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Original article

Elevating street trees to infrastructure status: A comparison of street tree spacing guidelines in Los Angeles with U.S. peer cities

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ABSTRACT

While researchers recognize the health and ecological benefits of green infrastructure, at the level of city governance trees are relegated to second class status compared to other infrastructure with which they compete for space in the public right-of-way. The result is an unwelcoming environment for walking, cycling, and socializing, particularly in disadvantaged neighborhoods, at a time when city governments are also pursuing ambitious plans for Complete Streets and green infrastructure to address compound challenges related to health, equity, and the environment. This article contributes a thorough review of municipal street tree spacing guidelines through a comparison of guidelines in eight California and nine large U.S. cities, consideration of their change over time, an in-depth examination of laws applying to tree placement in Los Angeles, and interviews with City of Los Angeles staff. Results demonstrate that guidelines in many of the municipalities studied are more restrictive than legally required, vary greatly between cities even while evidence does not support the efficacy of one approach over another, and have not changed substantially over time to align with shifting priorities. Centralized control of the right-of-way could help align guidelines and practice with municipal goals and facilitate consideration of competing priorities.

1. Introduction

The world's population is growing increasingly urban with the percentage of the population living in urban areas expected to increase from 55 % in 2018 to 68 % in 2050 (United Nations, 2018). In many U.S. cities, zoning codes are being amended to encourage additional density to accommodate this growing population, through easing restrictions on height, setbacks, Accessory Dwelling Units (ADUs), lot divisions, and parking, among other things. This will ultimately decrease the area of open space on privately-owned land, leaving residents increasingly reliant on public green space (Haaland and Van Den Bosch, 2015). The public right-of-way, a term used in the U.S. for the public space given to transportation functions, including streets and sidewalks, offers perhaps the single greatest opportunity to reimagine public space for a denser future, given the area it commands, its proximity to all residents, and the control that the government has over it (Laurian, 2019; Prytherch, 2018 p. 48–49). Roads alone comprise 20–30 % of urban land area (Clifton et al., 2008), with a whopping 70 % of public space dedicated to automobiles (Mueller et al., 2020).

Just as cities are changing policies to accommodate increased density, policies which shape the right-of-way must be considered to realize public spaces that will best serve the health and well-being of residents. There is a current movement away from automobility in the U.S. and toward recognition of streets as places for walking, biking, and socializing. This is evident in the proliferation of Complete Streets policies, which strive to accommodate diverse populations and transit modes (Gregg and Hess, 2019), and programs like Great Streets, People Streets, Play Streets, and Open Streets in the City of Los Angeles (City of Los Angeles Department of Transportation, n.d.), which positions the street as a social space, a shift accelerated by the COVID-19 pandemic (Moreno

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et al., 2021). Green space is critical to encouraging these functions and is part of the larger concept of green infrastructure, a topic of increasing interest for its potential to deliver diverse co-benefits to human health and well-being (e.g., reduced stress, increased physical activity), the environment (e.g., improved air and water quality), and the economy (e.g., reduced energy costs and mediated impacts of extreme heat and flooding) (Nieuwenhuijsen, 2021; Parker and Zingoni De Baro, 2019). This confluence of interest in the right-of-way, and the need to increase open and green space to meet per capita goals as urban populations increase, suggests that now is the time to make real progress toward municipal policies which support these goals.

Street trees are the most frequently considered type of green infrastructure in city policies. They are owned and cared for by municipalities and they provide substantial benefits given their proximity to people and the built environment (Aryal et al., 2021; Coleman et al., 2022). This article examines city policies dictating street tree placement relative to other so-called "gray infrastructure" using a thorough review of guidelines in the City of Los Angeles and comparisons with peer cities in California and the U.S.

1.1. Green and gray infrastructure

While the term green infrastructure has only been widely used since 2012 (Parker and Zingoni De Baro, 2019), the right-of-way as green space and recognition of its myriad functions is not new. Street trees have been planted in Paris since the 1300 s and have since been one of the city's defining features (Laurian, 2019). Frederick Law Olmsted extolled the importance of connected landscapes to realize the ecological and social benefits of green spaces in the 19th century (McMahon, 2000). Early 20th century supporters of street trees in the U.S. decried the lack of space provided for them as roads became increasingly car-dominated (Mulford, 1920). The importance of streets to social life was famously opined by Jane Jacobs (1961). More recently, scholars have suggested that the use of streets for public green space could contribute to this social function, with Pincetl and Gearin (2005) encouraging cities to use "feral land" (e.g., streets, alleys, parking spaces) for public green space. The Dutch "Woonerf" concept establishes shared streets prioritizing pedestrians in which landscaping plays a crucial role (Ben-Joseph, 1995). Superblocks, implemented in Barcelona, similarly reclaim local streets as public space (Mueller et al., 2020), and Li and Wilson (2023) have shown how this could be accomplished in Los Angeles.

In demanding more of the right-of-way, it is important to recognize the numerous uses competing for space, those elements commonly referred to as gray infrastructure. These include paved surfaces, utilities, signage, and streetlights, to name a few (Cameron and Blanuša, 2016). Idealized visions of Complete Streets and the full benefits of green infrastructure require coordinated, interconnected networks (Gregg and Hess, 2019; Nieuwenhuijsen, 2021). Yet planning in the right-of-way takes place in departmental silos, a division of labor that challenges coordination (Zabel and Häusler, 2024). The diagram in Fig. 1 explains who constructs and maintains the right-of-way in Los Angeles, from the City's *Great Streets DIY Manual* (itself a telling title) (City of Los Angeles, 2017). Street trees, representing only one small piece of this puzzle, are planted and managed by an array of city departments, non-profits, and property owners (Eisenman et al., 2021; Smart et al., 2020).

