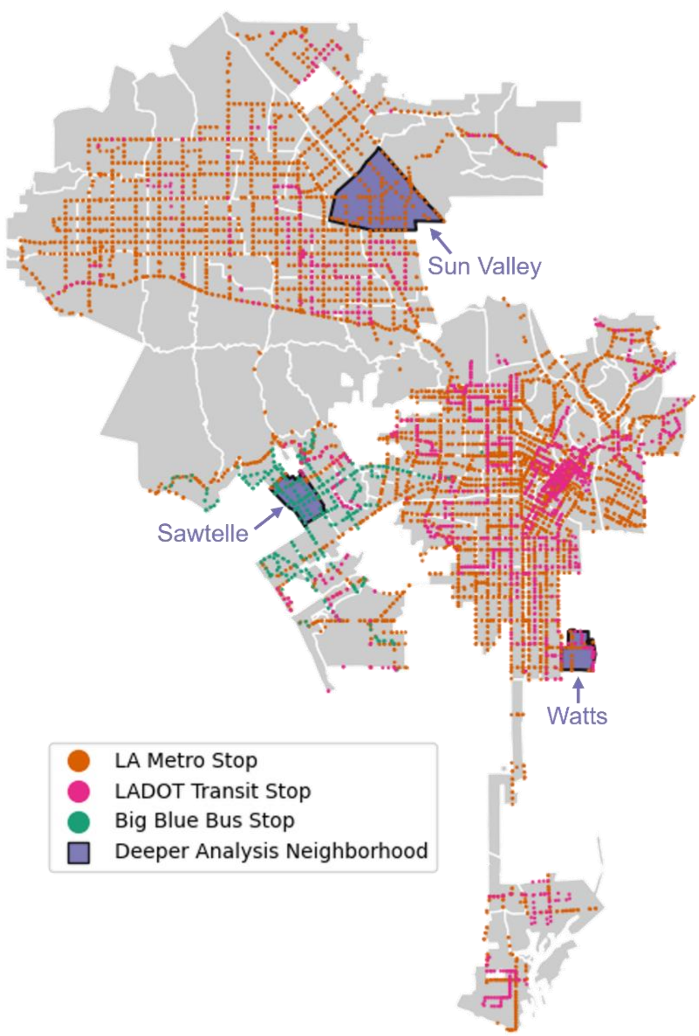
There may also be prevalent issues with streetlights being out for prolonged periods of time. Los Angeles, like many other cities, is experiencing a surge in the theft of copper wire from streetlights, resulting in outages that are unusually costly and time-consuming to repair (City of Los Angeles Public Works Bureau of Street Lighting, 2024). From 2018 to 2022 the number of theft-related incidents reported to the Bureau of Street Lighting (BSL) skyrocketed from 607 to 6,344, resulting in a significant backlog of repairs and expected repair times that can exceed 180 days (City of Los Angeles Public Works Bureau of Street Lighting, 2024). Additionally, BSL's practice of prioritizing repairs based on maintenance requests likely disproportionately limits its ability to meet lighting needs in low-income communities and communities of color, as research has shown that residents in higher-income areas and areas with more white residents are more likely to report issues through 311 systems (Clark et al., 2013; Kontokosta et al., 2017).

Data and Methodology

This project investigated three key questions: 1) what is the current spatial distribution of adequate shade and lighting in the City of Los Angeles, 2) to what extent are the locations of existing bus shelters aligned with the locations of "higher-priority" bus stops where providing basic amenities is most important, and 3) what is the magnitude and spatial distribution of site constraints that may pose obstacles to the installation of bus shelters at unsheltered higher-priority stops? To answer these questions, this project integrated two separate levels of analysis, the scopes of which are visualized in **Figure 1**:

1. A citywide analysis of the City of Los Angeles, covering all Metro, Big Blue Bus, and LADOT Transit bus stops in the City, that used existing quantitative data.
2. An in-depth analysis of three neighborhoods (Sawtelle, Sun Valley, and Watts) that incorporated additional data collected during 202 nighttime site visits. As noted earlier, Sawtelle, Sun Valley, and Watts were identified by *Changing Lanes* as areas for deeper analysis, because they represent different neighborhood typologies while prioritizing equity.

Figure 1. *Study area map*



Citywide Measures

Table 1 lists the measures calculated for the citywide analysis and the data sources used for each measure. **Appendix I** provides a detailed description of the process for generating each measure.

Table 1. *Citywide Measures Calculated for All Stops and Relevant Data Sources*

CATEGORY	MEASURES	SOURCES
Bus stop locations	**Stop location** Consolidated bus stop location (with stops within 25 feet of each other treated as one stop)	• LA Metro Bus GTFS from October 2023 • LADOT Transit GTFS from October 2023 • Big Blue Bus GTFS from October 2023
	Neighborhood of bus stop	• Los Angeles Times Mapping LA Neighborhood Boundaries from City of Los Angeles GeoHub
Shade	**Presence of bus shelter**	• Bus shelter availability by LA Metro stop provided by agency • Bus shelter availability by Big Blue Bus stop provided by agency • Bus shelter availability by stop scored for STAP provided by StreetsLA
	Distance to nearest tree Distance to the nearest public tree accessible without crossing the street	• Locations of trees managed by the Bureau of Streets Services from City of Los Angeles GeoHub • Locations of trees managed by the Recreation and Parks Department from City of Los Angeles GeoHub • Street centerlines from City of Los Angeles GeoHub
	Total tree canopy in bus stop area Total tree canopy in the area within 75 feet of the stop that is accessible without crossing the street	• Tree canopy polygons from Los Angeles Region Imagery Acquisition Consortium land cover data • Street centerlines from City of Los Angeles GeoHub
Lighting	**Distance to nearest streetlight**	• Locations of streetlights from City of Los Angeles GeoHub
Priority level	**Ridership** Average weekday boardings and average weekday boardings relative to other stops in the same City Council District	• Ridership data from LA Metro, LADOT Transit, and Big Blue Bus for October 2023 provided by agencies • LA City Council District boundaries from Los Angeles GeoHub

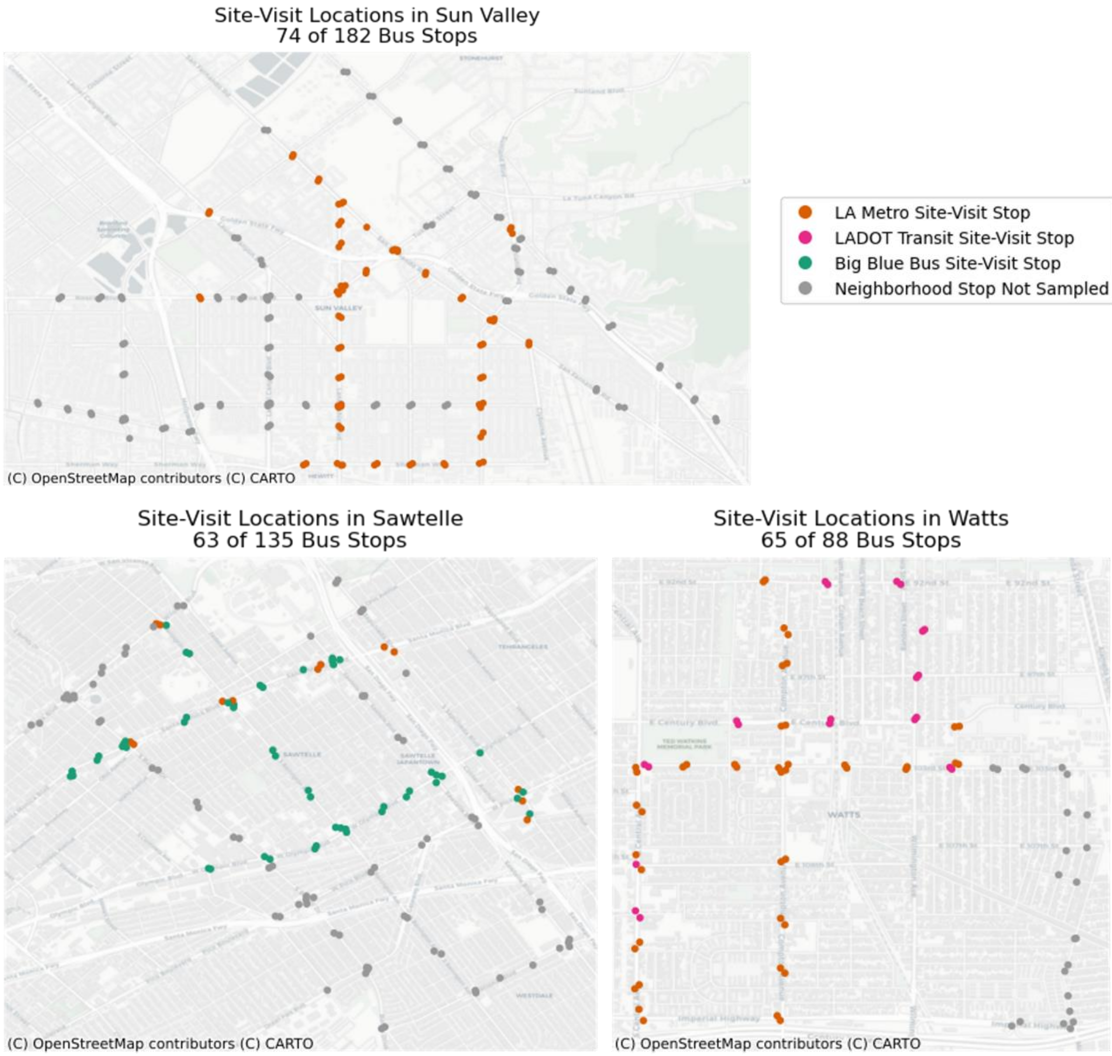
	Residential demographics Whether the stop is located within a census tract designated as a Metro Equity Focus Community (EFC)	• Metro 2022 EFC designations from Metro Equity Information Hub
	Projected heat exposure Projected temperatures in the census tract that the stop is located within	• Projected temperatures from California Heat Assessment Tool
	Long wait times Whether the stop serves a route with average headways surpassing 30 minutes during weekday peak service hours	• LA Metro Bus GTFS from October 2023 • LADOT Transit GTFS from October 2023 • Big Blue Bus GTFS from October 2023
	Key destinations Number of key destinations within 0.25 miles	• Number of nearby destinations by stop scored for STAP provided by StreetsLA
Site constraints	**Street and land-use classifications** Classification of street stop is on; nearest land use to stop and dominant land use within the block as determined by contribution to total frontage	• Street centerlines and classifications from City of Los Angeles GeoHub • Zoned land uses from City of Los Angeles GeoHub
	Sidewalk widths Whether the stop is located on a sidewalk at least 10 feet wide and whether the stop is located on a sidewalk at least 8 feet wide	• Sidewalk polygons from City of Los Angeles GeoHub • Code for calculating sidewalk widths from polygons from Sidewalk Widths NYC project

Site-Visit Measures

This project selected approximately 70 bus stops per neighborhood for its in-depth analysis integrating data from site visits. In total, site visits were conducted at 202 stops, accounting for 50% of all stops across the three site-visit neighborhoods, with specific coverage rates of 41% in Sun Valley, 47% in Sawtelle, and 74% in Watts. **Figure 2** shows the locations of all site-visit stops as well as the other stops within each site-visit neighborhood. Site-visit locations were selected to maximize coverage of "higher-priority" stops, determined by using the STAP prioritization scores calculated by StreetsLA. This sampling strategy was chosen to fulfill this project's core objective of understanding the adequacy of shade and lighting at higher-priority bus stops in Los Angeles. Due to this non-random sampling strategy, site-visit results are not intended to be representative of all bus stops in the study neighborhoods.

Instead, the results are an assessment of bus amenity quality along the most important transit corridors in each area.

Figure 2. *Locations of site-visit stops and other stops within deeper analysis neighborhoods*



All site visits were carried out after sunset in February 2024. Conducting site visits after sunset was vital to collecting key data related to the adequacy of lighting, including streetlight maintenance issues and nighttime illuminance levels. All site visits were conducted by teams of two research assistants per stop to ensure data quality and assessor safety. **Table 2** contains a summary of the data collected during these site visits, and the environmental assessment form used during site visits can be found in **Appendix II**.

***Table 2**: Site-Visit Data Collected*

CATEGORY	MEASURES
Shade	Presence of bus shelter; type of bus shelter (advertising vs. non-advertising); level of potential shade provided by trees in stop area
Lighting	Illuminance measured at bus stop; subjective assessment of adequacy of lighting; distance to nearest streetlight; type of nearest streetlight; illuminance measured at nearest streetlight; whether nearest streetlight was broken (off or flickering); percentage of streetlights visible from stop that were broken; presence of other sources of light; whether stop lighting was blocked or reduced by nearby trees or vegetation
Other amenities	Presence of seating; presence of trash cans; presence of real-time bus arrival information
Site Constraints	Sidewalk widths

Overview of Analysis

This project integrated these measures to investigate the adequacy of shade and nighttime lighting at bus stops in Los Angeles. In Part I, this project used the site-visit data to examine bus stop conditions in each site-visit neighborhood and identify the factors that contribute to the adequacy of nighttime lighting and shade. The presence of shelters, nearby trees, and proximity to streetlights were calculated from the citywide data and compared to the site-visit data to evaluate the accuracy of these citywide measures for individual stops and for individual neighborhoods once aggregated to this level. Measures were considered accurate for individual stops if at least 95% of the calculated data matched the site-visit data. Aggregated measures for neighborhoods were considered accurate if there were no statistically significant differences between the metrics calculated from the citywide data for the sample of site-visit stops and those calculated from the site-visit data at the 95% confidence level. For example, two-sample t-tests were used to test whether the average distance to the nearest streetlight calculated from the citywide data for each neighborhood was different from the average distance to the nearest streetlight calculated from the site-visit data for that same neighborhood. Citywide measures that were found to be accurate were then analyzed to identify areas with particularly poor access to shade and lighting.

In Part II, a priority score was calculated for each bus stop, based on its ridership, surrounding residential demographics, projected heat exposure, wait times, and proximity to key destinations. The top third of bus stops with the highest scores were considered "higher-priority" stops. This methodology was designed to largely mirror the methodology that STAP used to understand bus stop priority for the installation of new bus shelters. However, the methodology and resultant higher-priority stops identified by this project differ from those identified by STAP because this project utilized updated data sources, including more recent ridership data and scheduled route frequencies, and because this project scored all citywide bus stops instead of just those that do not already have bus shelters. This project then analyzed the alignment between bus stop priority and shelter availability. Most importantly, this project identified the locations of higher-priority bus stops that do not have bus shelters and the neighborhoods with particularly high concentrations of these stops.

Finally, Part III of this project analyzed the impact of sidewalk widths and zoning constraints that affect whether locations can accommodate standard bus shelters. The most notable constraint is that shelters cannot interfere with the provision of a minimum 4-foot-wide clear path of travel for wheelchair users to comply with ADA requirements. Bus shelter siting is also constrained by the classifications of adjacent streets and the zoning of surrounding properties. Transit shelters cannot be placed along local streets adjacent to residential land uses and are unlikely to be installed near single-family residential land uses (Los Angeles Office of the City Clerk, 2022). There are also a variety of other requirements that bus shelter placements must satisfy related to sidewalk conditions and avoiding interference with pedestrian circulation, driver lines of sight, and access to other sidewalk elements. The impact of these requirements could not be determined at scale, but it is important to note that existing bus shelter designs could not be installed at all bus stops that satisfy sidewalk, street classification, and land-use requirements. In addition to estimating the magnitude of these constraints, this project compared the neighborhoods with higher concentrations of unsheltered higher-priority stops to the neighborhoods with higher percentages of bus stops that may not be able to accommodate bus shelters due to inadequate sidewalk widths or restrictions arising from the surrounding street and land-use classifications. This analysis was used to understand the extent to which site constraints will pose obstacles to addressing unmet needs at higher-priority stops, and which neighborhoods are particularly burdened by these constraints.

Results

Part I: Lighting and Shade at Bus Stops in Los Angeles

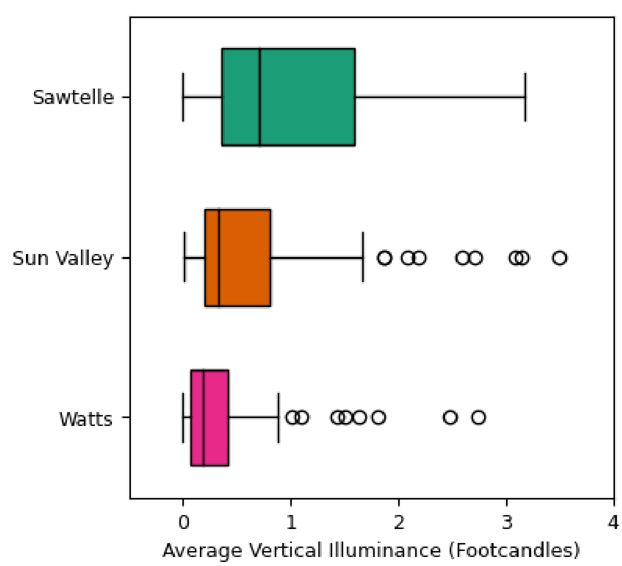
The first section of the results discusses the current distribution of adequate lighting and shade in Los Angeles. It begins by presenting findings from the site visits concerning bus stop conditions and the factors that contribute to the adequacy of nighttime lighting and shade. Two-way chi-square tests were used to test the significance of differences across neighborhoods for all site-visit measures. The p-values of these tests are reported, and significance levels are denoted in all figures with *,**,*** indicating significance at the 90%, 95%, and 99% levels, respectively. This section then describes which citywide measures were found to be accurate through comparisons to the site-visit data. Sufficiently accurate citywide measures are reported, and areas with particularly poor access to lighting and shade are highlighted.

