Identifying Quantified Safety and Traffic Calming Benefits of Trees

Requested by
Bart van der Zeeuw, Division of Design

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List of Abbreviations and Acronyms

3R	resurfacing, restoration and rehabilitation (Indiana)
AASHTO	American Association of State Highway and Transportation Officials
ADEQ	Arizona Department of Environmental Quality
B-C	benefit-to-cost
Caltrans	California Department of Transportation
CRZ	clear recovery zone
CTAG	Comprehensive Turbulent Aerosol Dynamics and Gas Chemistry (air quality model)
DBH	diameter at breast height
DNR	Department of Natural Resources
DOT	department of transportation
DTSD	Division of Transportation System Development (Wisconsin)
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
IRSC	International Roadside Safety Conference
KYTC	Kentucky Transportation Cabinet
LAD	Leaf Area Density
LES	Large Eddy Simulation (air quality model)
MMA	master maintenance agreement
MOA	memorandum of agreement
MoDOT	Missouri Department of Transportation
MOU	memorandum of understanding
NAIP	National Agricultural Imagery Project (USDA)
NCHRP	National Cooperative Highway Research Program (TRB)
QL2	Quality Level 2 (U.S. Geological Service)
RDG	Roadside Design Guide (AASHTO)
ROW	right of way
RVET	Roadside Vegetation Evaluation Toolkit (Texas)
SHS	State Highway System
SVC	single-vehicle crash
SVI	street view images
TOW	tree outside of woodland
TRB	Transportation Research Board
TxDOT	Texas Department of Transportation
UHI	urban heat island
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Service
VCP	vehicle-pedestrian
VCV	vehicle-vehicle
VRS	virtual reference station
WA	Wildflower Area

Executive Summary

Background

Conventional wisdom and anecdotal evidence support the proposition that landscaped and tree-lined streets provide safety and traffic calming. Other benefits of trees include reduced urban heat island effect, improved air and water quality, carbon sequestration, ecological habitat and reduction of human stress and anxiety. Legitimate safety concerns that roadside trees act as fixed objects and may contribute to more negative crash outcomes, however, are the basis of some California Department of Transportation (Caltrans) policies regarding trees.

The potential risks or benefits of tree-lined roadways can be considered in the context of roadway characteristics such as roadway type, posted speed limits, and roadside features such as guardrails, curbs and others. The land use context — rural, urban or suburban — may also determine the impacts of roadside trees.

Currently, Caltrans uses the Traffic Calming Guide and Safety Performance Estimation Tool to evaluate the possible inclusion of various safety and traffic calming measures in transportation projects. The tool relies on quantifiable benefits, measured either in reduction in fatal and serious injuries, or reductions in speed, to evaluate the relative effectiveness of various countermeasures. While the Traffic Calming Guide includes trees and landscape as a potential countermeasure, Caltrans has not obtained data that can inform development of a comparable quantifiable benefit. The Safety Performance Estimation Tool does not currently include trees as a potential countermeasure.

This Preliminary Investigation gathered literature and reporting from transportation agencies about current interpretations and practices regarding trees in roadside design and efforts to identify and quantify the safety and traffic calming benefits of trees.

Summary of Findings

Survey of Practice

An online survey was distributed to state department of transportation (DOT) members of the then-current Transportation Research Board (TRB) standing committees on Roadside Safety Design (AKD20) and Landscape and Environmental Design (AKD40), and the American Association of State Highway and Transportation Officials (AASHTO) Committees on Maintenance and Design. (**Note**: The current TRB committee is the Standing Committee on Roadside Landscape and Environmental Design, Operations and Maintenance (AKL18).) The online survey was also distributed to transportation-related contacts at selected Canadian municipalities and providences.

Twenty-four individuals representing 19 states and two Canadian jurisdictions responded to the survey:

- City of Moncton (Canada)
- Saskatchewan Ministry of Highways (Canada)
- Alaska
- Arizona
- Arkansas
- Connecticut
- Florida (FDOT)
- Hawaii
- Indiana
- Kansas
- Kentucky
- Michigan
- Missouri (MoDOT)
- Nevada
- New Hampshire
- New York
- Oregon
- Rhode Island
- Virginia
- Washington
- Wisconsin

Note: The survey received two responses from New York State, Rhode Island and Wisconsin DOTs.