1.2. Role of policy

Clear policies are critically important in this context, providing common requirements for everyone to follow. One primary means of communicating these standards for street trees is with spacing

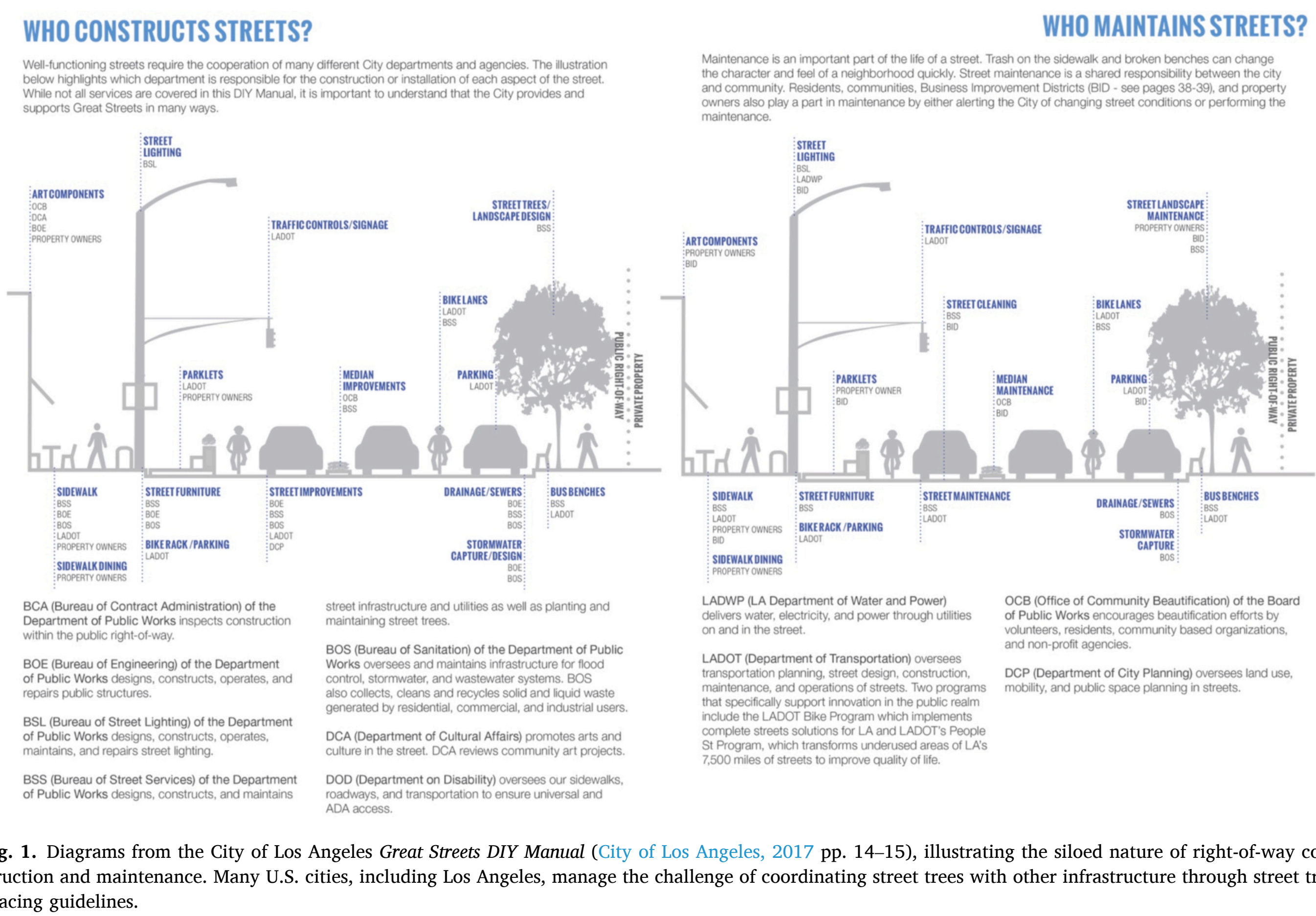

Fig. 1. Diagrams from the City of Los Angeles *Great Streets DIY Manual* (City of Los Angeles, 2017 pp. 14–15), illustrating the siloed nature of right-of-way construction and maintenance. Many U.S. cities, including Los Angeles, manage the challenge of coordinating street trees with other infrastructure through street tree spacing guidelines.

guidelines, which outline the distances that trees must maintain to gray infrastructure elements and to each other. These guidelines serve to severely limit the available area for planting new street trees and result in large expanses of unshaded hardscape, yet few studies address this topic (Macdonald et al., 2006; Monteiro et al., 2020).

There is relatively more existing literature on policies more broadly defined, for example the presence and quality of tree regulation plans (Conway and Urbani, 2007; Dempsey, 2022; Kolosna and Spurlock, 2019; Romero, 2021), the management of such policies, in the form of staff, community support, and financial investment (Hilbert et al., 2019; Hill et al., 2010; Romero, 2021; Warren et al., 2011), or tree preservation ordinances (Galenieks, 2017; Hilbert et al., 2019; Landry and Pu, 2010). Among studies which compared outcomes, policies were generally positively correlated with greenness or canopy measures, supporting the view that policy is important (Conway and Urbani, 2007; Hilbert et al., 2019; Landry and Pu, 2010).

Braverman (2008) digs deeper into the "less prestigious (and also less scrutinized) forms of legal norms and practices" that regulate street construction, and by extension trees, such as professional engineering standards. These standards, such as the "Green Book" from the American Association of State Highway and Transportation Officials (AASHTO), are deeply entrenched in engineering practice (Prytherch, 2018 p. 78). They directly influence tree placement, especially through requirements for clear sight triangles at intersections, intended to promote safety for pedestrians and vehicles. Macdonald et al. (2006) summarized tree spacing guidelines in 30 California cities and analyzed intersection requirements, finding that trees are more strictly regulated than other right-of-way elements at intersections, such as parked cars.