Lighting in Site-Visit Neighborhoods

Illuminance measurements at bus stops are the only way to quantitatively measure actual nighttime lighting levels. Stops in the highest income site-visit neighborhood (Sawtelle) were substantially more likely to have adequate lighting, while stops in the lowest-income neighborhood (Watts) were substantially less likely to have adequate lighting. There are many critical issues with nighttime lighting in Watts, including widespread streetlight maintenance issues. However, inadequate lighting is primarily the byproduct of a lack of bus shelters equipped with lighting amenities and insufficient illuminance cast by *functioning* streetlights.

Assessors captured two direct measures of nighttime lighting during site visits: average vertical illuminance at each bus stop and assessors' judgement of how well-lit the stop felt. **Figure 3** shows the distribution of average vertical illuminance measurements by neighborhood. While there is considerable variation between stops within each neighborhood, bus stops in Sawtelle generally had the highest illuminance levels and bus stops in Watts generally had the lowest illuminance levels.

***Figure 3**. Distribution of average vertical illuminance measurements by neighborhood*



Thresholds for lighting adequacy were derived from the full dataset and then applied to all site-visit stops to correct for differences in subjective perceptions of illuminance levels between assessor teams. A multinomial logit model was fit to the data to calculate the probabilities that a stop would be rated "Not at all well-lit," "Somewhat well-lit," or "Very well-lit" at different levels of vertical illuminance, after controlling for which team had completed the site visit. The results of this model are visualized in **Figure 4**. Above 1 footcandle, bus stops were most likely to be considered "Very well-lit" and at above 0.5 footcandles, bus stops were most likely to be considered "Somewhat well-lit" and more likely to be considered "Very well-lit than "Not at all well-lit". Notably, this threshold for somewhat adequate lighting aligns with the APTA security lighting standards, which set a standard of at least 0.5 footcandles of minimum vertical illuminance for open exterior transit facilities. These thresholds were then applied to the measured illuminance data to calculate the percentage of stops meeting each lighting threshold, which revealed significant disparities. **Figure 5** shows that there were significant differences in the percentage of stops receiving at least 0.5 footcandles (p<.001) and at least 1 footcandle (p=0.01) of average vertical illuminance across neighborhoods. Site-visit stops in Sawtelle were more than twice as likely to receive at least 1 footcandle of vertical illuminance or at least 0.5 footcandles of vertical illuminance than stops in Watts.

Figure 4*. Relationship between average vertical illuminance and rating of lighting levels*

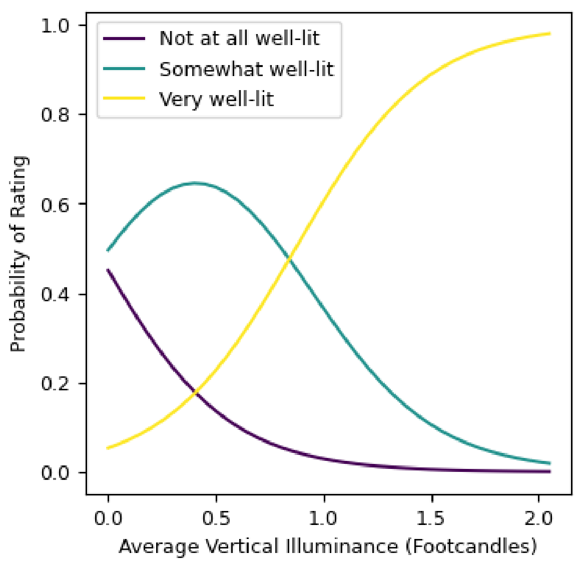
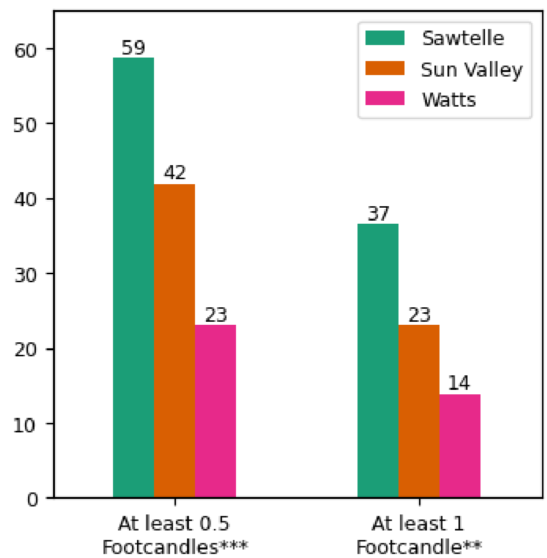


Figure 5. *Percent of site-visit stops meeting vertical illuminance thresholds by neighborhood*



The data clearly demonstrate systemic differences in the adequacy of lighting in bus stops across neighborhoods. During site visits, assessors also collected additional data to understand various potential contributors towards this variation.

Lighting inadequacies in Watts are largely a result of insufficient streetlight illuminance, although they may be exacerbated by longer distances between bus stops and streetlights. Assessors measured the vertical illuminance five feet from each bus stop's nearest functioning streetlight, and there were significant differences in the percentage of streetlights that met vertical illuminance thresholds (p=.001 for 0.5-footcandles; p=.01 for 1-footcandle) (**Figure 6**). While about 60% of the nearest streetlights in both Sawtelle and Sun Valley cast enough light for 0.5-footcandles to reach assessors, only about 30% of the nearest streetlights in Watts cast this level of light. Additionally, site-visit stops in Sawtelle were generally closer to the nearest streetlight and site-visit stops in Watts were generally further, exacerbating issues with the trends in these streetlights' illuminance levels (**Figure 7**).

***Figure 6**. Percent of nearest functioning streetlights meeting vertical illuminance thresholds by neighborhood*

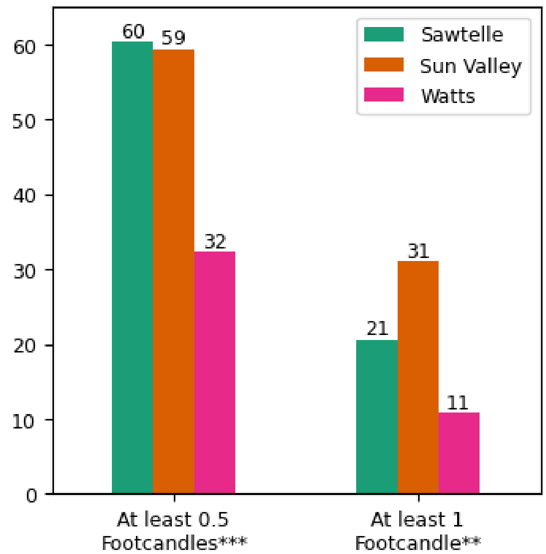
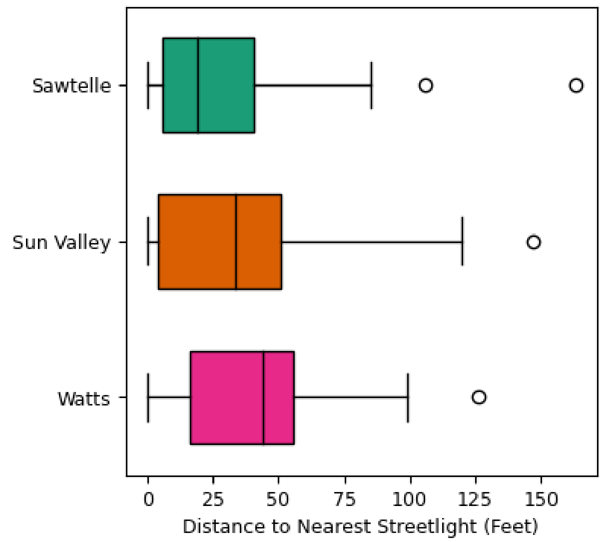


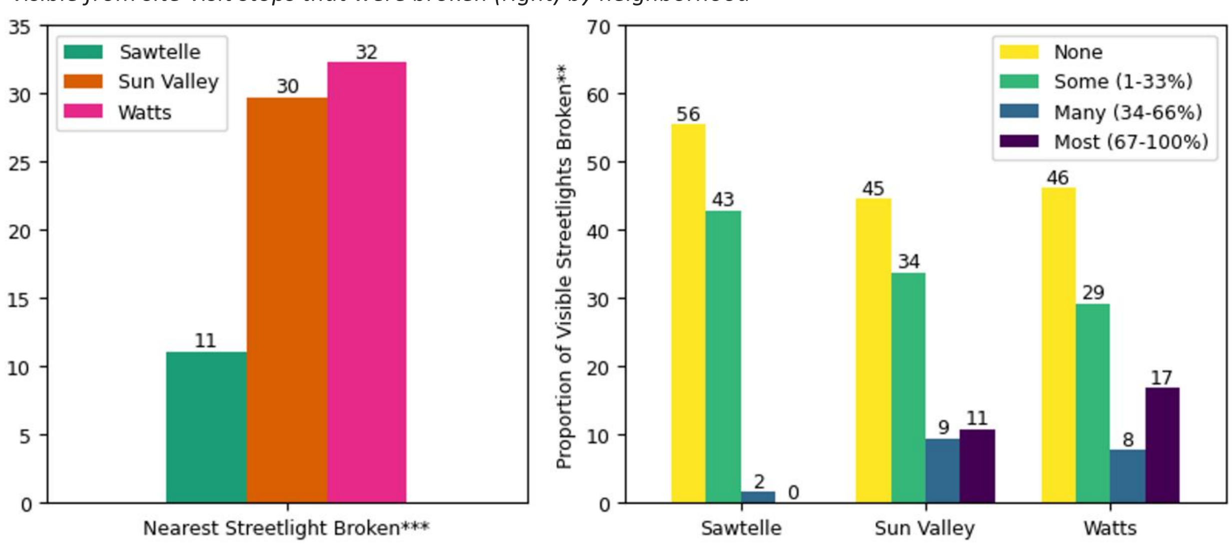
***Figure 7**. Distances from site-visit stops to the nearest streetlight by neighborhood*



Comparing the vertical illuminance measurements taken at stops to those taken at streetlights helps illustrate the improvements that could be made simply through increased proximity to streetlights. In Sun Valley, bus stops are generally not as well-lit as the areas next to a streetlight, indicating that lighting levels could be improved solely by factoring streetlight proximity into decisions about bus stop locations. In contrast, there is limited potential for improvement through bus stop relocations in Watts due to the low illuminance levels cast by the streetlights themselves. Notably, site-visit stops in Sawtelle were actually generally better lit than areas next to a streetlight due to the contributions of stop-specific amenities like integrated bus shelter lights.

There were also large disparities in the prevalence of streetlight maintenance issues (**Figure 8**).

***Figure 8**. Percent of site-visit stops where the nearest streetlight was broken (left) and percent of streetlights visible from site-visit stops that were broken (right) by neighborhood*

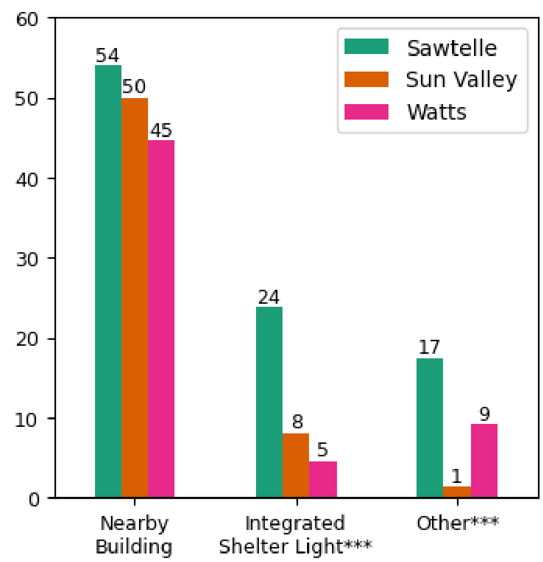


The streetlights nearest to the site-visit stops in Sawtelle were substantially less likely to be out than streetlights in Sun Valley and Watts (p=.01). This difference was symptomatic of a larger trend, where substantially more of the streetlights visible from site-visit stops were out in Sun Valley and Watts (p=.01).

In contrast, the proportion of streetlights that were pedestrian-scale did not vary across neighborhoods (p=.72). While pedestrian-scale lighting provides substantially better illuminance at eye level, these types of streetlights were rare, appearing at only about 12% of site-visit stops across all study neighborhoods. There were also not significant differences in the extent to which nearby trees blocked or reduced the lighting at site-visit stops across study neighborhoods (p=.41). About 20% of stops experienced impediments to their lighting from surrounding vegetation across all neighborhoods.

Many stops also benefited from other nearby sources of light, most commonly nearby buildings, which were primarily commercial businesses (**Figure 9**). While all neighborhoods had similar rates of stops benefitting from the light of nearby buildings (p=.57), site-visit stops in Sawtelle were significantly more likely to have a bus shelter with a functioning integrated light (p=.002) or other source of light (p=.004). Other sources of light ranged widely, from decorative overhead lights to lighting in nearby parks to brightly lit billboards.

Figure 9. *Percent of site-visit stops with other sources of nighttime lighting*



An ordinary least squares (OLS) regression model was used to identify the factors that were the most important determinants of the average vertical illuminance measured at site-visit stops. The dependent variables included: the distance to the nearest streetlight, the illuminance measured at that streetlight, whether the streetlight was pedestrian-scale, whether the streetlight was broken, whether the streetlight was blocked by vegetation, whether the bus stop benefitted from additional lighting from nearby buildings, an integrated shelter light, or another source of lighting, and neighborhood fixed effects. The results of this regression are in **Table 3**.

After holding all other variables constant, the only statistically significant determinants of average vertical illuminance at site-visit stops were the vertical illuminance measured at the nearest streetlight, the presence of an integrated shelter light, and the presence of a nearby building producing significant additional illumination. The effect of the presence of an integrated shelter light was particularly striking, raising average vertical illuminance by nearly 1.6 footcandles, all else held equal. Therefore, while the prevalence of streetlight maintenance issues in Watts deserves immediate attention, it is not the root cause of inadequate lighting at bus stops. Instead, inadequacies are primarily the result of insufficient illuminance cast by the streetlights that were *not* experiencing issues and the lack of integrated bus shelter lights, the latter of which is a consequence of the use of non-advertising shelters within the neighborhood.

Table 3. *Results of OLS Regression Explaining Variation in Average Vertical Illuminance at Site-Visit Stops*

Stop characteristic	**Effect size (in footcandles)**	**p-value**
Intercept	0.39**	0.05
Distance to the nearest streetlight	0.00	0.31
Average vertical illuminance measured at nearest functioning streetlight	0.28***	0.00
Nearest streetlight pedestrian-scale	-0.07	0.80
Nearest streetlight broken	-0.17	0.37
Nearest streetlight blocked by vegetation	-0.05	0.78
Presence of an integrated bus shelter light	1.58***	0.00
Permanent building producing significant additional illumination	0.44***	0.00
Presence of other source of light	0.10	0.69
Stop in Sawtelle (Sun Valley as reference category)	0.02	0.90
Stop in Watts (Sun Valley as reference category)	-0.16	0.35
R^2: 0.350; Adjusted R^2: 0.315 Number of observations: 197		
,, *** indicate significance at the 90%, 95%, and 99% levels, respectively*		

Shade in Site-Visit Neighborhoods

The percentage of bus stops in a neighborhood that have shelters does not tell the whole story when it comes to the adequacy of shade and lighting. Shelters vary in terms of their size and features. Additionally, accounting for shade from trees revealed that site-visit stops in Sun Valley had the least access to shade, a disparity that was not apparent from just data about the presence of shelters.