Agency Tree-Planting Policies and Guidance

Over half of responding agencies provided links to policies, procedures or tools that guide the planting of roadside trees, as highlighted in Table ES1. A few agencies provided statements or brief descriptions of overarching policies that do not favor tree planting, summarized following the table.

Table ES1. Agency Tree-Planting Policies and Tools

State/Country (Jurisdiction)	Guidance or Other Resource
Canada (City of Moncton)	Moncton Subdivision Development: Procedures, Standards and Guidelines
Canada (Saskatchewan)	RSMM 550-10: Setbacks, Roadside Management Manual
Arizona	• Roadside Development program website • Roadside Vegetation Management Guidelines
Florida	• Landscape Policy • Section 105, Aesthetic Design, 2025 FDOT Design Manual • Part 2, Chapter 5, Aesthetic Effects of the Project Development and Environment Manual
Indiana	• Landscape Planting Index • Tree pruning guides
Kansas	• Policy: Non-Highway Use of Right-of-Way for Gateway/Welcome Features Landscaping and Artwork • Section 908, Trees, Shrubs and Other Plants, Specifications for State Road and Bridge Construction
Kentucky	Complete Streets, Roads and Highways Manual
Michigan	Michigan Design Manual (Road Design)
Missouri	MoDOT Engineering Policy Guide Category 808: Planting Trees, Shrubs and Other Plants
New York	Chapter 28, Landscape Architecture and Community Design for Transportation, Highway Design Manual
Virginia	Landscaping design guidelines are currently being updated.
Washington	• Roadside Policy Manual • Integrated Roadside Vegetation Management Plans
Wisconsin	• Chapter 27, Planting and Aesthetic Design, Facilities Development Manual • Section 632, Furnishing and Planting Plant Materials, 2025 Standard Specifications

Arkansas DOT rarely plants trees in the right of way (ROW). *New Hampshire DOT* prefers not to plant trees to avoid maintenance responsibilities and to decrease shade to increase snow and ice melting. *Oregon DOT* typically only plants trees to meet mitigation commitments for project delivery and is generally opposed to roadside tree planting due to risks involving wildlife on the road or trees falling onto the road.

Federal Guidance

Some respondents described reliance on two AASHTO guidance documents, both available for purchase, when setting agency tree-planting policy:

- A Policy on Geometric Design of Highways and Streets, 7th edition (2018) (also referred to as the Green Book). This publication includes multiple references to trees, including Section 7.2.4.1, Clear Zones.
- Roadside Design Guide, 4th edition (2011). This publication addresses the presence or removal of trees.

Federal Highway Administration also addresses the clear zone, which plays a role in many agencies' decision-making when planting trees.

Additional information from survey respondents is presented below in six topic areas:

- Factors influencing tree-planting decisions.
- Other factors influencing placement of roadside trees.
- Responsibility for maintenance.
- Considering the benefits of trees.
- Agency interest in quantifying benefits of trees.
- Closing comments.

Factors Influencing Tree-Planting Decisions

Various factors and criteria impact agency decisions to plant — or not plant — roadside trees. While not all respondents provided information for every criterion, several commonalities emerged in the information provided for these factors:

- Land use context.
- Public interest and stakeholder considerations.
- Roadway types and classes.
- Posted or actual driving speed.
- Roadside features.

Land Use Context

Several respondents mentioned clear zones, either as a consideration or hard limit on tree planting (*Arizona, Indiana, Kansas* and *New York*). Respondents also cited other land use-related criteria:

- Adjacent land use or context sensitive factors (*Arizona, Michigan, Missouri, Nevada, Rhode Island, Virginia* and *Moncton, Canada*).
- Project requirements that include offsetting tree cutting (*Connecticut* and *New Hampshire*).
- Screening or buffering needs (*Michigan, Missouri* and *Washington*) or for general aesthetic purposes (*Arizona, Florida* and *Michigan*).

While over half of the responding agencies do not apply different practices for planting roadside trees in urban, suburban and rural contexts, others reported differences in practices that consider land use:

- Dependence on coordination with local jurisdictions (*Florida* and *Wisconsin*).
- Reduced focus on tree planting in rural areas (*Kentucky*, *Nevada* and *Moncton, Canada*).