1.3. Evidence of performance differences

Tree spacing standards vary tremendously between cities, yet there is little evidence that one standard outperforms others with respect to tree health, human safety, or municipal liability (Aryal et al., 2021; Coleman et al., 2022; Macdonald et al., 2006). The ideal spacing of trees from each other is generally addressed in studies related to commercial forestry and silviculture which consider tree spacing in gridded arrays, not the linear rows typical of street trees (Aryal et al., 2021). In that context, there is some evidence that reduced spacing may result in accelerated early growth, possibly due to a reduction in evaporative water loss (Erkan and Aydin, 2016). The only article located which considers street tree spacing found that trees planted closer together had canopies which extended perpendicular to the street and were larger, although tree management practices such as pruning were not considered (Aryal et al., 2021). Other aspects of tree interaction with gray infrastructure, such as tree pit size, tree grates, and sidewalk width, were found to be important to tree health for some species in Kyoto City, Japan (Tan and Shibata, 2022).

Considerations of public safety and municipal liability go hand in hand, with lawsuits filed against local governments for negligent design or maintenance (Prytherch, 2018 pp. 70–71), as well as trip and fall injuries and non-compliance with the Americans with Disabilities Act (ADA), in part due to tree-related sidewalk damage (Galperin, 2021; Mullaney et al., 2015). Safety concerns generally relate either to visibility or roadside "clear zones," a practice that became standard after a 1966 congressional hearing on automobile safety, which are intended to minimize vehicle collisions with roadside fixed objects (Eisenman et al., 2021; Marshall et al., 2018). Many existing studies focus on driver safety with respect to trees in the clear zone, generally finding that it is important to consider rural and urban contexts differently and that in the urban context, roadside trees may actually have a protective effect by making the road feel narrower which can lead to decreased driving speeds (Cox et al., 2017; Eisenman et al., 2021; Marshall et al., 2018; Wolf and Bratton, 2006). Zhu et al. (2022) provide a rare example considering safety for pedestrians, finding that in Melbourne, Australia, pedestrian casualties decreased when street tree density and canopy increased. In a simulation experiment, Macdonald et al. (2006) found that high-branching street trees near intersections did not significantly impact driver visibility, or at least impacted visibility much less than did other common objects, such as parked cars.

This article builds on the work of Macdonald et al. (2006), expanding their survey of tree spacing guidelines to U.S. cities outside of California and comparing updated guidelines to analyze change over time. It also adds an in-depth look at the motivations behind existing guidelines, through review of legal codes and interviews with city staff, to better understand the challenges and opportunities for revising them to answer the following research questions:

1. To what extent are guidelines in current use dictated by law? How difficult would they be to change?
2. What evidence exists regarding efficacy of current guidelines with respect to safety or tree health?
3. Are there emerging best practices that increase urban canopy while maintaining safety? What elements should a model code consider?
4. Have guidelines shifted in the last 20 years? Have planning ideals been operationalized?

2. Data and methods

2.1. Study area

Dense cities are not necessarily compact. Perhaps nowhere exemplifies what William Fulton termed "dense sprawl" better than Los Angeles, California (Eidlin, 2005), a condition which presents significant barriers both to private green space as well as access to public open space in parks. Tree cover on private property declined in Los Angeles County by 13.6 % from 2000 to 2009 (Lee et al., 2017). This trend is likely to continue as small bungalows and houses built in the post-war period are replaced with large homes, and accessory dwelling units are incentivized to create affordable housing. Extreme heat days are projected to at least triple in many parts of the city by 2050. This hazard will impact some communities more severely based on the microclimate, disparities in their existing tree canopy, and their reliance on public transportation. Recent studies indicate that only one quarter of bus stops have transit shelters in Los Angeles (Turner et al., 2023). Given this context, the City of Los Angeles could benefit greatly from the kind of distributed, public green space which could be provided by a robust network of street trees and parkways.

2.2. Data

This study gathered tree-related guidelines from Los Angeles as well as other California and U.S. cities. Table 1 outlines the selected cities, inclusion criteria, and the guidelines or standards reviewed. California cities were identified using Macdonald et al. (2006), selecting those cities with the least restrictive tree spacing requirement for at least one element, and updating the metrics based on a review of current guidelines. Peer cities in the greater U.S. were selected based on their population being within the top 30 in the U.S., having been designated a "Tree City USA" for at least 25 years, and having received a Growth Award as a Tree City. The Tree City USA program is led by the Arbor Day Foundation and indicates that cities have met four core standards, including formation of a tree board or department, adoption of a tree care ordinance, establishment of a community forestry program, and observance of Arbor Day. Growth Awards are given in recognition of additional efforts beyond those core standards (Arbor Day Foundation, n.d). These designations were used as a means of identifying cities which have shown a sustained interest in urban forestry and may be more likely to have tree spacing guidelines which are designed to support a robust tree canopy. While New York City has not received a Growth Award, it was included due to its long tenure as a Tree City (27 years) and its status as the most populous city in the U.S.

Table 1
Cities included in study, with inclusion criteria and tree spacing guidelines reference.