In the site-visit neighborhoods, there was no statistically significant difference in the percentage of stops with a shelter present (p=.30), but there *were* significant differences in the types of shelters present across neighborhoods (**Figure 10**). Shelter types matter because advertising shelters are substantially more likely to contain additional features like integrated lights, which this project found to be the most significant determinant of nighttime lighting levels at bus stops, whereas non-advertising shelters contain fewer other amenities. **Figure 11** displays an example of each type of shelter. Stops in Sawtelle were significantly more likely to have an advertising shelter present (p=.04), while stops in Watts were significantly more likely to have a non-advertising shelter present (p=.01)

Figure 10*. Percent of site-visit stops with bus shelters by neighborhood*

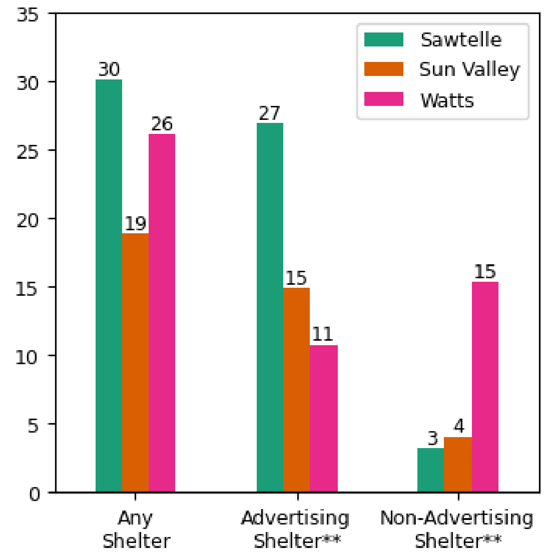


Figure 11*. Example of an advertising shelter at Pico Westbound / Sepulveda Nearside in Sawtelle (left) and a non-advertising shelter at Compton Northbound / Century Nearside in Watts (right)*

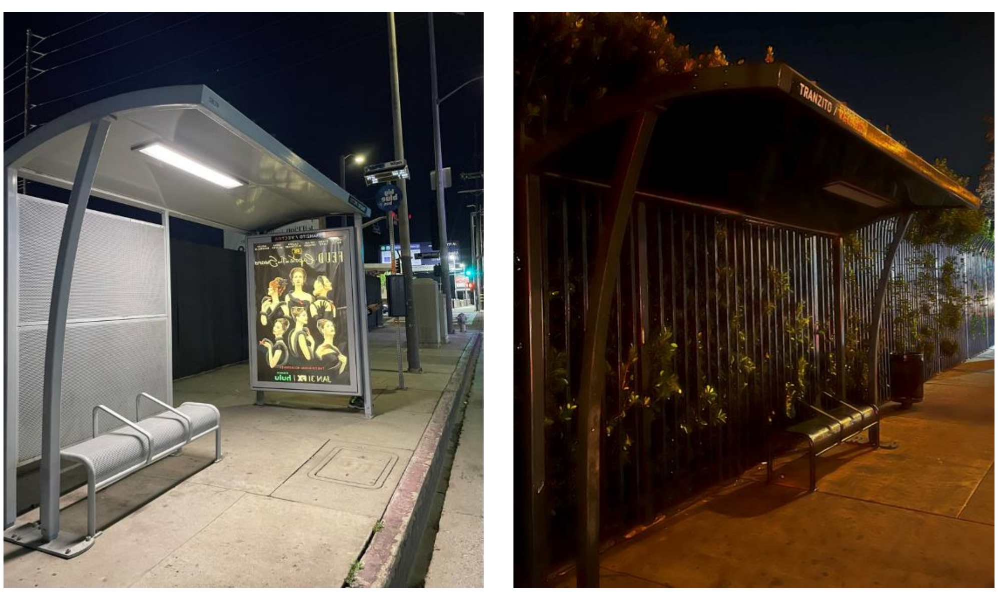


Image sources: Photographs from site visits

Figure 12. *Percent of site-visit stops with tree in bus stop area by neighborhood*

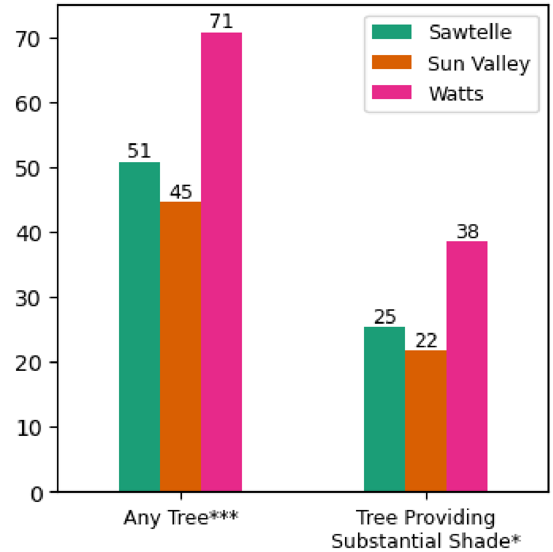
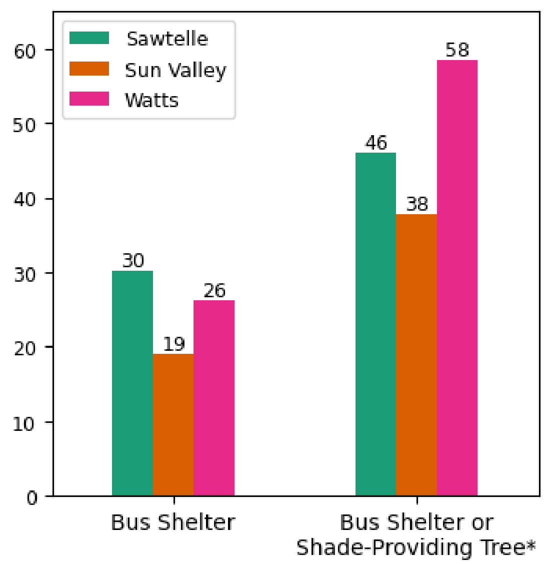


Figure 13. *Percent of site-visit stops with adequate shade by neighborhood*



The site-visit data also offer insight into the shading potential of trees, and how often trees are able to fill gaps in shade availability. Site-visit stops in Watts were both more likely to have a tree present (p=.01) and more likely to have a tree present that was judged to be capable of casting meaningful shade at the time of the site visit (p=.07) (**Figure 12**).

It is important to note that site visits were conducted during February 2024 and reflect wintertime tree canopy conditions. Some of the trees not capable of providing substantial shade would be expected to continue providing negligible shade in coming years due to their maturity or species. However, other trees not capable of providing substantial shade at the time of the site-visits were mature, deciduous trees that may provide substantial shade during the summer. While assessors did not record the specific limitations of trees (related to maturity, species, or seasonality), it was subjectively judged that trees in Sawtelle and Sun Valley appeared to be more likely to be deciduous trees, and trees in Watts appeared to be more likely to provide consistent amounts of shade throughout the year. This difference suggests that although site-visit stops in Watts were more likely to be near a tree providing substantial shade during the time of the site-visits, there may be a smaller gap in shade availability across site-visit neighborhoods during the hottest time of the year, when shade is most important.

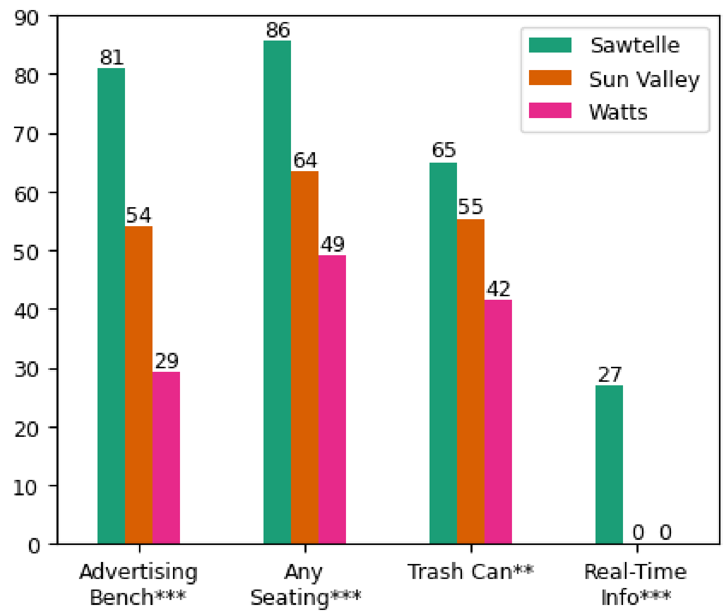
Despite this important caveat, there was a strong relationship between the percentage of stops with any tree present and the percentage of stops with a tree providing substantial shade. As a result, the presence of any tree can be considered a good measure for understanding relative differences in shade availability, although it consistently overestimates the percentage of stops at which riders receive meaningful shade from trees. In the site-visit neighborhoods, accounting for trees substantially increased the percentage of stops considered to have adequate shade by as much as 32% in Watts (**Figure 13**). Accounting for trees also revealed larger disparities in access to shade than could be detected from the shelter data alone. While the slightly lower percentage of site-visit stops with shelters in Sun Valley was not statistically significant (p=.30), the percentage of site-visit stops in Sun Valley receiving shade from either a bus shelter or a tree was significantly lower than the percent of site-visit stops with shade in other neighborhoods (p=.05).

Other Amenities in Site-Visit Neighborhoods

Site-visit stops in Sawtelle, the neighborhood with average shade levels and the highest lighting levels, also had the highest access to seating, trash cans, and real-time information.

Site-visit stops in Sawtelle were significantly more likely to feature other amenities, including seating (p<.001), trash cans (p=.03), and real-time information (p<.001) (**Figure 14**). Differences in seating availability were due to differences in the presence of advertising benches (p<.001), as different neighborhoods had similar rates of bus shelters and therefore similar rates of integrated shelter seating. Strikingly, the only site-visit stops that were found to have real-time information were all in Sawtelle, and every stop with real-time information was served by Big Blue Bus. While this project is focused on shade and lighting, the site-visit data highlight that the locations of amenities are highly correlated. Neighborhoods with less access to shade and lighting at bus stops likely also have less access to other basic amenities at these stops.

***Figure 14**. Percent of site-visit stops with seating, trash cans, and real-time information by neighborhood*



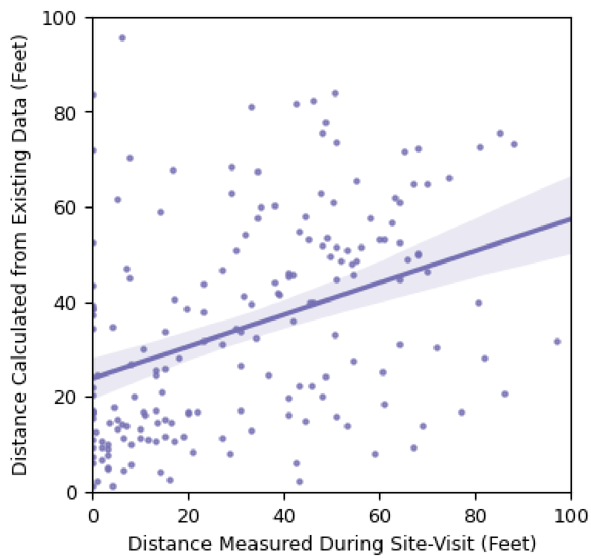
Citywide Analysis of Lighting

There are no citywide datasets that accurately represent the adequacy of lighting at individual stops, but the average distance to the nearest streetlight can underscore trends across neighborhoods.

Table 4. *Summary of the Accuracy of Citywide Measures of Lighting*

	Percent of Stops Covered	**Accurate for Stops**	**Accurate for Neighborhoods**
Distance to Nearest Streetlight	95%	No	Yes

Figure 15*. Distance to nearest streetlight from citywide data vs. site-visit measurements*



Distance to the nearest streetlight was the only lighting measure that could be calculated for all citywide stops from existing data. However, these calculated distances do not account for many important aspects of lighting quality and were also not reliable for individual stops. **Figure 15** shows the relationship between the distances measured during site visits and the distances calculated from existing spatial data. The two measurements are moderately correlated (*r*=0.42) but the citywide data are not a reliable measure for any given bus stop. These inaccuracies are primarily caused by spatial inaccuracies in the bus stop data, although the streetlight data also have some spatial inaccuracies and missing streetlights. As a result, the average difference between the calculated and measured distances from each bus stop to the nearest streetlight was 20 feet.

In contrast, the average distance to the nearest streetlight calculated for each neighborhood was found to be very consistent with site-visit data (**Table 5**). There were no statistically significant differences between the average distance calculated from available data and the average distance measured during site visits for any of the neighborhoods. Therefore, average distances were judged to be a reliable way of highlighting trends across neighborhoods.

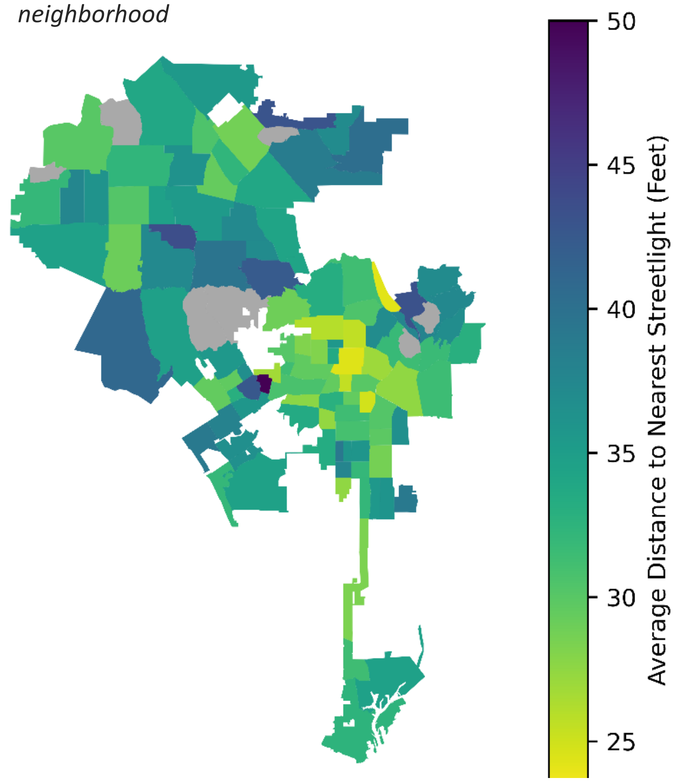
Table 5. *Neighborhood-Level Accuracy of Average Distance to the Nearest Streetlight*

Neighborhood	**Citywide Data (feet)**	**Site-Visit Data (feet)**	**Difference (feet)**	**p-value (two sample t-test)**
Sawtelle	28	29	-2	0.73
Sun Valley	31	33	-2	0.64
Watts	40	42	-2	0.62
,, *** indicate significance at the 90%, 95%, and 99% levels, respectively*				

Bus stops are generally closer to streetlights in denser neighborhoods.

Figure 16 shows the average distance from each neighborhood's bus stops to the nearest streetlight. Note that for all citywide measures, including average distance to the nearest streetlight, results are only reported for neighborhoods with at least 10 bus stops. Neighborhoods with fewer than 10 bus stops are shown in grey on all maps. Bus stops are generally closer to streetlights in denser neighborhoods, and the shortest distances are in the neighborhoods in the eastern part of Central LA, near Downtown. In contrast, bus stops are generally further away from streetlights in the more suburban San Fernando Valley. This finding is similar to past research that has found that streetlight density is lower in lower density neighborhoods of Los Angeles (Los Angeles Department of Transportation, 2021).

Figure 16. *Average distance to the nearest streetlight by neighborhood*



Citywide Analysis of Shade

Bus shelter data are accurate and reliable for understanding shade coverage at stops and at the neighborhood level. Nearby trees are useful for estimating shade coverage at the neighborhood level but not the stop level. Tree canopy data are not accurate for understanding shade coverage at either the stop or neighborhood level.

***Table 6**. Summary of the Accuracy of Citywide Measures of Shade*

	Percent of Stops Covered	Accurate for Stops	Accurate for Neighborhoods
Bus Shelter Present (Consolidated)	75%	Yes	Yes
Distance to Nearest Tree	100%	No	Yes
Total Tree Canopy in Bus Stop Area	100%	No	No

This project calculated three citywide measures of shade: the presence of a bus shelter, distance to the nearest public tree, and the total area of tree canopy in the bus stop area. Bus shelter data were only available for 75% of all bus stops, primarily due to minimal data coverage of stops served exclusively by LADOT (see Appendix I for more detail). However, the available data were determined to be highly accurate for both stops and neighborhoods through comparisons to data collected during the site visits. The citywide shelter data matched the site-visit data for 97% of the site-visit stops with citywide shelter data. Of the 42 bus stops that were reported as having a shelter in the citywide data, 95% were confirmed to have a shelter. Additionally, the two stops that did not actually have shelters that were reported in the citywide data were both located along the relatively new San Fernando Bike Path, the construction of which may have resulted in the removal of previously existing shelters. Of the 132 bus stops that were reported as not having a shelter in the citywide data, 99% were confirmed not to have a shelter during the visits. The shelter data were also highly accurate at the neighborhood level. There were no statistically significant differences between the percent of site-visit stops reported to have shelters in the citywide data and the percent of these stops found to have shelters during site visits for any of the neighborhoods (**Table 7**).

Table 7. *Neighborhood-Level Accuracy of Shelter Presence*

Neighborhood	Citywide Data	Site-Visit Data	Difference	p-value (two sample t-test)
Sawtelle	29%	30%	-2%	0.78
Sun Valley	19%	19%	0%	0.96
Watts	25%	26%	-1%	0.87
,, *** indicate significance at the 90%, 95%, and 99% levels, respectively*				

The site-visit data also suggest that the data missing from the citywide analysis may not be unduly biasing the results. Of the 26 site-visit stops with missing shelter data, 31% had a shelter present and 69% did not. This suggests that within the site-visit neighborhoods, bus stops that were missing citywide data were no more or less likely to have a shelter than bus stops with citywide data on shelter availability. Therefore, the amount of data missing from a neighborhood is not necessarily contributing to an overestimate or underestimate of shelter availability in neighborhoods with less data coverage.

The data on whether there was a public tree near each bus stop were accurate enough for neighborhood-level analysis but not for stop-level analysis. A binary logit model was fit to the site-visit data on whether there was a tree in the bus stop area to create a threshold for determining a “nearby” tree. The resultant threshold was about 100 feet (about a 20 second walk), which is similar to the distance used to capture trees within a bus stop area in other research (Lanza & Durand, 2021). Using this threshold, 75% of the 109 bus stops that were reported to have a nearby tree in the citywide data were confirmed to have a tree present during site visits, and 71% of the 93 bus stops that were reported not to have a nearby tree in the citywide data were confirmed not to have a tree present during site visits. These results indicate that the data on nearby trees have balanced error rates between “false positives'' where a stop that was reported as having shade in the citywide data did not actually have shade and “false negatives” where a bus stop that was reported as not having shade in the citywide data actually did have a tree present. However, the data were not accurate enough to ascertain tree availability for individual stops, because only 73% of the determinations from the citywide data matched the site-visit data, which was substantially below this project’s threshold of 95% accuracy. Despite this, the data were sufficiently accurate when aggregated to the neighborhood level. There were no statistically significant differences between the percent of site-visits stops reported to have a tree present in the citywide data and the percent confirmed to have a tree present for any of the three site-visit neighborhoods (**Table 8**). The consistency between the public tree data and the site-visit data at the neighborhood level suggests that this metric can be used to identify trends in tree availability across neighborhoods.