Public Interest and Stakeholder Considerations

Some agencies do not often consider public interest in tree planting decisions (*Alaska*, *Kansas* and *Moncton, Canada*). Others generally consider public interest (*Connecticut*, *Nevada* and *Wisconsin*) or reported more specific public or stakeholder considerations in tree-planting decisions.

Aesthetics

- Landscaping with trees and aesthetics are considered beneficial based on public input or agency assessments (*Kentucky*).
- Public requests for replacement tree or screening/buffer trees are considered (*Rhode Island*).
- Trees are considered for shade and beautification purposes (*Hawaii*).
- Trees are planted in roadside parks, rest areas, for screening unsightly areas and for roadway enhancement while providing for future development (*Missouri*).

Local Government Preferences or Requests

- City governments request permits for trees that are planted at city cost and maintained by the city requesting the permit (*Arkansas*).
- Enhanced planting designs are requested and negotiated during the project scoping phase of locality-initiated projects (*Virginia*).
- Local agency input on new project landscaping is generally requested; local agencies can also apply for a tree-planting permit outside the scope of a road project (*Michigan*).
- Municipalities may request trees in the context of community sensitive design improvement projects (*Wisconsin)*.

Neighborhood Character or Context

- Appropriate tree planting mitigates construction vegetation removal and considers public interest and neighboring property owner needs (*Washington*).
- Context Sensitive Solutions design principles include local stakeholder preferences (*Michigan*).
- Public concerns over trees relate to potential neighborhood character changes (*New Hampshire*).

Urban Areas

- Increased tree-planting efforts occurs in more populated areas where public interest is typically stronger (*New York*).
- Public interest is a primary factor considered in urban areas (*Arizona*).

Roadway Types and Classes

Some respondents noted that trees would be considered in any roadway type (*Michigan, Nevada* and *New York*) or within the ROW in general (*Moncton, Canada*). Others identified specific roadway types appropriate for tree planting:

- *Roadway type or functional classifications* such as arterial and collector (*Alaska*), local and minor collector (*Kentucky*), U.S. and state routes (*Missouri*) and local collectors (*New Hampshire*).

- *General road type* including rural/urban distinctions (*Arizona* and *Rhode Island)*, slow/high speed distinctions (*Connecticut* and *Hawaii*).

Posted or Actual Driving Speed

Respondents generally referenced clear zones (*Michigan, Nevada, Rhode Island, Virginia* and *Wisconsin*) or identified design or posted speeds (*Arizona*, *Florida* and *Wisconsin*) as impacting tree-planting decisions. Other agencies allow trees on roads with speeds up to 45 mph (*Alaska, Connecticut, Kentucky, New Hampshire* and *New York*).

Roadway Features

Most agencies generally consider roadside features in tree-planting decisions:

- *Curbs and gutters*. Some responding agencies plant more trees behind curbs and gutters or next to sidewalks, while others noted that curbs, gutters or sidewalks do not provide space or protection to plant trees.
- *Guardrails and barriers*. Some respondents noted that guardrails or barriers offer driver protection and therefore encourage the planting of more trees.

Other Factors Influencing Placement of Roadside Trees

Agencies consider characteristics of planted trees, distance from the road edge and roadside slope when deciding how and where to place roadside trees.

Characteristics of Planted Trees

Certain tree characteristics contribute to their selection and how they are placed in agency ROW or the clear zone:

- *Tree trunk diameter.* The most common tree trunk diameter reported for planting in the clear zone is 4 inches or less. Other agency practices:
    - 2 to 3 inches (*New Hampshire*).
    - 6 inches (*Hawaii*).
    - 4- to 6-inch caliper trees are generally planted outside the clear recovery zone (*Florida*).
    - All trees are planted outside the clear zone regardless of tree trunk diameter (*Nevada*).
- *Planting density.* Planting purpose or context dictates planting density for several agencies that may use a higher planting density in lower-speed areas. While lower-density plantings are used in areas where visibility is needed for security and maintenance, higher-density planting may also be done in areas where screening is needed.
- *Species.* A variety of factors or methods influence the choice of tree species:
    - Drought-tolerant species that are well adapted or native to the location (*Arizona, Connecticut, Florida, Nevada, New York, Rhode Island, Washington* and *Wisconsin*).
    - Local governments, other agencies or landscape architect choose species (*Alaska, Florida* and *Indiana*).
    - Roadside conditions or salt tolerance may favor using non-native trees in certain locations (*Michigan, New Hampshire, New York* and *Rhode Island*).
    - Species lists or other guidance (*Kentucky, Nevada, Michigan* and *Virgina*).