City	State	Top 30 Pop.	Tree City USA		California	Guidelines Reference
			No. of years	Growth Award (No. of years)	Included in Macdonald et al. (2006)	
Los Angeles	**California**	●				City of Los Angeles Department of Public Works (2023)
New York	New York	●	27			City of New York Parks and Recreation (2016)
Chicago	Illinois	●	41	21		City of Chicago (2000)
Phoenix	Arizona	●	37	27		City of Phoenix Water Services Department (2021), City of Phoenix (2012, detail 230)
Philadelphia	Pennsylvania	●	47	16		City of Philadelphia Department of Streets (2021, pp. 8–10)
San Jose	California	●			●	Dudek (2021)
Fort Worth	Texas	●	44	23		City of Fort Worth (2020)
Charlotte	North Carolina	●	43	2		City of Charlotte (2023), Charlotte Urban Forestry (2022)
San Francisco	California	●	15/36**		●	City and County of San Francisco (2018)
Seattle	Washington	●	38	23		Seattle Department of Transportation (2020), Trees for Seattle (n.d.)
Nashville*	Tennessee	●	28	11		Metropolitan Government of Nashville and County (n.d.)
Portland	Oregon	●	46	26		Portland Parks and Recreation (2016)
Fresno	California		20		●	City of Fresno Public Works Department (n.d.)
Oakland	California		36		●	City of Oakland, California (n.d.)
Anaheim	California		39		●	City of Anaheim Department of Public Works (2003)
Freemont	California				●	City of Fremont (2005)
Pleasanton	California		7		●	Data could not be located, used Macdonald et al. (2006)

* Nashville-Davidson Metropolitan Government (balance)
** San Francisco County / South San Francisco

In addition, federal, state, and local codes and standards applying to the City of Los Angeles were reviewed and are outlined in Table 2. Finally, a series of four semi-structured interviews were conducted with staff with the City of Los Angeles in the Fall of 2023, including with members of the Board of Public Works Office of Forest Management and staff from the Department of City Planning Urban Design Studio on September 28, staff from the Bureau of Street Services Urban Forestry Division on October 19, the Bureau of Street Services on November 13, and the Sidewalk Division within the Bureau of Engineering on November 30. Regular meetings with city staff as part of ongoing work with the Urban Trees Initiative also provided useful insight.

2.3. Methods

Using the work of Macdonald et al. (2006) as a starting point, a comparative table for each element in the right-of-way was created to identify the California cities with the least restrictive requirement for at least one element. This approach assumes that guidelines already implemented are adequate in terms of safety and those which are least restrictive are best suited to support an expanded tree canopy. Given the almost two decades that have passed since the work of Macdonald et al. (2006), information was verified and updated as necessary based on a review of current guidelines. Municipal guidelines for California and other U.S. cities pertaining to trees were found with Google searches for "[City] tree spacing guidelines," "[City] tree spacing," and "[City] tree standards," as well as through review of websites for various city agencies, in particular public works and urban forestry, and standard plans published by bureaus of engineering.

Extensive review was conducted of codes and standards applicable to Los Angeles at the federal, state, and local level with the assumption that regulation of the right-of-way with respect to trees would generally be concerned with safety and visibility, space for utilities and their maintenance, and accessibility for those with disabilities. Once located, documents were searched using keyword "tree" as well as for individual gray infrastructure elements (e.g., "fire hydrant"). Additionally, tables of contents were reviewed for sections of possible relevance. Additional codes and standards were identified through the interviews with city staff.

Interviews were conducted over Zoom and Google Meet and followed a semi-structured format, primarily aimed at understanding the

Table 2
Codes and guidelines at federal, state, and local levels reviewed applying to the City of Los Angeles.

Codes and Guidelines Reviewed	Source	Federal	State	Local
Public Right-of-Way Accessibility Guidelines	U.S. Access Board (2023)	●		
California Streets and Highways Code	California Legislative Information (n.d.)		●	
2019 California Fire Code	International Code Council (2019)		●	
Natural Resources - Department of Forestry and Fire Protection	Thomson Reuters (n.d.)		●	
2022 California Building Code	International Code Council (2022)		●	
Pedestrian-Rail Crossings in California	California Public Utilities Commission (2008)		●	
2020 City of Los Angeles Fire Code	International Code Council (2020)			●
City of Los Angeles Municipal Code	City of Los Angeles (2024)			●
Standard Plans	City of Los Angeles Bureau of Engineering (n.d.)			●
Street Design Manual	City of Los Angeles Bureau of Engineering (1986)			●
City of Los Angeles Supplemental Street Design Guide	City of Los Angeles Bureau of Engineering (2020)			●
City of Los Angeles Complete Streets Design Guide	City of Los Angeles (n.d.)			●
Parkway Landscaping Guidelines	City of Los Angeles Bureau of Street Services (2023)			●
Manual of Policies and Procedures	City of Los Angeles Department of Transportation (2023)			●
Natural Gas Service Guidebook	SoCalGas (2023)			●

ways that existing codes are implemented, the motivations behind them, and the perceived challenges of loosening guidelines. Interview questions were outlined in agendas in advance and included more specific questions pertaining to code requirements (e.g., clarification as to whether trees are permitted in the clear sight triangle at intersections following an exception in the Municipal Code) as well as more open-ended questions (e.g., What are the greatest challenges to fitting street trees into the existing right-of-way?) Interview subjects were chosen based on guidance from long-term collaborators within the City of Los Angeles.

3. Results

3.1. Peer city comparison

Los Angeles guidelines are compared with those of other California cities in Table 3 and other U.S. cities in Table 4, considered separately because of feedback during interviews that it is important to consider municipal policies which share common state-level regulations, and that California is uniquely litigious among U.S. states. The California cities in this study include Anaheim, Fremont, Fresno, Oakland, Pleasanton, San Francisco, and San Jose. U.S. cities include New York, Chicago,

Table 3
Tree spacing guidelines in California cities, given as the distance (in feet) of clearance required from gray infrastructure elements to street trees. The minimum clearance for each gray infrastructure element is summarized in the "California Minimum" column.