Table 8. *Neighborhood-Level Accuracy of Measures of Tree Shade*

	Tree Present				**Tree Casting Substantial Shade**			
Neighborhood	**Citywide Data**	**Site-Visit Data**	**Difference**	**P-value (two sample z-test)**	**Citywide Data**	**Site-Visit Data**	**Difference**	**P-value (two sample z-test)**
Sawtelle	54%	51%	+3%	.61	25%	25%	0%	1.00
Sun Valley	39%	45%	-5%	.34	15%	22%	-7%	.10
Watts	71%	71%	0%	1.00	60%	38%	+22%***	.00
,, *** indicate significance at the 90%, 95%, and 99% levels, respectively*								

In contrast, the data on tree canopy within each bus stop area were not usable at the stop or neighborhood level. The site-visit data were used to calculate the canopy area threshold that equalized the percent of site-visit stops reported to have substantial shade based on the total area of the canopy within the stop area in the citywide data and the percent of site-visit stops found to have a tree casting meaningful shade present during the site-visits. The resultant threshold was at least 550 square feet of canopy. At this threshold, only 63% of the 66 bus stops reported to have substantial tree shade in the citywide data were confirmed to have substantial tree shade during site visits and 79% of the 136 bus stops reported not to have substantial tree shade were confirmed not to. Additionally, the data were not reliably accurate at the neighborhood level (**Table 8**). Most significantly, the canopy data strongly overestimated tree shade in Watts. This was particularly unexpected because the trees in Watts were observed to be the least likely to be seasonal, deciduous trees, which should have resulted in the site-visit data for Watts (which were collected in February) being the most aligned with the tree canopy data (which were derived from imaging conducted during the fall).

Therefore, the presence of a bus shelter was determined to be the only reliable measure of shade availability for individual stops, and the prevalence of bus shelters and prevalence of nearby trees were found to be the only reliable measures of shade availability for neighborhoods. These calculations are limited by their inability to account for the amount of shade cast by the trees near bus stops, which underscores the importance of collecting, processing, and publishing up-to-date data on tree canopy, which evolves relatively rapidly across years.

The neighborhoods where stops are less likely to have shelters are also generally neighborhoods where stops are less likely to be near a public tree. In particular, the northeastern portion of the San Fernando Valley has very low shade availability across shelters or trees.

Across all neighborhoods with at least 10 bus stops, the percentage of stops with shelters ranges from close to zero to 43% (**Figure 17**). While this range demonstrates that there is considerable variation

Figure 17. *Presence of shelter by stop (left) and percent of stops with shelters by neighborhood (right)*

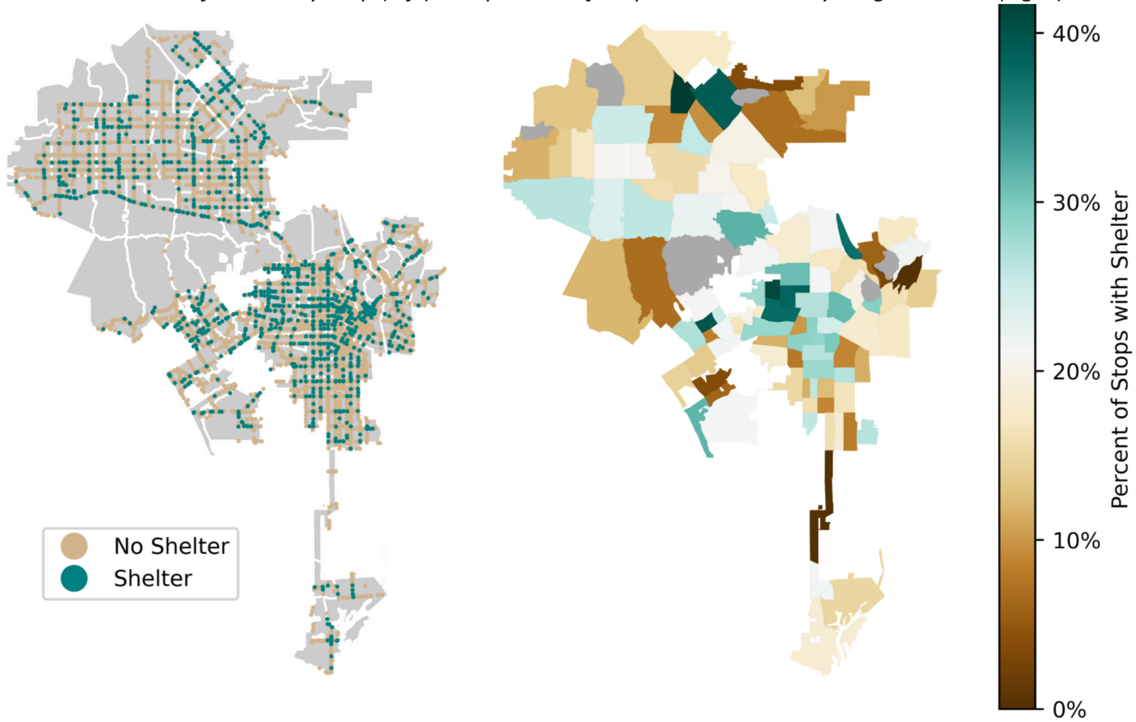
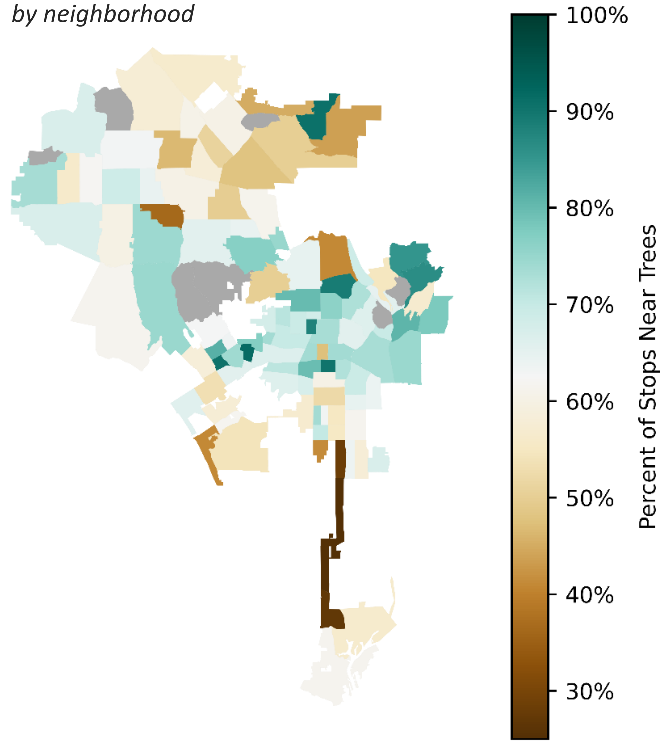


Figure 18. *Percent of stops with nearby trees by neighborhood*



across the City, there are no neighborhoods where the majority of bus stops have shelters. Many of the neighborhoods where the highest percentages of bus stops have shelters are clustered in the western part of Central LA, including Fairfax, Mid-Wilshire, Hancock Park, Larchmont, and Hollywood. The neighborhoods where the lowest percentages of bus stops have shelters are clustered in the high-income, northern part of the Westside, including Pacific Palisades and Brentwood, and the northeastern section of the San Fernando Valley including Sunland, Tujunga, and Shadow Hills.

The percent of stops with a tree within 100 feet by neighborhood is shown in **Figure 18**. Notably, tree availability at bus stops is generally lower in the San Fernando Valley, particularly the northeast area of the San Fernando Valley, while it is higher in the denser areas of Central and East Los Angeles.

Neighborhoods where bus stops are less likely to have shelters are often the same neighborhoods where bus stops are less likely to be near trees. For example, the Tujunga and Shadow Hills neighborhoods in the northeast area of the San Fernando Valley have among the lowest rates of shelter and shade availability. These neighborhoods are not in the area of Los Angeles most frequently discussed in conversations about shade equity, where overall tree canopy coverage is the lowest. This divergence may be a result of differences in tree species, since the data on nearby public trees do not account for the level of shade provided and include species like Palm Trees that are largely decorative rather than shade-producing. However, this difference may also be the result of differences between trends in shade at bus stops and general trends in shade in neighborhoods as a whole, since bus stops are usually located along the busiest transportation corridors rather than representative streets within an area.

Part II: Alignment Between Bus Stop Priority and Shelter Locations

The second section of the results describes findings related to the alignment between stop priority and shelter availability. This section first describes the locations of bus stops that this project awarded the most points across the various components of the prioritization framework, which was designed to largely mirror the STAP prioritization methodology, but which diverged from STAP by using updated data sources and scoring all citywide bus stops, regardless of whether they already have a shelter (see Appendix I for more detail). It then describes how these components come together to highlight the areas where providing adequate shade and lighting is most critical. This section then compares the locations of higher-priority stops with the locations of existing shelters to identify the areas with particularly high concentrations of higher-priority stops that do not currently have shelters.

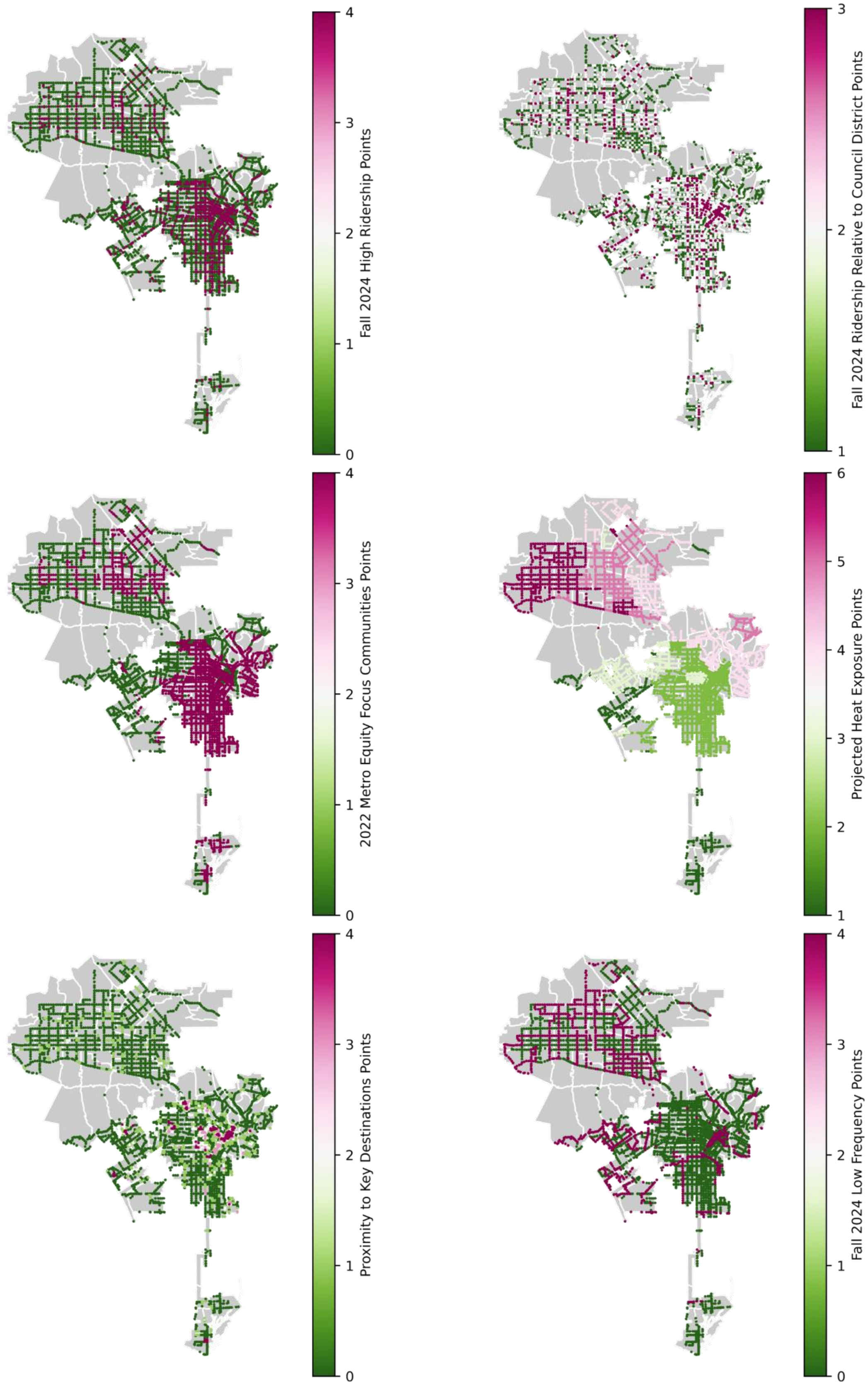
Although there are high priority stops located throughout Los Angeles, an equity-driven prioritization framework highlights that shelters are particularly important in two distinct geographic areas. One of these higher-priority areas spans the Eastside, eastern half of Central LA, and South LA. The other spans the area of the San Fernando Valley from Van Nuys to the western edge of the City.

Although the new STAP contract will significantly increase the number of bus shelters, there will only be enough new shelters to cover about one third of bus stops in Los Angeles. As such, it is important to understand which locations are the highest priority for providing shelters.

Figure 19 shows stops' scores, where higher scores indicate higher priority, across all the components of the prioritization framework. Many of these scores highlight the area spanning the Eastside, Central LA, and South LA, which is the area of Los Angeles that most frequently surfaces during equity-focused work, because of the high representation of Black and Latinx residents and low-income households in this area. The stops that served at least 100 average weekday boardings in Fall 2024 are overwhelmingly located in the Central LA neighborhoods spanning Downtown, Westlake, Koreatown, Pico-Union, and Harvard Heights. The stops within a quarter mile of the highest number of destinations considered in the STAP analysis are also highly clustered in Central LA, particularly Downtown. Similarly, the majority of the stops located in Equity Focus communities are in South LA, Central LA, and the Eastside, although there are also stops located in Equity Focus communities in parts of the San Fernando Valley, including Van Nuys and Pacoima.

However, the STAP prioritization framework also highlights the importance of providing bus amenities in certain parts of the San Fernando Valley. The parts of Los Angeles projected to experience the most severe heat are generally in the San Fernando Valley and Eastside, with the western part of the

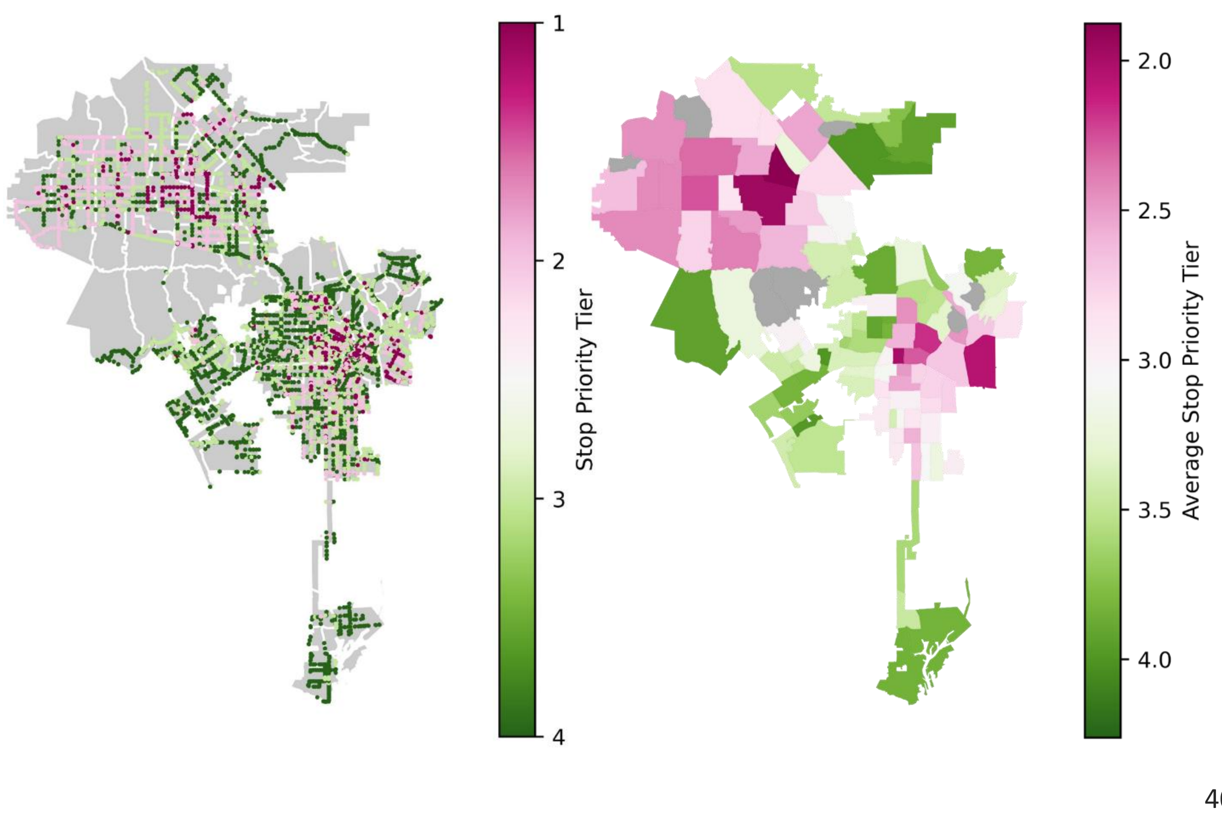
***Figure 19**. Points awarded to stops by prioritization scoring component*



San Fernando Valley (including Northridge and Reseda) expected to face the most intense heat in the coming years. Additionally, the stops that served routes that ran less than every 30 minutes during weekday peak-hours in Fall 2024 are much more likely to be located in the San Fernando Valley or Westside. The stops that have high levels of ridership relative to other stops within the same council district are definitionally distributed throughout different geographic areas, but clusters of these stops highlight key travel corridors with comparatively high ridership, such as Reseda Blvd and Van Nuys Blvd in the San Fernando Valley.