Distance from the Road Edge

Clear zone considerations were the most common factor identified by responding agencies when determining how far from the road edge to plant trees. Agencies also use other factors such as prescribed distance (2 to 30 feet), lateral offset requirements, and state or federal guidance. *Alaska DOT* has no applicable requirements for distance from trees to road edge; *Missouri DOT* is guided by planting plans.

Roadside Slope

A range of factors are examined when agencies consider the placement of trees on roadside slopes:

- *Selected by landscape architect or in design phase* (*Alaska, Florida* and *Wisconsin).* In *Alaska*, all installations known to the respondent are in medians or flat areas behind sidewalks.
- *Slope ratio limits for trees*:
    - Up to 2:1 (*Connecticut, Michigan* and *Nevada*). The *Nevada DOT* respondent reported success when retaining soil in front of and behind trees.
    - Up to 4:1 (*New Hampshire* and *Arizona*). *Arizona DOT* plants trees farther away from the travel lane the steeper the slope and considers design speed, traffic volume and roadway geometric criteria.
    - From 10(H):1(V) to 6 (H):1(V) (*Kentucky*).
- *Slope type*:
    - Backslope over fore slope (*Indiana*).
    - Cut or fill slope (*Wisconsin*).
    - Downslopes generally have a wider clear zone, depending on context (*Washington*).

Responsibility for Maintenance

For many agencies, local governments are responsible for maintaining planted trees, often through maintenance agreements. In some jurisdictions, maintenance responsibilities are shared. A few state DOTs reported sole responsibility for tree maintenance.

Oregon DOT lacks resources for tree maintenance, but friends' groups may get permission to plant trees in approved ROW locations. Typically, the *Saskatchewan Ministry of Highways* does not plant trees and maintaining any trees is the landowners' responsibility. Other practices:

- *Local government tree maintenance*. In municipalities or on university properties the road owner performs tree maintenance (*Alaska* and *Washington*), particularly when trees are planted at a city's request (*Arkansas*). The city parks department maintains trees (*City of Moncton),* and counties perform all highway maintenance including removal and pruning of trees (*Wisconsin*).

  Five responding agencies have executed maintenance agreements with local entities (*Connecticut*, *Indiana, New York, Rhode Island* and *Wisconsin*).

- *Shared maintenance responsibility*. Some agencies use various types of agreements to define circumstances that determine responsibilities for tree maintenance among state DOTs, local agencies and contractors (*Arizona, Florida, Kentucky, Michigan* and *Virginia*). Developers or communities also may share tree maintenance responsibilities (*Nevada* and *New Hampshire*).

- *State DOT tree maintenance*. *Hawaii, Kansas* and *Missouri DOTs* are responsible for roadside tree maintenance.

Considering the Benefits of Trees

While many agencies indicated significant interest in quantifying or measuring the safety benefits or traffic calming impacts of trees planted in ROWs or clear zones, most have not attempted to do so. Respondents from Florida and Virgina DOTs provided information on early attempts to quantify or measure the safety or traffic calming benefits of trees.

Florida Department of Transportation

As the Florida DOT respondent noted, "While our procedures have language to measure such attributes, in practice this has proven very elusive to quantify." Language related to safety benefits of trees appears in three guidance documents:

- One-page Landscape Policy includes a reference to measuring the costs and benefits of landscaping in general.
- The Aesthetic Design section of the FDOT Design Manual; see Section 105.6 Safety and Scenic Beauty, which notes that landscaping can help reduce "driver monotony, a real safety concern."
- Part 2, Chapter 5, Aesthetic Effects of the Project Development and Environment Manual notes that "FDOT considers Aesthetic Effects (AE) during project development because it influences community cohesion, community values and can affect the travel experience."