	Distance of Tree (feet)								
	Anaheim	**Fremont**	**Fresno**	**Oakland**	**Pleasanton**	**San Francisco**	**San Jose**	**Los Angeles**	**California Minimum**
Tree Spacing (by size of tree)									
Small		35	20	15-20	45	15-20		**25-40**	**15**
Medium		35	20	20-25	45	20-25		**25-40**	**20**
Large		35	20	25-35	45	35		**25-40**	**25**
Intersections									
Signalized									
Approach to Intersection	40	15	30	20		25	40	**50**	**15**
Departure from Intersection	25	15	30	20		5	40	**50**	**5**
Unsignalized									
Approach to Intersection	25	15	30	20		25	40	**45**	**15**
Departure from Intersection	10	15	30	20		5	40	**45**	**5**
Stop sign									
Approach to Intersection	25		30			20	20		**20**
Departure from Intersection	10		30			20	20		**10**
Alley entrance			15					**20**	**15**
Driveway apron									
Residential	10	8	10	5	10		5	**8**	**5**
Commercial	10	8	10	10	10		10	**8**	**8**
Railroad tracks								**100**	**100**
Utilities and Fire Safety									
Utility pole			15	5		5		**20**	**5**
Streetlight (by tree size)									
Small	15	15	20	20		9	20	**20**	**9**
Medium	15	15	20	20		15	20	**20**	**15**
Large	15	15	20	20		21	20	**20**	**15**
Pedestrian Light								**15**	**15**
Water Meter or Vault				5			5	**6**	**5**
Water line									
Main		5	3	10					**3**
Other line		5	3						**3**
Sewer line									
Main	10	8	8	10			10		**8**
Other line	10	8	8	5			10		**5**
Catch Basin	5							**6**	**5**
Fire Hydrant	5	5	10	5		5	5	**10**	**5**
Gas Meter				5				**8**	**5**
Gas line		8	3	10					**3**
Underground utilities or utility box			5				5		**5**
Accessibility, Signage and Other									
Transit Shelter						6		**10**	**6**
Clear path of travel								**5**	**5**
Parking meter				3		3			**3**
Roadway sign									
Critical Safety						20	20		**20**
General	10		5			5	20		**5**
Parking	10		5			3			**3**
Distance from curb									
Standard	3	8				0-3			**3**
Restricted parking zone	3	8				8			**8**

Table 4
Tree spacing guidelines in U.S. cities, given as the distance (in feet) of clearance required from gray infrastructure elements to street trees. The minimum clearance for each gray infrastructure element is summarized in the "U.S. Min." column.

	Distance of Tree (feet)										
	New York	**Chicago**	**Philadelphia**	**Charlotte**	**Seattle**	**Nashville**	**Portland**	**Phoenix**	**Fort Worth**	**Los Angeles**	**U.S. Min.**
Tree Spacing (by size of tree)											
Small		20-25	15	30	20		25		25	**25-40**	**15**
Medium		20-25			20		25		25	**25-40**	**20**
Large		20-25	30	40	20		25		25	**25-40**	**20**
Intersections											
Signalized											
Approach to Intersection	40	30	30		30	25	25		40	**50**	**25**
Departure from Intersection	40	20	15		30	25	25		40	**50**	**15**
Unsignalized											
Approach to Intersection	40	30	15		30	25	25		40	**45**	**15**
Departure from Intersection	40	20	15		30	25	25		40	**45**	**15**
Stop sign											
Approach to Intersection	30		30				20				**20**
Departure from Intersection	30		15				20				**15**
Alley entrance											
Approach		20					5		15	**20**	**5**
Departure		10					5		15	**20**	**5**
Driveway apron											
Residential	7	10	10		7.5				10	**8**	**7**
Commercial	7	10	10		7.5				10	**8**	**7**
Railroad tracks		50								**100**	**50**
Utilities and Fire Safety											
Utility Pole	25		15	30	10		5			**20**	**5**
Streetlight (by tree size)											
Small	20	12	15	30	20	10	15		10	**20**	**10**
Medium		12	15	30	20	10	25		10	**20**	**10**
Large	30	12	15	30	20	10	25		10	**20**	**10**
Pedestrian Light			15	15						**15**	**15**
Water meter or vault											
Small to med. planting area	2				5		5	3		**6**	**2**
Large planting area	2				5		10	3		**6**	**2**
Water line											
Main	6		5		5		5	6-10			**5**
Other line	2		1.5		5		5	6-10			**1.5**
Sewer line											
Main			5		5			6-10			**5**
Other line			1.5		5			6-10			**1.5**
Catch Basin		5	5			10	5		10	**6**	**5**
Fire Hydrant	5	5	15	5		10	10	6		**10**	**5**
Gas Meter	2*				5			3		**8**	**3**
Gas line											
Main	2*		5		5		5**				**5**
Other line	2*		1.5		5		5**				**1.5**
Underground utilities/box											
Small tree				15	5	10	5		5		**5**
Large tree				15	5	10	5		10		**5**
Accessibility, Signage and Other											
Transit Shelter	5						5			**10**	**5**
Clear path of travel	4-6		3-5					5		**5**	**3**
Parking meter	5										**5**
Roadway sign											
Critical Safety			5				20/5***				**5**
General	6		5				10/5***				**5**
Parking	6		5				10/5***				**5**
Distance from curb											
Standard		2	1.5-3		3				1.5-2		**1.5**
Restricted parking zone	Do not plant	2	1.5-3		3				1.5-2		**1.5**

[*] From edge of tree bed; not considered when specifying U.S. minimum in final column
[**] 3 feet for small planting sites
[***] Clearance at front of sign / back of sign

Philadelphia, Charlotte, Seattle, Nashville, Portland, Phoenix, and Fort Worth. There is great variation in guidelines between cities, both in terms of which gray infrastructure elements are included and the buffers required around them. Current guidelines were located for all cities except Pleasanton, which used data from Macdonald et al. (2006). In addition to the gray infrastructure elements presented in Tables 3 and 4, there were several other elements that can impact tree placement which were included in the guidelines of only a single city, captured in Table 5.

Generally, codes and guidelines for gray infrastructure, as outlined in Table 2, do not address their relationship to trees. In the rare case in which a code states a buffer around a gray infrastructure element, it is typically less restrictive than the tree spacing guidelines require. For example, the California Fire Code requires three feet clearance around fire hydrants while the Los Angeles tree spacing guidelines require 10 feet (International Code Council, 2019 §507.5.5).