Figure 20 shows the result of aggregating the components of the prioritization framework and converting these scores into four priority tiers, where Tier 1 stops are the highest priority and Tier 4 stops are the lowest priority. The highest priority stops are generally clustered in two broad areas. First, there are many higher-priority stops in Boyle Heights and the Central LA area spanning Westlake, Koreatown, and Pico-Union, and a notable number of higher-priority stops in South LA. These stops are generally located in Equity Focus Communities, have high ridership, and are near important, trip-generating destinations. Second, there are clusters of similarly higher-priority stops in certain areas of the San Fernando Valley, particularly around Van Nuys and in neighborhoods west of Van Nuys (like Northridge). These stops experience the most severe extreme heat and are generally served by infrequent bus routes, which allowed stops to rise to the top of the prioritization framework if they were located in an area of the San Fernando Valley with comparatively high demographic need. At these stops, ridership is generally lower, but the riders who do take the bus are the most likely to be subject to long wait times in extreme heat, highlighting the unique importance of providing access to shade in this area. The average priority tier in each neighborhood, which is also shown in **Figure 20**, emphasizes the same pattern.

***Figure 20**. Priority tier by stop (left) and average stop priority tier by neighborhood (right)*



Regarding the site-visit neighborhoods, Sun Valley and Watts rank 34th and 45th respectively, out of the 107 neighborhoods with at least 10 bus stops, based on the average priority tier of their stops. In contrast, Sawtelle ranked much lower (78th), like other neighborhoods in the Westside. Some, but not all, of the stops in Watts are higher-priority (in Tiers 1 or 2). Like other higher-priority stops in the Eastside, Central LA, and South LA, higher-priority stops in Watts received a disproportionately high share of their points from high ridership, high proximity to key destinations, and equity importance, and received a disproportionately low share of points from high exposure to extreme heat or long wait times.

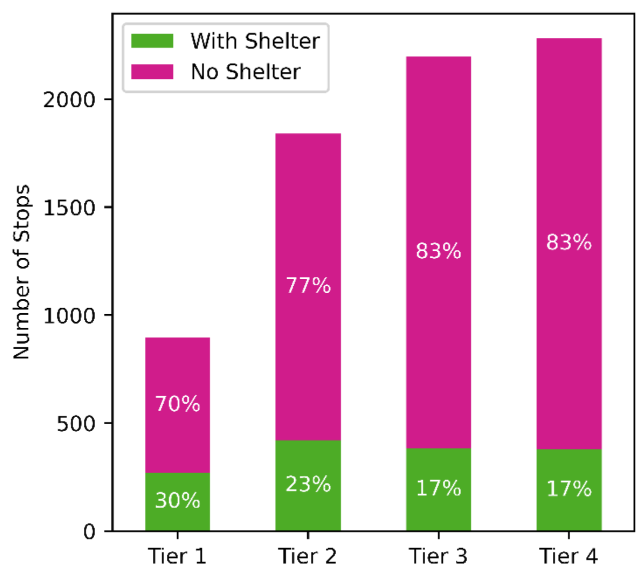
The higher-priority site-visit stops in Sun Valley are also reasonably representative of other higher-priority stops in the San Fernando Valley. Like other higher-priority stops in the San Fernando Valley, they received a disproportionately high share of their points from exposure to extreme heat and equity importance, and a disproportionately low share of points from proximity to key destinations. However, higher-priority stops in Sun Valley were less likely to be served by infrequent routes, making them somewhat unique within the San Fernando Valley.

Sawtelle, like other neighborhoods in the Westside, has very few higher-priority stops. The higher-priority stops that do exist scored highly by serving hotspots of high ridership and proximity to key destinations, such as by being located by the Sepulveda Station of the Metro E Line.

Although higher-priority stops are comparatively more likely to have bus shelters than lower-priority stops, most still do not have shelters.

Higher-priority stops (those in Tier 1 or Tier 2) are comparatively more likely to already have a bus shelter. While 30% of Tier 1 stops and 23% of Tier 2 stops have shelters, only 17% of lower-priority stops have shelters (**Figure 21**). Despite this, the overwhelming majority of higher-priority stops do not have shelters. Moreover, since there are a larger number of lower-priority stops, there are actually more shelters located at lower-priority stops (763) than at higher-priority stops (691).

Figure 21. *Presence of shelters by stop priority tier*

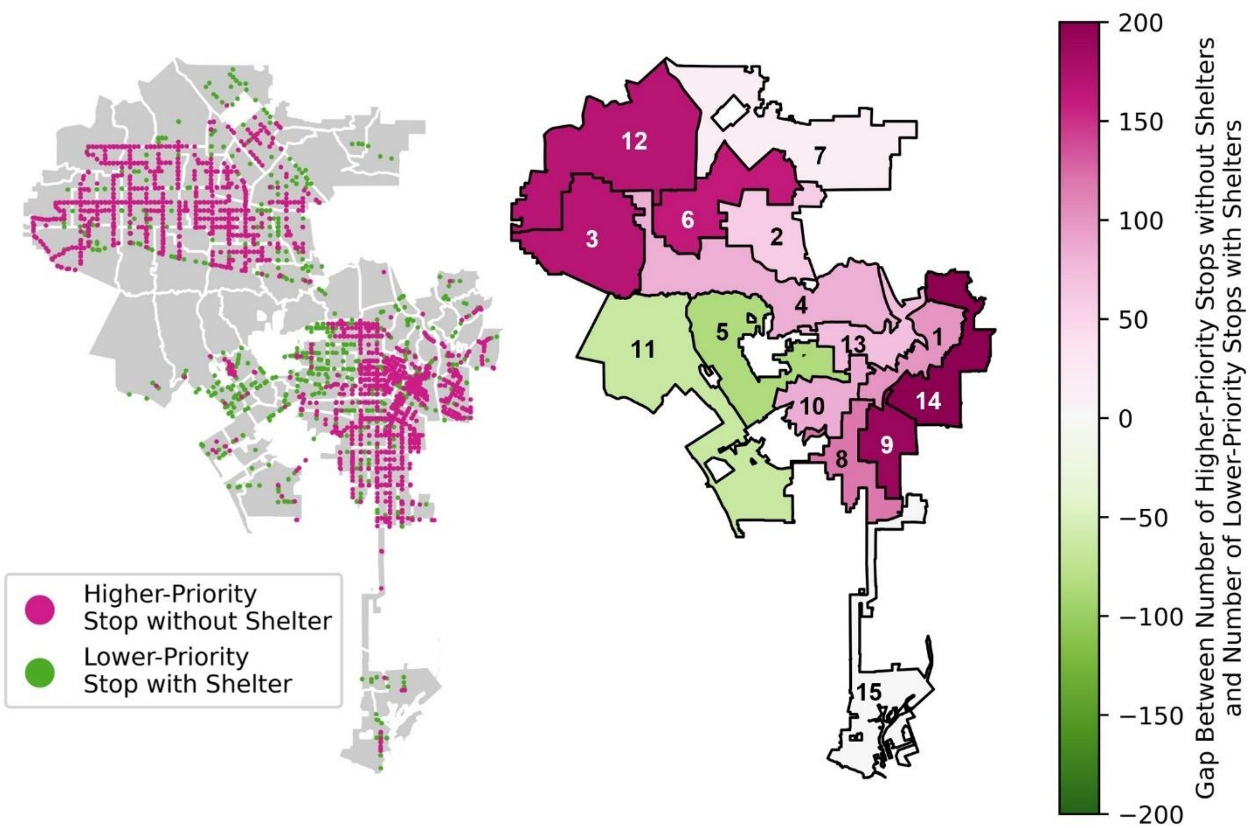


The mismatch between stop priority and current bus shelter locations exhibits such a strong spatial pattern that a small number of council districts (Districts 3, 6, 9, 12, and 14) contain the majority of all higher-priority stops without shelters. In contrast, council districts on the Westside have more than enough existing shelters at lower-priority stops to cover all of their unmet shelter needs.

Higher-priority unsheltered stops and lower-priority sheltered stops are distributed unevenly throughout Los Angeles (**Figure 22**). Priority areas highlighted earlier (Boyle Heights, the eastern neighborhoods of Central LA, South LA, and southwestern neighborhoods of the San Fernando Valley) have disproportionate shares of higher-priority stops that do not have shelters. In contrast, moderate-income neighborhoods in the Westside or western neighborhoods of Central LA, particularly Fairfax, Mid-Wilshire, and Sawtelle, have disproportionately high shares of lower-priority stops that do have shelters. The bus stops in the highest-income neighborhoods of the Westside are also generally lower-priority but are also less likely to have bus shelters.

As a result of these strong spatial patterns, more than half of the higher-priority bus stops without shelters are located in just five of the 15 Los Angeles City Council Districts - Districts 3, 6, 9, 12, and 14. In contrast, there are two districts (Districts 5 and 11) where the number of lower-priority stops with shelters actually exceeds the number of higher-priority stops without shelters (**Figure 22**).

Figure 22. *Locations of higher-priority stops without shelters and lower-priority stops with shelters (left), and difference between the number of each by City Council District (right)*



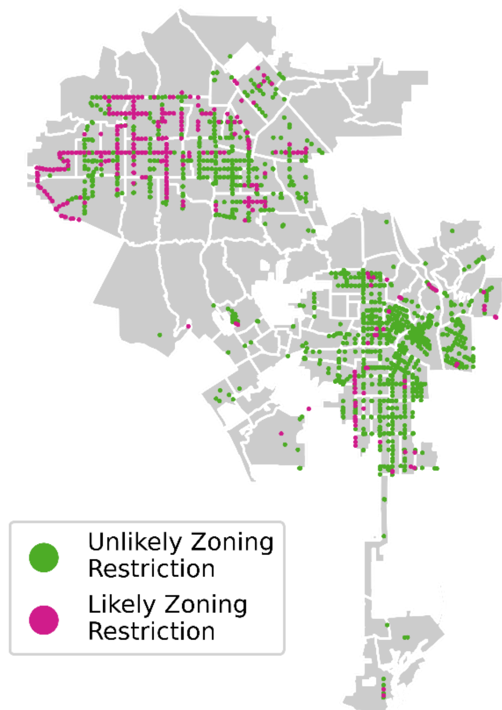
Part III: Magnitude and Spatial Distribution of Site Constraints

The third and final section of the results discusses findings related to the extent to which site constraints will pose obstacles to addressing unmet needs at higher-priority stops, and which neighborhoods are particularly burdened by these constraints.

Street and Land-Use Classifications

Restrictions on installing bus shelters in residential areas (particularly single-family residential areas) may prevent up to 19% of higher-priority bus stops without shelters from having this unmet need addressed. These restrictions may be particularly prevalent barriers to serving higher-priority bus stops in the San Fernando Valley.

***Figure 23**. Likelihood of zoning-based restrictions at higher-priority stops*



Bus shelters are not permitted along hillside local or hillside limited streets or along local streets adjacent to residential land uses (including multi-family residential uses). Additionally, bus shelters are unlikely to be installed near single-family residential land uses, although StreetsLA evaluates potential shelter sites in residential areas on a case-by-case basis (unless the site is along a local street, in which case shelters are not allowed) (Los Angeles Office of the City Clerk, 2022). This constraint affects far more bus stops in higher-income or more suburban areas (regardless of income), where much of the land is zoned for single-family use.

Street and land-use restrictions may prevent shelter installation at up to 11% of the highest-priority stops (those in Tier 1) and up to 19% of all higher-priority stops (those in Tier 1 or Tier 2). This represents a substantial barrier to placing shelters where they are most needed, which is almost exclusively borne by neighborhoods in the San Fernando Valley (**Figure 23**). While single-family zoning may be a signifier of wealth in denser areas, it is widespread in the more suburban areas of Los Angeles. In the low-income neighborhood of Sun Valley, this restriction could prevent the installation of a variety of higher-priority shelters along Saticoy Street. In the moderate-income neighborhoods of Northridge and Reseda, about 60% of higher-priority stops without shelters may face land-use based barriers to shelter installation.

Sidewalk Widths

The available sidewalk data are no longer reflective enough of current conditions to determine physical constraints at individual stops, but the data can be used to understand trends in how many bus stops are located on sidewalks wide enough to support a standard advertising bus shelter.

Table 9. *Summary of the Accuracy of Citywide Measures of Sidewalk Widths*

	Percent of Stops Covered	Accurate for Stops	Accurate for Neighborhoods
Sidewalk Width	83%	No	10+ Feet Only

StreetsLA's existing Transit Shelter Placement Guidelines assume a sidewalk width of at least 10 feet to accommodate a standard advertising shelter and at least 8 feet to accommodate a non-advertising shelter, while maintaining a minimum 4-foot-wide clear path of travel for wheelchair users (Los Angeles Office of the City Clerk, 2022). Due to this, citywide sidewalk data was evaluated regarding if it accurately captured whether bus stops were located on sidewalks that were at least 10 feet wide or at least 8 feet wide. Sidewalk measurements and citywide calculations were designed to capture the widest part of the sidewalk within the bus stop area.

There were frequently substantial differences between the sidewalk widths measured during site visits and the calculated sidewalk widths, although calculations of whether a sidewalk was at least 10 feet wide were more reliable than calculations of whether a sidewalk was at least 8 feet wide. With regard to accurately identifying 10-foot wide sidewalks, 76% of the 71 sidewalks that site-visit stops were located on that were reported to be at least 10 feet wide in the citywide data were measured to be at least this wide, and 82% of the 89 sidewalks that site-visit stops were located on that were reported to be under 10 feet wide in the citywide data were measured to be under this threshold. While this level of accuracy is insufficient for identifying individual stops that cannot accommodate a standard advertising shelter, the data has relatively balanced error rates. In contrast, 93% of the 130 sidewalks that site-visit stops were located on that were reported to be at least 8 feet wide in the citywide data were measured to be at least this wide, and only 33% of the 30 sidewalks that site-visit stops were located on that were reported to be under 8 feet wide were measured to be under this threshold. As a result, the available citywide data could create a substantial number of "false negatives" of stops labeled as being unable to accommodate a non-advertising shelter despite actually being able to.

At the neighborhood level, there was no statistically significant difference between the percentage of bus stops located on sidewalks at least 10 feet wide based on site-visit measurements and the citywide data. In contrast, the percentage of bus stops in Watts located on sidewalks at least 8 feet wide was significantly higher than the percentage reported in the existing citywide data, which could lead to a dramatic overestimation of the disparity in sidewalk widths between Watts and the other site-visit neighborhoods. Due to these discrepancies, this project only reports the percentage of bus stops on sidewalks at least 10 feet wide, which is wide enough to accommodate a standard advertising bus shelter, and only does so at aggregate levels (i.e., by priority level and by neighborhood).

Table 10. *Neighborhood-Level Accuracy of Measures of Sidewalk Widths*

	Sidewalk 10+ Feet Wide				Sidewalk 8+ Feet Wide			
Neighborhood	**Citywide Data**	**Site-Visit Data**	**Difference**	**P-value (two sample z-test)**	**Citywide Data**	**Site-Visit Data**	**Difference**	**P-value (two sample z-test)**
Sawtelle	56%	56%	+1%	.90	87%	90%	-3%	.48
Sun Valley	55%	55%	-1%	.90	91%	88%	+3%	.43
Watts	20%	17%	+3%	.59	64%	83%	-19%***	.00
,, *** indicate significance at the 90%, 95%, and 99% levels, respectively*								

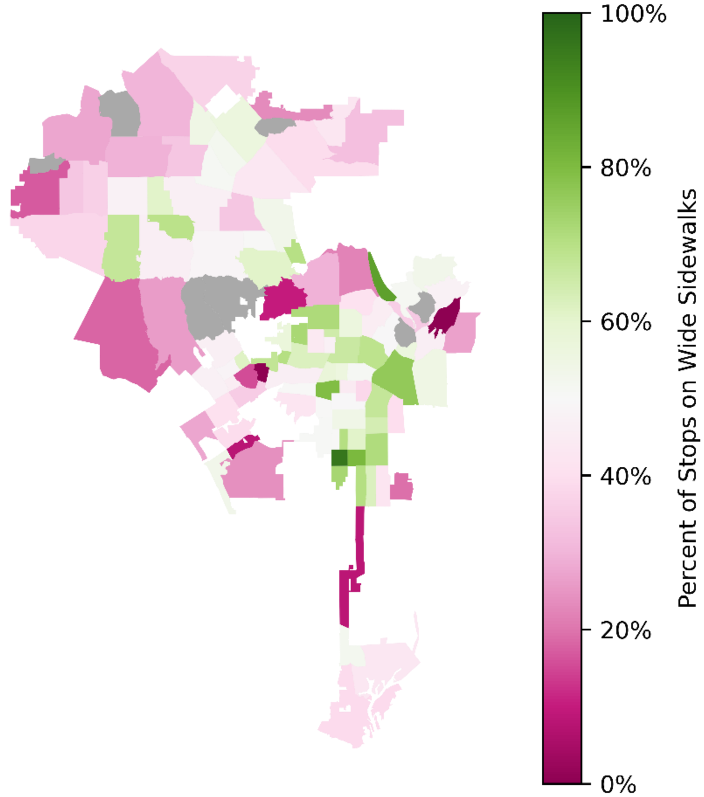
Narrow sidewalks are a major barrier that could inhibit the installation of standard advertising shelters at up to 53% of higher-priority stops without shelters. While this barrier is sizable, it does not have a disproportionate effect in lower-income neighborhoods of Los Angeles, and therefore does not explain why, overall, lower-income neighborhoods have higher rates of higher-priority bus stops without shelters.