Guidelines have changed little during the past 20 years. Reductions were made in a few cases - from 15 to 10 feet for fire hydrants in Fresno and 25–50 feet to 15–25 feet between trees in Oakland. The greatest changes occurred in San Francisco, where reductions were made to intersection departure (10–5 feet), traffic signs (25–20 feet), and utility poles (6–5 feet). Los Angeles, on the other hand, *increased* the space required from driveways, from 6 to 8 feet. Several cities added a greater level of detail to their guidelines, with Los Angeles adding pedestrian lights, San Francisco adding streetlights, and Oakland adding driveways, streetlights, utility poles, and subsurface utilities.

3.2. Interviews

Several themes emerged across the four interviews conducted: 1) these are guidelines, not codes; 2) concern for safety and liability drives conservative tree spacing guidelines; 3) context matters when deciding how to implement the guidelines; 4) there is a tendency toward providing "more than enough" space; 5) bus stops present a unique challenge; and 6) the goal should be bigger shade trees, not always more trees.

1. Guidelines, not codes: Tree spacing guidelines are not rigidly enforced, with decisions made on a case-by-case basis and exceptions made, especially for small stature trees. At the same time, the 45-foot visibility triangle at intersections was mentioned repeatedly as a barrier.
2. Concern for safety and liability: One interviewee asserted that California is "one of the most litigated states." The obstruction of visibility for drivers by trees was a particular concern, especially at intersections, driveways, and alleys. Reliance on pruning to address visibility concerns is not desirable because trees are currently trimmed only once every 17 years. Tree root damage to sidewalks and driveways pose a hazard for trip and fall injuries and impede accessibility. Narrow sidewalks and parkways exacerbate these challenges.
3. Context matters: One reason that guidelines are not followed in some cases is that what is best varies for different street typologies, the speed of drivers (in particular for ingress and egress to driveways), whether the area is commercial or residential, whether approaching or departing from intersections, and the stature of a particular tree.
4. Tendency toward "more than enough": Many different departments, utility companies, and property owners may need to perform work on infrastructure in the right-of-way and prefer to have as much working space as possible. Workers may not take precautions to avoid damaging trees. Sometimes exact locations for subsurface utilities are not known in advance, so an additional margin of error is desirable. There is a desire to have "more than enough" room to perform maintenance with difficulty defining what would be "enough." Larger clearances than required are sometimes provided around street furniture, like bus shelters, to provide surplus room and ensure ADA compliance.
5. Coordination challenges at bus stops: While bus stops are one area with the greatest need for shade, they present a particular coordination challenge. LA's Metro system includes 26 transit operators who frequently change stop locations and can do so without approval from the City because they are overseen by the state Public Utilities Commission (PUC). Additionally, five different bus lengths have doors in different locations, so it is difficult to maintain a clear boarding area at all potential door locations.
6. Bigger, better trees, not necessarily always more: Given historically limited water supplies and maintenance challenges, more trees will not always be desirable. The focus should be on accommodating large-stature trees to support a robust canopy, maintaining existing trees, and enlarging tree wells to allow large trees to thrive.

Table 5
Tree spacing requirements included in guidelines for selected cities.

	Distance of Tree (feet)	City
Intersections		
Crosswalks	25	San Francisco
Traffic signals	20	San Jose
Driveway apron at cul-de-sac	4	Freemont
Utilities and Fire Safety		
Electrical		
Underground electrical	10	Oakland
Guy wire ground support	5	Fresno
Water, Sewer and Stormwater		
Sewer vents	5	San Francisco
Stormwater line	8	Freemont
Fire, Gas and Other Utilities		
Aboveground utility boxes	3	San Francisco
Fires escapes	10	San Francisco
Oil fill pipe	4 (from edge of bed)	New York
Coal chute	2 (from edge of bed)	New York
Accessibility, Signage and Other		
Basements	10	Oakland
Overhangs	5	Fresno
Concrete improvements	6	Fresno
Curb ramps	4	Pleasanton
Pedestrian furniture	3	San Francisco
Building entrances	Do not plant	New York

4. Discussion

4.1. Key findings

4.1.1. Guidelines are not dictated by law, making them easier to change

With a few exceptions, tree spacing guidelines are not driven by code requirements, but are more often addressed in standards and guidelines. Where codes exist, their requirements are often significantly less than the standard used for the tree spacing guidelines. The most impactful of these discrepancies is likely the setback of trees from intersections. Los Angeles Municipal Code requires that intersections "*without traffic control signals or stop signs* have a clear visibility triangle extending 45 feet from the intersection, *except trees trimmed to the trunk to a line at least 8 feet above the level of the intersection*" (emphasis added) (City of Los Angeles, 2024 §62.200). The need for a clear visibility triangle was brought up repeatedly in interviews with city staff; however, staff was generally unaware of this exception and it has not been implemented in practice. Substantial changes could be made to existing tree spacing guidelines without requiring any changes to existing laws and codes.

4.1.2. Guidelines are driven by coordination challenges and risk aversion

There is little evidence that one approach to tree spacing guidelines is better than another with respect to safety or tree health. Guidelines are instead motivated by coordination challenges and risk aversion. Tree spacing guidelines in the City of Los Angeles are more conservative than many other cities in California and the wider U.S. Brought up in every interview with city staff was the enormous challenge presented by doing work in the right-of-way due to the sheer number of elements needing to fit in a space-constrained area and the number of agencies involved in managing those elements. The challenge of coordinating work, the need for ongoing maintenance, and the feeling that dimensions for right-of-way elements are not precise, leads to a tendency to enlarge setback dimensions, as does general risk aversion (stemming at least in part from liability fears) and related resistance to change.

4.1.3. Little convergence around best practices over time

Tree spacing guidelines in the cities studied vary widely and have changed little (at least in California) over the last two decades, suggesting that no single approach has proven to perform the "best," echoing the limited findings from the literature. One area where there does seem to be an emerging best practice, however, is in consideration of a greater level of nuance. For example, some cities (e.g., San Francisco, Anaheim, Chicago), have different setback requirements for the approach vs. the departure side of intersections. Chicago guidelines similarly treat approach and departure sides of alley entrances differently. Driveway setbacks for commercial vs. residential use are treated differently in Oakland and San Jose while in San Francisco, New York, and Portland, guidelines require different setbacks at streetlights depending on tree stature. Some cities, including Oakland, New York, Philadelphia, and Portland, have different requirements for setbacks from utility lines depending on whether a main or branch line.

4.2. Linking to the literature

4.2.1. Right-of-way space is contested, and consideration of co-benefits is difficult

This study confirms the findings in the existing literature, that allocating space for street trees in the right-of-way is difficult due to the density of gray infrastructure and the lack of centralized control that can lead to poor communication and animosity between departments (Braverman, 2008; Zabel and Häusler, 2024). Coordination challenges hamper consideration of co-benefits when making decisions related to street trees. While planning goals commonly aim to reduce automobile dependence, requirements for clear sight triangles at intersections, for example, undercut those goals by making streets less hospitable to pedestrians (Macdonald et al., 2006). While driver safety is a leading concern motivating spacing guidelines, it would be difficult, given the diffuse responsibility for trees, to weigh this concern against the potential health and fiscal benefits of a pedestrian-friendly environment. Complete Streets policies, a widely adopted attempt to consider streets more holistically, have for the most part not been translated into practice, an indication of the headwinds cities face in approaching the right-of-way with co-benefits of trees in mind (Gregg and Hess, 2019).

4.2.2. Codes, guidelines, and practice do not align

Cities should follow the advice of Prytherch (2018 p. 2), that "any rethinking of the street…in *theory* must remain firmly grounded in the details of engineering and law *in practice*." This study aligns with the existing literature in finding that there are multiple margins for error seemingly added as engineering standards are translated to spacing guidelines and those guidelines are implemented in practice. Engineering standards themselves tend toward maximalism, designing around the largest vehicles and highest traffic volumes (Prytherch, 2018 p. 86). Where evidence exists that spacing guidelines are driven by engineering standards, such as with the clear sight triangle at intersections, the guidelines are often more restrictive than those standards would require and, in practice, they are not always followed. Rather decisions are made by individual city representatives, such as planners, engineers, and arborists, on a case-by-case basis following unwritten rules that are sometimes more restrictive than those written (Braverman, 2008; Macdonald et al., 2006). In the City of Los Angeles, decisions about tree placement and species during construction projects are up to individual inspectors from the Bureau of Street Services Urban Forestry Division and interpretations of guidelines can vary.

4.2.3. Green and gray infrastructure are treated differently

In interviews with city staff, an arborist pointed out that trees are the only subsurface element in the right-of-way not included in the statewide dig alert system, which requires that subsurface utilities be located prior to digging in the right-of-way, aligning with the findings of Braverman (2008), who argued that this type of "non-management" can be as powerful as the most intense regulations. Akin to the treatment of cyclists and pedestrians in AASHTO guides, which are understood to be optional compared to the standards set for automobiles (Prytherch, 2018 p. 104), green infrastructure, including street trees, are likewise treated as optional, given whatever space is left after gray infrastructure is in place. While green infrastructure has evaded an exacting definition (Grabowski et al., 2022), infrastructure (understood here to imply gray infrastructure) is "the substructure or underlying foundation, especially the basic installations and facilities on which the continuance and growth of a community depends" (McMahon, 2000). Given the well-documented benefits of trees to humans and the environment, street trees could easily be included under this definition. This explicit and forceful articulation of street trees, and green infrastructure more broadly, as infrastructure, without the diminishing (in practice) "green" preceding, could lead to more successful operationalization of civic ideals (Grabowski et al., 2022).

4.3. Policy implications – towards a model code

4.3.1. Federal and state agencies impact municipal standards

Some of the tree spacing guidelines come from engineering standards such as the Green Book developed by federal agencies like AASHTO. Given potential municipal liability for poorly designed roads (Prytherch, 2018 p. 70–71), municipal governments are unlikely to support designs that are counter to established professional standards, suggesting the need to revise those standards, even if they do not have the force of law. The federal government also has the power to implement pro-tree standards and to make them law, following the example of the Manual on Uniform Traffic Control Devices (MUTCD) which is mandated by the federal government to be adopted as the legal state standard (Prytherch, 2018 p. 110). The relationship between state- and municipal-level agencies is also important. For example, the constant relocation of bus stops in Los Angeles, under the purview of the state's Public Utilities Commission (PUC), makes it difficult to provide trees in an area where shade is most needed and contributes to the feeling that copious space is required to accommodate uncertainty. While technically legal changes would not be required to implement less restrictive tree spacing guidelines, state and federal agencies could have a meaningful impact.

4.3.2. Treat right-of-way standards more like building codes

One staff member from the City of Los Angeles characterized the right-of-way as the "wild west" while an official interviewed by Braverman (2008) called the sidewalk "managed chaos," making the comparison that if an expert were told how big a building was, they would be able to tell you where the fire exits need to be located. This is because buildings, unlike the right-of-way, are subject to detailed building codes, with the International Building Code (IBC) serving as the model adopted in all 50 states (International Code Council, n.d.). For tree spacing guidelines, and other policies shaping the right-of-way, to be more like building codes, they would need to be more detailed, provide drawings to clarify requirements, and be embedded in an approval process. As is clear looking at Tables 3–5, most cities currently address only a fraction of gray infrastructure elements in their tree spacing guidelines. Macdonald et al. (2006) argued for more flexible requirements that are not one-size-fits-all. Counterintuitively, the solution could be more requirements rather than less. Building codes are so detailed to accommodate greater nuance, and frequently outline different requirements for different circumstances. This could permit consideration of street typology, approach or departure from an intersection, land use type, and tree stature, among other factors. Building codes, such as ADA requirements, often include visual illustrations. A similar strategy could help clarify street tree requirements, such as where distance should be measured at the edge of a driveway, currently provided by a minority of cities. Finally, conformance with building codes is embedded in the permitting process, which applies to public as well as private projects. This process ensures consistent application of standards as well as an opportunity early in the design process to request clarification where codes may be unclear for a given circumstance.