Up to 53% of higher-priority stops without shelters in Los Angeles are located on sidewalks that are less than 10 feet wide, which is the minimum sidewalk width assumed for the placement of a standard advertising shelter in StreetsLA's existing Transit Shelter Placement Guidelines. This constitutes a major barrier to providing amenities at the stops where they are most needed, but this statistic is a ceiling on the percentage of bus stops that cannot be given a shelter due to their sidewalk widths. In some cases, the sidewalk assignments used in this analysis may be incorrect. Due to inaccuracies with the bus stop locations, bus stops could have been associated with a narrow sidewalk segment separated from the street by a grass parking strip even if the actual bus stop is located on a wider sidewalk segment running all the way from the property line to the curb. In other cases, the data are correct, but stops could be given wider sidewalks by relocating the stop or expanding the sidewalk without major construction (such as by paving over a grass parking strip between the sidewalk and the curb). Additionally, smaller bus shelters can be installed on narrower sidewalks and many non-advertising shelters are already located on sidewalks less than 10 feet wide.

Regrettably, the existing sidewalk data were not reliable enough to estimate the percentage of bus stops located on sidewalks that are at least 8 feet wide, which is the minimum width assumed for the placement of a non-advertising shelter. Although this is a limitation of this research, the emphasis of STAP is on providing larger, amenity-rich bus shelters. The current STAP contract sets a goal of providing only 450 new non-advertising shade structures in comparison to 3,000 new advertising bus shelters. As such, while 53% represents a ceiling on how many higher-priority bus stops may not accommodate standard advertising bus shelters, it is likely a reasonable approximation of how many higher-priority bus stops can be easily accommodated by the new shelters that have been the focus of STAP thus far. Additionally, this analysis underestimates sidewalk issues in other ways because some wide sidewalks are in poor enough condition that a bus shelter could not be installed without costly sidewalk repairs that may discourage shelter installation.

Many bus stops in low-income neighborhoods are located on sidewalks that are too narrow to accommodate a standard advertising shelter. Despite this, inadequate sidewalks at bus stops, which are sometimes presented as a cause of comparative disinvestment in lower-income neighborhoods, are actually more common in *higher-income* areas of Los Angeles. **Figure 24** shows the percentage of stops in each neighborhood located on sidewalks that are at least 10 feet wide. Bus stops are more likely to be on sidewalks that are wide enough to accommodate a standard advertising bus shelter in the area of Central and South LA that includes the neighborhoods of Manchester Square, Vermont Knolls, Florence, Historic South-Central, and Downtown. In contrast, bus stops are the least likely to be on sidewalks that are wide enough to accommodate a standard advertising bus shelter in wealthy Westside neighborhoods including Pacific Palisades, Brentwood, Cheviot Hills, Mar Vista, and Venice.

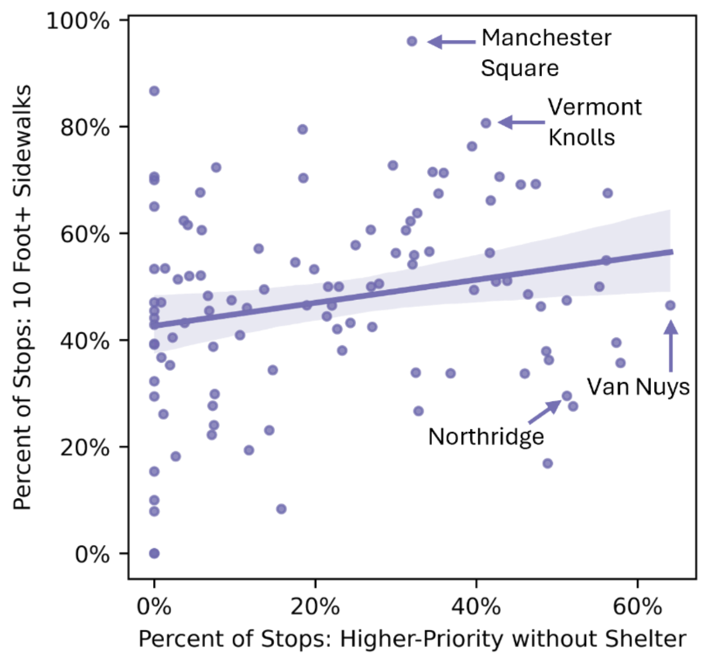
***Figure 24**. Percent of stops on wide sidewalks by neighborhood*



This finding differs from other research about areas where sidewalk widths create the most burdensome constraints. For example, Brozen et al. (2022) found that commercial sidewalks were narrower in South LA and narrower in areas with more people of color after controlling for income, which creates a barrier to equitable access to outdoor dining in Los Angeles (Brozen et al., 2022). However, these seemingly divergent findings are not incompatible, because sidewalk widths are largely correlated *with* land use, and Brozen et al. investigated disparities along a *single land use* (commercial properties). In South Los Angeles, bus routes generally run along major streets that are dominated by commercial land uses, whereas higher income neighborhoods in the Westside are dominated by single-family land uses (even along many bus routes). Since sidewalks are generally much narrower along residential land uses, particularly single-family land uses, bus stops are therefore less likely to be located on a wide sidewalk in areas with lots of single-family zoning.

As a result, there is actually a weak but positive correlation between the percent of a neighborhood's stops that are higher-priority but lack bus shelters and the percent of a neighborhood's stops that are on sidewalks at least 10 feet wide, indicating that the places with the most need are not systematically the places where that need is the hardest to meet due to physical constraints. Despite this, there are still specific neighborhoods with high rates of unsheltered, higher-priority stops and low rates of wide sidewalks, such as Van Nuys and Northridge, where sidewalk widths may substantially constrain efforts to address inequities in shelter distribution (**Figure 25**).

***Figure 25**. Relationship between percent of higher-priority stops without shelters and sidewalk widths by neighborhood*



Sidewalk widths are a major barrier to installing bus shelters throughout Los Angeles. However, they do not explain comparative disinvestment in Central LA, the Eastside, or South Los Angeles. In contrast, sidewalk widths may pose more of a widespread barrier to addressing unmet needs in higher-priority parts of the San Fernando Valley, like Northridge.

Conclusion

Bus shelters have the potential to overcome disparities in the built environment, but their current locations and types are often exacerbating disparities instead. This research highlighted the vital role of bus shelters in providing adequate shade and nighttime lighting. Despite their potential benefits, shelters are inequitably distributed throughout Los Angeles. Areas where bus stops are the least likely to have a shelter are often the places where bus stops are the least likely to be near trees. Through the analysis of both citywide and site-visit data, the San Fernando Valley emerged as having particularly low access to shelters and trees. This is particularly concerning given that this area is also the hottest part of Los Angeles and is projected to experience the most extreme heat in the coming years. In addition, simple measures of bus shelter availability do not account for disparities in the adequacy of nighttime lighting. While integrated bus shelter lights are the most effective way of improving lighting levels, these lights are significantly less common in non-advertising shelters. As a result, lower-income neighborhoods of color, like Watts, that have historically been labeled as having less "ad-revenue potential," may have the least access to transit-specific lighting amenities. This disparity demands particularly urgent attention because lighting amenities may be the most important in these neighborhoods due to systemic issues with streetlight maintenance and illumination levels.

STAP will increase the number of shelters and distribute them with an equity-driven prioritization framework. This is an important, meaningful step forward, but there are still remaining barriers to installing shelters where they are most needed. This research highlighted that many higher-priority bus stops are located on sidewalks that cannot accommodate a standard advertising shelter or are located adjacent to residential land uses where shelter installation is limited. These are significant obstacles to delivering adequate shade and nighttime lighting that affect bus riders traveling through all areas of Los Angeles. While many bus stops in low-income neighborhoods are located on sidewalks that are too narrow to accommodate a standard advertising shelter, site constraints alone do not explain why lower-income neighborhoods in Central LA, South LA, and the Eastside have comparatively high rates of higher-priority bus stops without shelters, which is likely a result of how advertising revenue potential has dictated the locations of bus amenities. In contrast, these site constraints are the most likely to inhibit efforts to remedy inequities in shelter availability at higher-priority bus stops in more suburban neighborhoods in the San Fernando Valley, including Northridge and Reseda.

There are unique challenges to providing adequate shade and nighttime lighting in different neighborhoods based on race, income, and density in the neighborhood. Low-income, dense neighborhoods have many higher-priority stops without bus shelters, and the true disparities in amenities may be understated by the shelter data, which do not account for features within the shelters or streetlight maintenance or power issues. However, the higher-priority stops in these neighborhoods are not systematically more likely to have site constraints that prevent the installation of standard advertising shelters with integrated lighting. In contrast, low-income suburban neighborhoods like Sun Valley may be the most in need of innovative solutions for providing adequate shade and lighting. The conditions of bus stops in more moderate-income neighborhoods also vary substantially based on density. Denser, moderate-income neighborhoods like Mid-Wilshire and Sawtelle have the most bus stop amenities relative to their level of need, perhaps as a result of income levels high enough to have attracted advertisement investment but moderate enough to have avoided widespread community opposition to the installation of advertisements in the public right of way. Despite this comparative lack of need for additional investment, many of the initial STAP shelters will be allocated toward replacing existing shelters in these neighborhoods. In contrast, moderate-income neighborhoods in the San Fernando Valley, like Reseda and Northridge, have high rates of unsheltered, higher-priority stops. These neighborhoods are also particularly likely to have zoning and sidewalk width constraints that will make it particularly difficult to address these needs. While these neighborhoods are moderate-income compared to the rest of Los Angeles, there are still bus riders who rely on transit who live in, or travel to, these neighborhoods, and who face particularly high temperatures and long wait times at stops in these areas.

Finally, accurate data that reflect bus riders' experiences are vital to effectively prioritizing improvements where they are most needed. Community members and transit advocates are often suspicious of a reliance on quantitative data, and for good reason. Existing quantitative data frequently fail to measure pertinent aspects of real-world conditions (like with the existing streetlight data) or are too outdated to be useful (like with the existing tree canopy data). However, quantitative data can play an important role in understanding citywide trends, increasing transparency in decision-making, and holding public agencies accountable. For data-informed planning to fulfill its potential to be equity-enhancing, transportation agencies must invest in data collection that accurately reflects bus riders' experiences. This project offers a proof of concept and a step toward that goal.

Recommendations

The following recommendations suggest strategies to improve shade and nighttime lighting at bus stops in Los Angeles. These recommendations can inform the City's existing shelter program and identify areas where researchers and advocates can work towards the development and implementation of solutions. Additionally, these recommendations highlight issues that planners and advocates working to improve bus stop conditions in other cities should consider.

Improving Shade and Nighttime Lighting

This project has demonstrated that shelters are a vital source of shade and lighting. The City of Los Angeles' new bus shelter program will greatly expand these benefits to a larger number of riders, and will do so with a thoughtful, equity-driven prioritization framework. This is an important, meaningful step forward, but there are still actions that would improve access to adequate shade and lighting where it is most needed:

1. **Recognize that bus shelters are a powerful intervention for providing both protection from heat and safe levels of lighting.** Shelters are an important source of shade in a city increasingly plagued by uncomfortable and unsafe temperatures. However, shelters with integrated lighting are also the most effective way of providing adequate nighttime lighting at bus stops. Considering stops' lighting needs in addition to their shading needs when deciding on bus shelter locations is vital to advancing gender-equity due to the key role that lighting plays in affecting safety and perceptions of safety for women and gender minorities. Factoring in lighting

needs is particularly important because street trees can simultaneously decrease the need for additional shade while increasing the need for lighting solutions provided below the canopy level if the tree canopy blocks or reduces the light from nearby streetlights.

2. **Develop a repeatable prioritization process to make it easier to reevaluate bus stop priority as conditions change and respond to new needs that emerge during implementation.** The components of an equity-driven prioritization framework often change and there have been particularly large, lasting changes since the onset of the COVID-19 pandemic. These changes have included altered ridership patterns and modifications to the Metro NextGen Bus Plan that have resulted in lower levels of service at bus stops than were originally planned for. Transitioning prioritization efforts that develop point-in-time lists to developing easily repeatable processes would make it easier to factor these new needs into ongoing infrastructure decisions when staff do not have the time to frequently replicate manual processes.
3. **Invest in innovative designs to provide shade and lighting at site-constrained bus stops.** About half of higher-priority bus stops are located on sidewalks with widths that may pose a barrier to accommodating standard advertising bus shelters. This is a significant obstacle to delivering adequate shade and nighttime lighting that affects bus stops throughout all areas of Los Angeles and demands increased attention and resources.
4. **Incorporate new metrics into the shelter prioritization framework to elevate gender-equity.** The use of an equity-driven prioritization framework for new shelter placements represents a landmark step forward for the City of Los Angeles and will reduce inequities in access to bus shelters. However, additional scoring components should be introduced to account for factors that are particularly important to women and gender minorities. For example, stops could receive more points based on what percentage of boardings occur midday (when women are more likely to be traveling) or in the evening (when amenities like additional lighting are most important). Key destinations could be expanded to include childcare centers, grocery stores, and other locations that are important for care-related travel.
5. **Find creative solutions overcome political and financial barriers to providing access to shade and lighting where it is most needed.** The higher-priority bus stops that lack bus shelters are highly concentrated in certain areas of Los Angeles, but citywide programs often have a strong focus on geographic equity across council districts. Creative solutions to this issue could include finding ways of having regional agencies, like Metro, councils of governments, or the metropolitan planning organization, SCAG, play a larger role in funding and siting bus shelters. Exploring ways of jointly administering bus amenity programs with other programs that have different areas of the highest geographic need could also uncover new ways of creating program-level geographic equity.
6. **Consider sources of shade and lighting when choosing the precise locations of bus stops along a route.** In the Los Angeles region, transit agencies have little control of whether their bus stops will receive amenities given that the responsibility lies with the municipalities. However, if deciding between potential stop locations, transit agencies should consider proximity to trees and brightly lit buildings when selecting precise bus stop locations along routes. These elements

of the built environment can have a large impact on increasing shade and lighting at stops without dedicated transit amenities.

Improving Data

This project also highlighted the ways in which existing data fail to measure vital aspects of shade and lighting and the extent to which many commonly used datasets no longer reflect current conditions. Accurate data that reflect bus riders' experiences are vital to effectively prioritizing improvements. The following recommendations address this need:

1. **Update and publish datasets derived from aerial imagery more frequently**. While the LARIAC program collects data every three years, many of the derived datasets currently being used for research, such as the sidewalk and tree canopy data, are up to an entire decade old. The publication of more up-to-date data is vital to supporting equity-focused research and planning.
2. **Invest in the collection of streetlight maintenance and illuminance data.** Despite substantial research demonstrating that 311 requests underrepresent needs in low-income communities and communities of color, the City of Los Angeles continues to prioritize streetlight maintenance work on the basis of 311 requests. Additionally, there are no data on actual lighting outcomes to address community members' concerns about the inadequate illumination of their streetlights. To address both issues, the City should proactively collect data on streetlight maintenance and illuminance issues. This study provides a proof of concept that could be implemented by hiring community-members to assess lighting adequacy at a sample of bus stops in their neighborhoods.

Adequate shade and nighttime lighting at bus stops are essential components of a gender-equitable transportation system. However, the current distribution of shade and lighting in Los Angeles is both inadequate and inequitable, and efforts to install bus shelters at the stops where they are most needed are hindered by a variety of obstacles. Addressing the design, political, and data constraints that currently limit the provision of shelters at higher-priority bus stops is necessary for making sure that the City's bus stops are safe and comfortable for all.

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Appendix I: Methodology for Calculating Citywide Measures

Bus Stop Locations

A large number of independent transit agencies operate buses that stop within the City of Los Angeles. This project focused on only the three transit agencies that serve the largest number of stops in Los Angeles - LA Metro, LADOT Transit, and the City of Santa Monica Big Blue Bus, to limit its scope for feasibility. Additionally, the stops served exclusively by the agencies with the next largest presences in the City (Culver CityBus and Torrance Transit) were not considered for new bus shelters in the STAP prioritization effort, so using just LA Metro, LADOT Transit, and Big Blue Bus stops aligned the scope of this project with the vast majority of the stops considered by the City's current amenity program.

This project used the LA Metro Bus General Transit Feed Specification (GTFS) (Los Angeles County Metropolitan Transportation Authority, 2023), LADOT Transit GTFS (LADOT Transit, 2023), and Big Blue Bus GTFS (Big Blue Bus, 2023) from Fall 2023 to create a dataset representing the locations of bus stops in the City of Los Angeles. Stops were included if they were located within 25 meters of the City's boundary. A 25-meter buffer was used to incorporate bus stops on the other side of the street in instances where a street comprises a border between Los Angeles and an adjacent city (such as with Centinela Avenue along the Los Angeles/Santa Monica border).

In many instances, two or more transit agencies serve a location that functions as a single bus stop with shared amenities. For this reason, this project considered multiple bus stops to be a single stop if they are within 25 feet of each other, which aligns with the threshold at which STAP considered multiple stops to be a single stop for the purposes of determining shelter priority. However, a primary challenge with using bus stop locations in geographic information system (GIS) analysis is that the locations are frequently not accurate enough for analyses at small spatial scales (such as the determination of whether two stops are within 25 feet of each other). Big Blue Bus locations are particularly prone to inaccuracies large enough to create other substantial errors (such as being spatially associated with the wrong side of the street) if they are not corrected prior to analysis. However, there are no uniform stop numbering or naming conventions shared across transit agencies with which to identify paired stops. For example, there are many bus stops at the intersection of Santa Monica Blvd and Bundy Dr, as buses travel north, south, east, and west, and can stop on either the nearside (before an intersection) or farside (after an intersection) as they cross the intersection in each direction. **Figure 26** displays the bus stop locations published by LA Metro and Big Blue Bus in their GTFS data. While the two LA Metro stops are also served by Big Blue Bus, the locations in the data are up to 93 feet apart.

To address these issues, this project manually edited all Big Blue Bus stop locations in QGIS that were located on a street with at least 10 Big Blue Bus stops and consolidated all Big Blue Bus and Metro stops located at intersections served by both agencies to a single point if the stops were close enough to share amenities, as determined by examining stops with Google Maps Street View. Throughout this project, additional stop locations were systematically edited when errors caused by inaccuracies were identified. For example, bus stop locations were edited when clusters of stops were spatially associated with a "nearest street" that did not match the stops' names. **Figure 27** displays the edited locations for the intersection of Santa Monica Blvd and Bundy Dr as an example. After these manual corrections, bus stops within 25 feet of each other were considered to be a single stop for all citywide analyses.

***Figure 26**. Published locations of bus stops at Santa Monica Blvd and Bundy Dr*

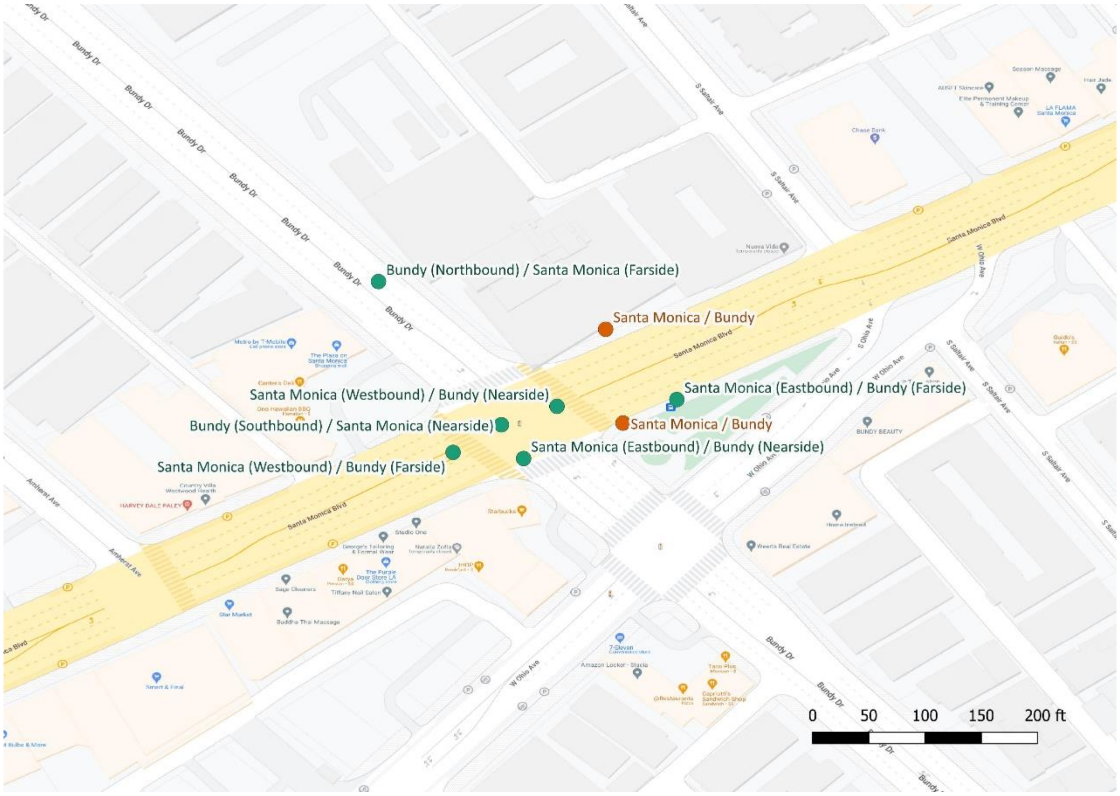
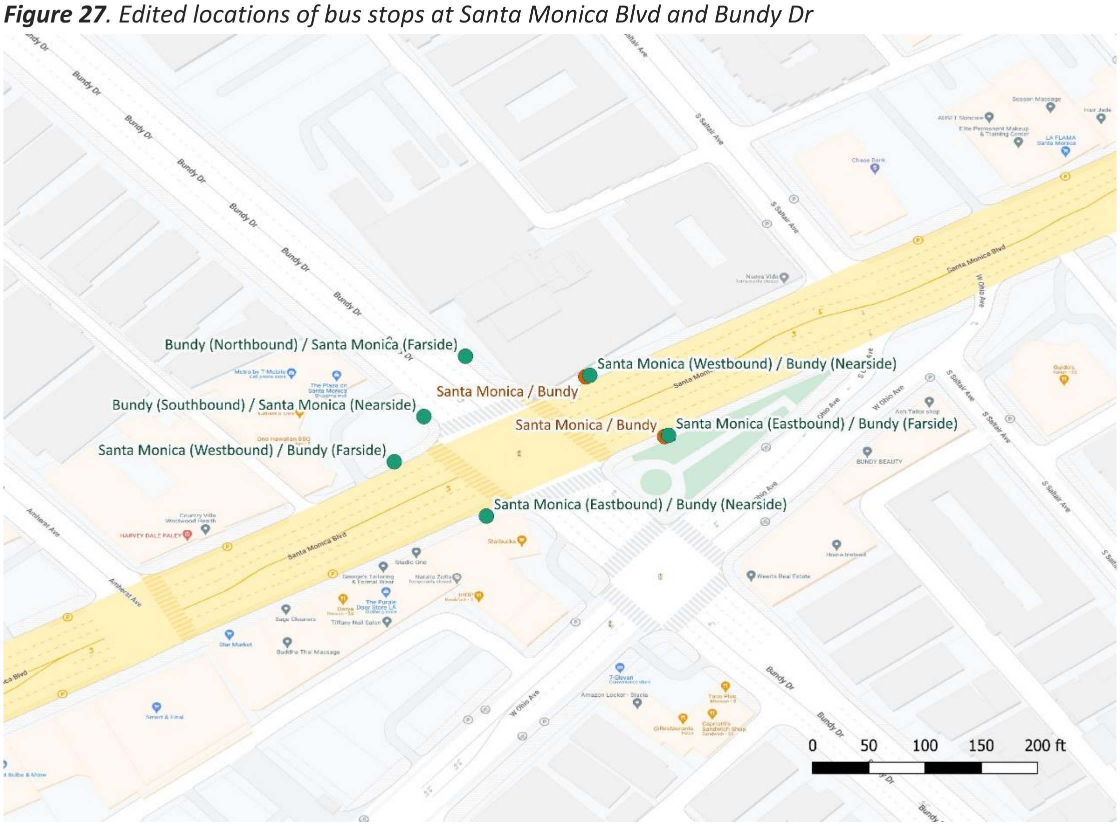


***Figure 27**. Edited locations of bus stops at Santa Monica Blvd and Bundy Dr*



Shade

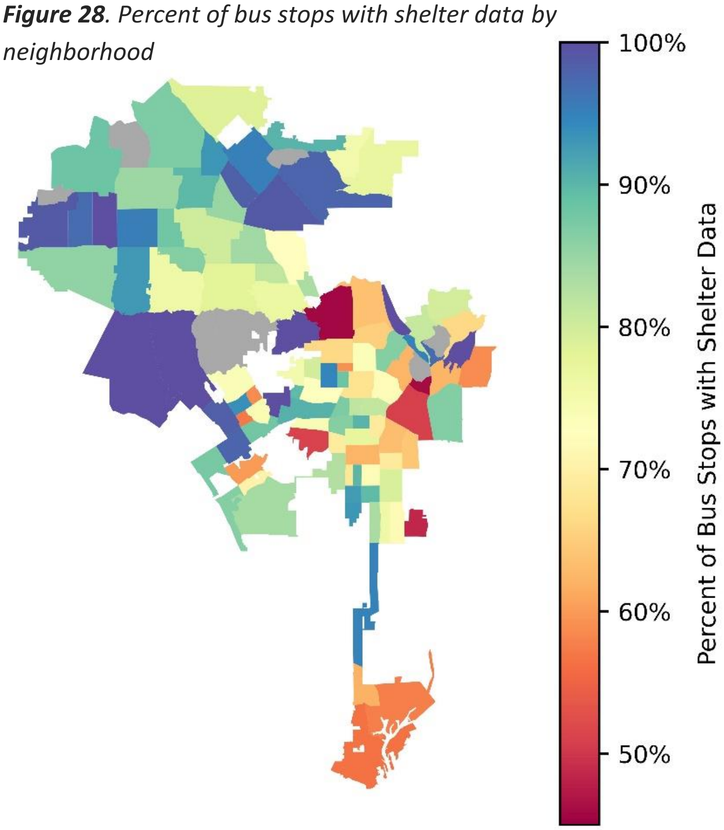
Dedicated bus shelters are the most direct way of providing riders with shade at bus stops. This project combined three datasets to determine shelter availability at individual bus stops:

1. LA Metro data on whether Metro stops have shelters
2. Big Blue Bus data on whether Big Blue Bus stops have shelters; and
3. StreetsLA data on whether stops assigned STAP prioritization scores were believed to have shelters.

While the Big Blue Bus and StreetsLA shelter data both contained stop IDs that could be used to match each shelter record with the GTFS stop locations, the Metro data solely contained spatial coordinates. Therefore, Metro shelter data were assigned the stop ID of the nearest bus stop in Metro's Fall 2023 GTFS. If multiple shelters were assigned the same stop ID during this process, only the data from the shelter closest to the stop was kept. Excluding these additional shelters further away from the bus stop locations was determined to be appropriate by using Google Maps Street View to visually inspect 5 random locations at which multiple shelters had joined to the same stop. Through these inspections, it was found that these instances generally occurred when the farther away shelters were located at former bus stops that no longer receive service.

The Metro and Big Blue Bus data were found to be more reliable and more comprehensive, so these data were used to determine shelter availability when possible. In the limited instances in which the Metro and Big Blue Bus data conflicted (e.g. the Metro data specified the presence of a shelter, and the Big Blue Bus data specified a lack of shelter at a shared stop), the stop was assumed to have a shelter, because this was the case in five of the six instances of conflict visually inspected through Google Maps Street View. If a stop did not have shelter information in either of these datasets, shelter information was then assigned from the StreetsLA dataset. Notably, the StreetsLA dataset primarily contains information about Metro stops and serves to fill in information for stops missing from the Metro shelter data. As a result, this process resulted in shelter information for 95% of stops served by either LA Metro or Big Blue Bus, but only 1% of stops served exclusively by LADOT (which account for 20% of total stops in the City).

***Figure 28**. Percent of bus stops with shelter data by neighborhood*



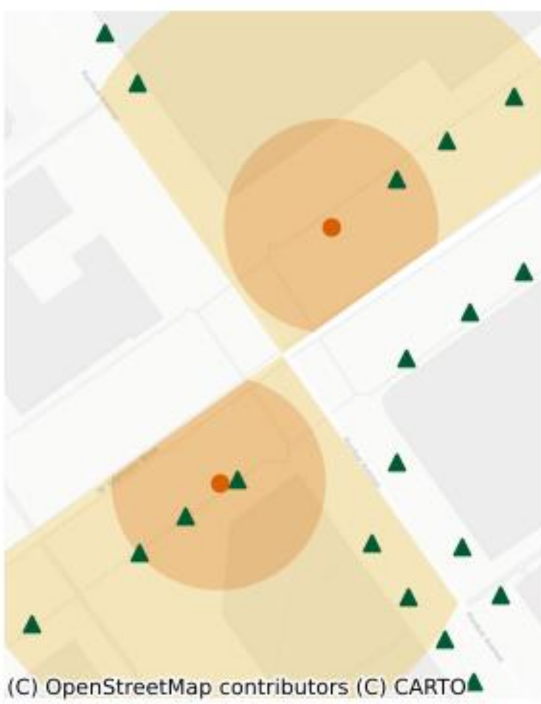
The combined data include shelter availability information for 75% of all stops, but data coverage varies by neighborhood. Since there was little information about shelter availability for LADOT stops, there is less complete information about how many bus stops have shelters in areas where LADOT provides more of the bus service. Since LADOT provides the largest share of service in the Harbor, Eastside, Central LA, and South LA areas of Los Angeles, these areas have the most shelter data missing from this analysis (**Figure 28**).

In addition to accounting for the presence of a bus shelter, this project calculated two measures of tree shade for each citywide stop: the distance to the nearest public tree that can be accessed without crossing any streets and the total area of tree canopy within 75 feet of the stop that can be accessed without crossing any streets.

To calculate both measures of tree shade, this project generated buffers representing the areas within 75 feet and 150 feet of each stop that can be accessed without crossing the street by clipping the buffers around each stop to a dataset of street centerlines from the Los Angeles Bureau of Engineering (Los Angeles Bureau of Engineering, Mapping and Land Records Division, 2020). **Figure 29** contains examples of these clipped buffers around two stops. The public tree dataset was created by combining two publicly available datasets: the locations of street trees managed by the LA Bureau of Streets Services (Los Angeles Bureau of Street Services, 2020) and the locations of trees within properties managed by the LA Department of Recreation and Parks (Los Angeles Department of Recreation and Parks, 2020). Next, the project calculated the distance from each bus stop to the nearest public tree located within its 150-foot buffer. This project used tree canopy data extracted from 2016 Los Angeles Region Imagery Acquisition Consortium (LARIAC) aerial imaging data, which was the most recent available canopy data, to calculate the total canopy area within each bus stop's 75-foot buffer.

These two measures are subject to different limitations. The distance to the nearest publicly managed tree cannot capture variation in the level of shade provided by different trees based on their

Figure 29*. Example of public trees (left) and canopy (right) within stop buffers around Olympic Eastbound / Purdue Nearside and Olympic Westbound / Purdue Nearside*



species, level of maturity, and landscaping, and this measure cannot account for the presence of trees located on private property that cast shade on the public right-of-way. As a result, it is generally a less representative measure of tree shade access at bus stops. **Figure 29** illustrates this difference - while the Eastbound bus stop (on the bottom of each map) is very close to several trees, each tree provides relatively little canopy. Conversely, the Westbound bus stop (on the top of each map) is slightly further from the nearest public tree but benefits from substantially more shade due to the larger canopy of the trees present.

Conversely, because the measure of tree canopy includes trees on private property, it may give bus stops credit for shade that is actually being provided in the private realm. Additionally, while the canopy data captures more variation in the amount of shade produced by individual trees, this variation may not reflect current conditions in any given month and may more rapidly become out of date, as trees mature and as their canopy waxes and wanes across seasons.

Lighting

Adequate lighting at a bus stop allows waiting transit riders to see other people who are waiting at or approaching the stop at a level of detail that allows them to anticipate threats to their safety and take evasive action if necessary (Nain & Murdoch, 1997; American Public Transportation Association, 2009). Transit riders' ability to clearly see vertical objects (including other people) is primarily determined by the level of *vertical* illuminance, or the concentration of lumens falling on a vertical surface, which is measured in foot-candles (American Public Transportation Association, 2009). The American Public Transportation Association's (2009) security lighting standards recommend an average illuminance level of 3 foot-candles and a minimum illuminance level of 0.5 vertical foot-candles for open exterior transit facilities. While local lighting guidelines do not differentiate between vertical and horizontal illuminance (the concentration of lumens falling on a horizontal surface, like the road), the current Caltrans Roadway Lighting Manual recommends that illuminance at bus stops be between 2-3 footcandles (California Department of Transportation Division of Traffic Operations, 2021), and the Los Angeles Bureau of Street Lighting sets a standard of 2.5 footcandles at bus stop facilities, which is consistent with the state recommendation (City of Los Angeles Bureau of Street Lighting, 2007).

Illuminance at a bus stop is determined by a variety of factors, including how bright the surrounding streetlights are and how far the bus stops are from these critical sources of light. Therefore, this project calculated the distance between each bus stop and the nearest streetlight using streetlight locations published by the LA Bureau of Street Lighting (Los Angeles Bureau of Street Lighting, 2020). However, this measure is limited, because it only reflects proximity to streetlights and cannot account for streetlights' illumination levels or whether they are in working condition.

Priority Level

This project assigned each bus stop to a priority tier with a methodology designed to largely mirror STAP's methodology, with key differences described in detail below. As a part of STAP, StreetsLA developed a methodology to prioritize the placement of new bus shelters based on ridership, residential demographics, heat exposure, service frequency, and proximity to key destinations.

In its prioritization work for STAP, StreetsLA only scored bus stops that do not already have a bus shelter to guide the allocation of new shelters across currently unsheltered stops. In contrast, this project calculated prioritization scores for all bus stops with service in Fall 2023. Having scores for all stops is critical to understanding how desirable the current distribution of bus amenities is and understanding which existing bus shelters should be replaced or relocated. Additionally, the STAP prioritization was done with data from prior to the onset of the COVID-19 pandemic. In comparison, this project used data reflecting conditions in Fall 2023 to account for broad changes to ridership and transit service that have taken place in the last four years, including the implementation of the Metro NextGen Bus Plan. Points were assigned to stops as follows, where higher points equated to a higher priority level:

Ridership: 4 points were awarded if a stop met a set ridership threshold (100 average weekday boardings) and 1-3 additional points were awarded on the basis of ridership relative to ridership in other stops within the same Council District. While the original STAP prioritization used average weekday boardings from October 2019, this project used average weekday boardings from October 2023, collected separately from Metro, Big Blue Bus, and LADOT Transit. While transit ridership has continued to grow in the recovery from the onset of the COVID-19 pandemic, current ridership relative to "pre-pandemic levels" has wide variations across stops and routes, and current ridership is more likely to accurately represent the variation in stop-level ridership in coming years than pre-pandemic ridership. Moreover, there have been widespread service changes since 2019, which have altered frequencies and created new routes, further limiting the applicability and coverage of pre-pandemic ridership.