4.3.3. *Centralize oversight*

It is likely no coincidence that a city like Paris, renowned for its tree-lined boulevards, manages those trees through a single centralized agency that answers directly to the city's mayor and council (Laurian, 2019). While right-of-way infrastructure in the U.S. is managed by a constellation of specialists without an understanding of the whole system (Engel-Yan et al., 2005), a parallel can again be drawn with buildings which might inform a future approach to the right-of-way. Buildings also accommodate infrastructure under the purview of engineers from different disciplines. It is the role of the architect to balance competing demands and the role of building and planning departments to ensure compliance with some baseline standards. Street trees, and other right-of-way elements, currently lack those roles which are critical for consideration of co-benefits and weighing benefits (health, well-being, environmental services) against costs (potential liability).

4.3.4. *Beyond tree spacing guidelines*

While tree spacing guidelines are important, only so much can be done within the constraints of existing sidewalks and parkways, especially considering ADA guidelines for accessible pedestrian routes and the space needed to support healthy trees. So-called "road diets" which retrofit streets for alternative transit modes, offer a possibility to take back space allocated to automobiles (Prytherch, 2018 p. 144), which could have the added benefit of improving safety (Johns Hopkins University, 2023). These strategies may be particularly important if large-stature trees (and their large shade canopies) are the goal, yet there does not seem to be encouragement in existing policies and standards for large tree wells. This suggests that in addition to tree spacing guidelines, tree policies should be combined with detailed standards pertaining to street typologies, which could dictate lane width and quantity, and other elements such as bicycle lanes and on-street parking. Existing Complete Streets policies could be a good place to start, but consideration of trees and implementation of those plans is lacking, again suggesting more centralized and holistic consideration of the right-of-way would be beneficial.

4.4. *Limitations*

This study focused on guidelines impacting street trees exclusively, even though street trees make up a relatively small percentage of the urban forest, perhaps only 5–10 % (McPherson et al., 2016; Smart et al., 2020). Despite this, their importance cannot be ignored given their proximity and potential benefits to residents, the focus put on them by urban tree planting initiatives, the control that city agencies have over them, and the increasingly important role they will play in a denser, hotter urban future. They also represent a huge portion of municipal spending on trees, with 2.7 times more spent on street trees than those in parks (Smart et al., 2020), making it critical to ensure that street tree programs are well managed. The detailed guidelines applied to private property trees could be the subject of future work.

It is also important to recognize that except for Los Angeles, this study relies on an analysis of written policies, even though written policies are not always followed in practice. The question of what is codified is of primary importance, however, in the context of the right-of-way, whose ownership is so diffuse. The comparison of policies in California over the past 20 years compares results from Macdonald et al. (2006), who gathered information through interviews in addition to written standards, with current guidelines gathered through written standards alone. It is possible that what is reported by Macdonald et al. (2006) does not reflect the written guidelines at that time.

Finally, the in-depth look at codes potentially shaping tree spacing guidelines was similarly focused on the Los Angeles context and therefore is not necessarily generalizable to other cities which may be under the purview of other municipal or state-level codes. This may impact the finding that tree spacing guidelines could be easily modified without changes to law. Although, as previously stated, even where laws and standards are not required to change, as in Los Angeles, pro-tree policies would still be beneficial.

4.5. *Conclusion*

This article contributes a thorough review of municipal tree spacing guidelines, a topic rarely considered in existing literature, through a comparison of guidelines in California and large U.S. cities, consideration of their change over time, an in-depth examination of laws applying to tree placement in Los Angeles, and interviews with staff in relevant departments within the City of Los Angeles. It finds little agreement on what might constitute best practices and suggests that adopting less restrictive guidelines currently utilized in other similar urban areas could support tree canopy goals without negative impacts to safety. Guidelines could be modified without changes to existing laws, although pro-tree changes to engineering standards at the federal and state levels would provide support to municipalities that are particularly concerned about liability.

As U.S. cities plan for a denser, hotter future and hope to realize the health, environmental, and fiscal benefits of ambitious networks of Complete Streets and green infrastructure, guidelines and practice must be aligned with those goals in a way that they are not currently. With the impacts of climate change and as tree canopy on private property declines, trees in the public right-of-way will increasingly serve as a basic element "on which the continuance and growth of a community depends," suggesting street trees, and green infrastructure more broadly, must be elevated to the level of gray infrastructure, and planned for and prioritized accordingly. Centralized control of the right-of-way might help realize that goal, using as a model building codes and the permitting process common to building projects, which could accommodate more detailed standards to address the unique scenarios presented by each right-of-way project and an added role, similar to that of an architect, who is specifically tasked with balancing competing priorities and assessing co-benefits, which fall through the cracks in the current system. This centralized control could also allow better coordination with larger-scale efforts like re-defining roadway design standards or road narrowing, which will be critical to achieving a robust canopy of large-stature trees in specific areas.

While municipal priorities have shifted in the last two decades, street tree spacing guidelines have not, and the ideals of ambitious plans have seemingly not been operationalized. In the current convergence of interest in improving the right-of-way to create more livable cities, there is an opportunity to ensure that in 20 years' time, guidelines align more closely with those ideals.

CRediT authorship contribution statement

Esther Margulies: Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. **Laura Messier:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **John P. Wilson:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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