Residential Demographics: 4 points were awarded if a stop was located in a Metro Equity Focus Community (EFC). Metro designates census tracts as EFCs based on a Metro Equity Need Index (MENI) score that accounts for what percentage of households in the census tract have incomes below $60,000, what percentage of households in the census tract do not have access to a vehicle, and what percentage of residents in the census tract are people of color. While the original STAP prioritization used EFC designations from 2019, this project used Metro's updated EFC designations from 2022 (Los Angeles County Metropolitan Transportation Authority, n.d., 2022). Metro's new equity-related work also includes a more nuanced approach that assigns all census tracts to one of five priority tiers based on its MENI score. However, this project used Metro's binary EFC designations, which consider census tracts assigned to the "Very High Need" or "High Need" tiers to be EFCs.

Projected Heat Exposure: 1-6 points were awarded based on the projected average maximum temperature during Heat Health Events during the months of June – August in the years 2021 – 2040 in the census tract that the bus stop is located in, according to the California Heat Assessment Tool (CHAT) (California Heat Assessment Tool, n.d.). Stops expected to face higher temperatures were awarded more points. This project used the same data source and projected temperature thresholds as the original STAP methodology.

Long Wait Times: 4 points were awarded if a stop served a low-frequency route. The STAP prioritization awarded points based on the initial planned frequencies in the Metro NextGen Bus Study, which considered a route to be infrequent if it was scheduled less than every 30 minutes during core service hours on weekdays. Given that the NextGen Bus Plan has been fully implemented with adjusted route frequencies, this project awarded points based on whether a stop actually served any routes that had low frequencies in Fall 2023. This project used the three transit agencies' GTFS data from Fall 2023 to calculate the average headway for each route (where each route's headway was defined as the median headway across all stops along the route) during weekday peak-hours (6AM-9AM and 3PM-7PM), and considered a route to be "low-frequency'' if the average weekday peak-hour headway was longer than 30 minutes. A stop was awarded points if it served any "low-frequency" routes.

Key Destinations: 0-4 points were awarded based on the number of nearby key destinations. The STAP scoring awarded points based on the number of destinations within 0.25 miles, and considered a broad variety of key destinations, including schools (including high schools, colleges, and universities), cultural facilities (including museums, theaters, and performing arts facilities), tourist destinations, medical facilities (including hospitals), employment centers, and commercial shopping districts. Since an accurate inventory of destinations to replicate the STAP methodology could not be recreated, this project used the STAP destination score directly for scored stops and the score of the nearest stop for unscored stops as a proxy for each stop's destination score.

After aggregating points across all metrics, stops were determined to be "higher-priority" if they received at least 11 points. This threshold aligns with the cutoff for Tier 1 or Tier 2 stops, which are the stops which StreetsLA considers for shelters on the basis of priority level.

Site Constraints

Sidewalk widths

There are a variety of site constraints that govern whether locations can accommodate existing bus shelter designs. The most notable constraint is that to comply with ADA requirements, shelters cannot interfere with the provision of a minimum 4-foot-wide clear path of travel for wheelchair users. The City's existing Transit Shelter Placement Guidelines assume a sidewalk width of at least 8 feet to accommodate a non-advertising shelter and at least 10 feet to accommodate an advertising shelter, while maintaining a clear path of travel (Los Angeles Office of the City Clerk, 2022). This project used a publicly available dataset of polygons representing the geospatial locations of sidewalks that was produced by the Los Angeles Bureau of Engineering for the citywide analysis (Los Angeles Bureau of Engineering, 2021). The widths of each sidewalk segment were recalculated using code primarily drawn from the work of Meli Harvey (Harvey, 2020/2023), and each initial sidewalk polygon was assigned the maximum calculated width of any of its segments.

Although the published sidewalk data includes calculated widths, sidewalk widths were recalculated because the Bureau of Engineering's algorithm uses the minimum width when a single sidewalk feature contains variable widths. While this is a reasonable assumption for many applications, using a sidewalk's minimum width to represent its width at all points will substantially underestimate the potential to install bus shelters at bus stops, because bus stops are usually located at the widest point of the sidewalk when a sidewalk contains variable widths. In these cases, the sidewalk usually runs from the property line to the curb in the bus stop area despite otherwise being separated from the street by a grass parking strip. **Figure 30** depicts a representative bus stop at a sidewalk with a variable width and the shape of the corresponding sidewalk polygon, demonstrating the importance of recalculating sidewalk widths for the purpose of understanding bus stop site constraints.

***Figure 30**. Example of bus stop at sidewalk with variable width comparing image of actual sidewalk (top) and shape of the associated sidewalk polygon (bottom) at Roscoe Westbound / Peoria Nearside*

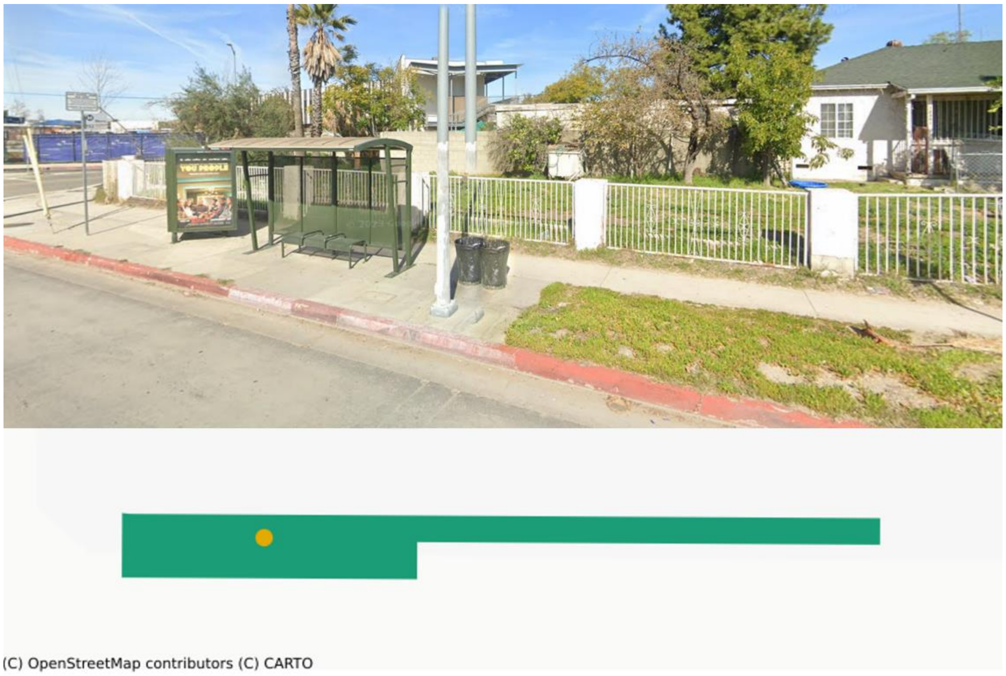


Image source: Google Maps Street View

The sidewalk width at each bus stop was determined by spatially joining each bus stop point to the nearest sidewalk polygon. Sidewalk values were excluded if the calculated distance between the stop and its nearest sidewalk was more than 10 meters, which resulted in the exclusion of 9% of bus stops. This threshold was determined through manual inspection of a sample of 15 bus stops on Google Maps Street View. While the bus stops with calculated distances slightly below 10 meters from the nearest sidewalk (i.e., those 7.5-10 meters away) had overwhelmingly been associated with the correct sidewalk, about half of bus stops with calculated distances slightly above 10 meters (i.e., those 10-15 meters away) had been associated with the wrong sidewalk. Bus stops can spatially join to an incorrect sidewalk for a variety of reasons, the most common being spatial inaccuracy in the bus stop location data or missing data in the original sidewalk polygon data. Sidewalk polygons can be missing from the original data if they were unable to be digitized from the aerial imaging because they were completely obscured by tree canopy or if the coloring of the sidewalk and adjacent pavement were too similar for the sidewalk to be detected (Los Angeles Bureau of Engineering, 2021). Occasionally, bus stops were associated with an incorrect sidewalk because there actually is no sidewalk at the bus stop, but this occurs much less frequently than data quality and data availability issues, so this project treats all stops over 10 meters from the nearest sidewalk as having missing sidewalk data. An inability to reliably identify bus stops located in places without a sidewalk present is one limitation of this analysis.

Since this project was focused on how sidewalk widths constrain bus shelter installations, the impact of recalculating widths was only evaluated regarding how the recalculations changed which sidewalks were believed to be at least 10 feet wide and which sidewalks were believed to be at least 8 feet wide. A sample of the sidewalk segments that had been associated with a bus stop (and were thus included in the analysis) and had recalculated widths that crossed one of these thresholds were investigated through a combination of visual inspection through Google Maps Street View and use of the site-visit data. For about 700 bus stops (about 8% of all stops), the published widths implied that the stops could not accommodate shelters that the recalculated widths implied the stops could accommodate. These instances overwhelmingly represented cases like the bus stop depicted in **Figure 30**, which motivated the recalculation of sidewalk widths. In most of these cases, the original published widths were about 5 feet and the recalculated widths were 10 or more feet, and manual inspection of the stops found that the stops were in areas that did have wide sidewalks.

For about 800 bus stops (about 9% of all stops), the converse discrepancy occurred, where the original published widths implied that the stops could accommodate shelters that the recalculated widths implied the stops could not accommodate. In these cases, the original published widths were typically at a threshold that the recalculated widths were slightly below - for example, the published width of the sidewalk was 10 feet and the recalculated width was 9.5 feet. Some of these discrepancies could have occurred because the calculated widths only contain integer values, although the Bureau of Engineering does not explain how its algorithm rounded calculated values. In these instances, manual spot checks revealed that neither set of calculated widths were substantially more likely to be correct. As a result, the data were treated as missing if original published widths implied that the stops could accommodate shelters that the recalculated widths implied the stops could not accommodate. This resulted in a final dataset with sidewalk widths for 83% of stops.

Street and Land-Use Classifications

Bus shelter siting is also constrained by the zoning classification of adjacent streets and properties. Bus shelters are not permitted along hillside local or hillside limited streets or along local streets adjacent to residential land uses. Additionally, bus shelters are unlikely to be installed near single-family residential land uses, although StreetsLA evaluates potential shelter sites in residential areas on a case-by-case basis (unless the site is along a local street, in which case shelters are not allowed) (Los Angeles Office of the City Clerk, 2022). This project used data on street classifications from the Mapping and Land Records Division of the Los Angeles Bureau of Engineering (Los Angeles Bureau of Engineering, Mapping and Land Records Division, 2020) and data on zoned land uses from the Los Angeles Department of City Planning (Los Angeles City Planning, 2023).

This project associated each bus stop with the nearest street centerline to determine each bus stop's street classification. These street classifications were excluded if the calculated distance between the stop and the nearest street centerline was more than 75 feet, which resulted in data being missing for 3% of bus stops. This threshold was determined by manually inspecting all 50 bus stops that were 65 to 100 feet from the centerline of the nearest street and identifying the threshold at which most bus stops had been associated with the correct street. Street classifications are usually missing if the bus stop is located on a private street (such as within the UCLA campus).

This project calculated two measures, the nearest land use and the dominant land use on the bus stop's block, to determine the land use around each stop. The nearest land use was determined by associating each bus stop with the nearest zoned area. This project also created an area representing the "block" that the bus stop is located in (the area along both sides of the street that the bus stop is located on that can be accessed without crossing a perpendicular street) for land-use determinations. The block was created by generating a 75-foot buffer around each bus stop's nearest street centerline, clipped to all other street centerlines. This project then calculated the area zoned for each land use within this block and designated the land use accounting for the largest share of total area as the dominant land use. Since the 75-foot buffer around each street centerline only contains a small portion of the adjacent properties, this functionally determines the dominant land use based on each use's contribution to the total frontage along the street. **Figure 31** shows two bus stops along the block of Saticoy St from Louise Ave to Amestoy Ave, the centerline of the street the stops are on (Saticoy St), the boundaries of the block generated by this process, and the zoned areas that were used to determine the dominant land use of this block. This example also shows that while Saticoy Eastbound / Louise Farside (on the left) is nearest to a commercially zoned area, and Saticoy Westbound / Amestoy Farside (on the right) is nearest to a single-family zoned area, both are on a block where the dominant land use is single-family residential. Since bus shelter siting decisions are evaluated on a case-by-case basis, this project considered bus stops on non-local streets where *either* the nearest or dominant land use was single-family residential to be bus stops where zoning could cause a restriction on the installation of bus shelters. This metric therefore represents a ceiling on the limitations imposed by this restriction and is not meant to reliably identify individual stops where shelters would be blocked, but rather highlight trends in land-use-based restrictions.

Figure 31*. Example of processed street and land-use data at Saticoy Eastbound / Louise Farside and Saticoy Westbound / Amestoy Farside bus stops*

Other Restrictions

Finally, there are a variety of other requirements that bus shelter placements must also satisfy. To accommodate a new shelter, sidewalks must be in adequate condition, have a lateral grade (the grade perpendicular to the street) of at most 2 degrees, and a longitudinal grade equal to the street's grade. Additionally, the City must maintain the a variety of clearances to ensure minimal interference with pedestrian circulation, driver lines of sight, and access to other sidewalk elements, such as maintaining at least 5 feet of clearance from fire hydrants and 10 feet of clearance from tree trunks (Los Angeles Office of the City Clerk, 2022). Whether a shelter could be placed at a bus stop while meeting these conditions could not be determined at scale for a variety of reasons, including limited data availability, inaccuracies in the bus stop locations, and the city's power to choose to remove some elements to make room for a bus shelter if doing so is determined to be the best choice for a given site. However, it is important to note that existing bus shelter designs could not be installed at all bus stops that satisfy sidewalk, street classification, and land-use requirements.

Appendix II: Bus Stop Environmental Assessment Form

Stop Name: **Survey ID:**

1.1 Which **transit agencies** have routes that stop here?	☐ Metro ☐ Big Blue Bus ☐ LADOT ☐ Other:
1.2 Is there clear **signage** showing which routes stop here?	☐ Yes ☐ No
1.3 Is there a **real-time arrival screen** at this bus stop?	☐ Yes, functioning ☐ Yes, non-functioning ☐ No
1.4 Is there a **trash can**?	☐ Yes ☐ No
1.5 Is there **seating**?*	☐ Yes, advertising bench ☐ Yes, seating in bus shelter ☐ Yes, other: ☐ No
2.1 Is there a **bus shelter**?*	☐ Yes, city advertising shelter ☐ Yes, city non-advertising shelter ☐ Yes, other bus shelter ☐ No
2.2 Does the bus shelter have a **functioning integrated light?**	☐ Yes ☐ No ☐ N/A (no bus shelter)
2.3 Are there any **trees** that can provide shade at this bus stop?*	☐ Yes, substantial shade ☐ Yes, minimal to no shade ☐ No nearby trees
2.4 Are there any **other potential sources of shade**?*	☐ Yes, specify: ☐ No
3.1 How close (in feet) is this bus stop to the **nearest streetlight?**	
3.2 What is the **type** of the nearest streetlight?*	☐ Traditional streetlight ☐ Pedestrian-scale streetlight ☐ Utility lighting
3.3 Is the streetlight **nearest** to this bus stop broken (off or flickering)?	☐ Yes, off ☐ Yes, flickering ☐ Not broken
3.4 What **proportion** of the streetlights visible from this bus stop are broken (off or flickering)?	☐ None ☐ Some (1-33%) ☐ Many (34-66%) ☐ Most (67-100%)
3.5 Are there other **sources of light** that meaningfully increase the illumination at this bus stop? *Select all that apply.*	☐ Lighting within bus shelter ☐ Permanent business/residence ☐ Mobile business ☐ Other (specify): ☐ No
3.6 Do nearby trees **block or reduce** the lighting at this stop?	☐ Yes ☐ No
3.7 What is the **measured illuminance** level (in footcandles) at this bus stop?*	Upwards: Left: Right: Towards street: Away from street:

3.8 What is the **measured illuminance** level (in footcandles) five feet from the nearest streetlight?*	Upwards: Towards streetlight:
3.9 How **well-lit** does this bus stop feel?	☐ Not at all well-lit ☐ Somewhat well-lit ☐ Very well-lit
4.1 Does this stop have a **sidewalk** present?	☐ Yes ☐ No
4.2 How **wide** (in feet) is the sidewalk?	
4.3 What is the sidewalk **grade** perpindicular to the street?	
4.4 What is the condition of the **sidewalk pavement quality** at this bus stop?*	☐ Good ☐ Fair ☐ Poor
5. Assess the possibility of constructing a bus shelter here.	
5.1 Is there a 16' long by 8' wide section of sidewalk available or could one be easily constructed?	☐ Yes, already available ☐ Yes, possible with moderate re(construction) or paving ☐ No, and not possible without major re(construction)
5.2 Are there any **building entrances/exits** that would prevent a shelter from maintaining **3' of clearance**?	☐ No ☐ Yes - Specify:
5.3 Are there any **vertical/subgrade elements or ventilation grates** that would prevent a shelter from maintaining **5' of clearance**?	☐ No ☐ Yes - Specify:
5.4 Are there any **driveways, access ramps, or trees** that would prevent a shelter from maintaining **10' of clearance**?	☐ No ☐ Yes - Specify:
5.5 Are there any **alley intersections** that would prevent a shelter from maintaining **20' of clearance**?	☐ No ☐ Yes - Specify:
5.6 Are there any **non-controlled street intersections** that would prevent a shelter from maintaining **45' of clearance**?	☐ No ☐ Yes - Specify:
6.1 Please use this space to record any other notable bus stop features or comments related to prior questions.	

*See surveyor guide for additional descriptions or information