Virginia Department of Transportation

Virginia DOT is currently researching the traffic calming effects of street trees to potentially expand their use within the clear zone for specific corridor character categories. While no conclusions have been drawn to date, the respondent shared interim findings provided by the research team that offered selected data:

> Crashes on streetscapes fully covered by tree canopy are 51% less likely to result in injury or death than those on streetscapes without trees. Even for arterial roads, which have a higher rate of severe crashes, presence even of 40% tree canopy may offset this hazard.

Note: These findings are sourced from *Urban Streetscape Design and Crash Severity*, cited on page 59 of the **Detailed Findings** section of this Preliminary Investigation.

Agency Interest in Quantifying Benefits of Trees

While several agencies reported no interest in quantifying or measuring safety or traffic calming benefits of trees in ROW or clear zones, the remaining 13 agencies were interested in seeking benefit data to inform tree-planting decisions for several reasons, as summarized in Table ES2.

Table ES2. Agency Interest in Quantifying Tree Benefits

Interest in Tree Benefit Data	State/Country (Jurisdiction) and Description
General Interest	*Alaska.* Expand understanding of benefits to justify costs and ROW acquisition needs. *Indiana.* The survey respondent commented, "Overcoming the long-standing message that all trees are hazards and should be removed is difficult to reframe without supporting data." *Nevada, Washington, Wisconsin.*
Interest for Speed Management	*Indiana, Michigan.* *Kansas.* Support current deliberations regarding transition areas.

Interest in Tree Benefit Data	State/Country (Jurisdiction) and Description
Interest for Other Purposes	*Canada (Saskatchewan)*. Traffic calming. *Arizona.* Support design reports during formative project development. *Arkansas*. Measure noise reduction effects of trees along high-speed roadways adjacent to neighborhoods. *Missouri*. Support Aesthetic Review Team exploring trees in the median and ROW generally. *Wisconsin*. Address endangered bat species concerns.

Anecdotal Evidence of Tree-Planting Benefits

Anecdotal or other evidence or general opinions about the benefits of roadside trees offered by respondents included the aesthetic value of trees that enhances livability (*Alaska*), visual appeal (*Hawaii*) and community interest in tree aesthetics (*Michigan, Nevada* and *New Hampshire*). General awareness of air quality or urban heat island effects of trees was noted by several agencies (*Hawaii, Nevada, Wisconsin* and *City of Moncton*), as well as temperature or climate regulation (*Wisconsin*). *Arizona DOT* shared a study on carbon sequestration in urban landscapes (see the citation for *Carbon Storage and Sequestration by Trees in Urban and Community Areas of the United States* on page 56).

The erosion control potential of roadside trees was noted by *Rhode Island, Michigan* and *Nevada*. *Wisconsin DOT* uses trees for stormwater applications.

Several respondents reported general observations regarding speed reduction and other driver behavioral changes from the presence of trees:

- The inner urban core has a high percentage of mature street trees and experiences low speeds (*City of Moncton*).
- The respondent commented, “I drive slower personally and have seen that the landscaped project near my house creates more uniform driving” (*Alaska*).
- Trees, and aesthetics in general, improve driver experience by not only calming traffic but calming the drivers themselves (*Nevada*).

Related Research and Resources

A literature search of publicly available domestic and international in-progress and published research identified publications that are organized into the following topic areas:

- Current Caltrans guidance.
- Methodologies, tools and quantification measures.
- Related domestic research.
- International resources.

Some categories are further organized according to national, state and other research and resources. Tables ES3 through ES6 summarize the cited publications by topic area beginning on page 13. Each table provides the publication or project title, the year of publication if research is completed and a brief description of the resource. Significantly more detail about each resource can be found in the **Related Research and Resources** section of this report.

Gaps in Findings

The survey received a robust response and responding transportation agencies appear very interested in data that illustrates the safety and other benefits of roadside trees. Agencies have started to consider various potential benefits of planting roadside trees, however, few responding agencies have initiated steps to collect or acquire the data. Research into quantifying the benefits of trees continues to increase, particularly in areas of traffic calming and managing environmental pollution effects.

Next Steps

Moving forward, Caltrans could consider:

- Monitoring the progress of the pending National Cooperative Highway Research Program (NCHRP) Project 17-136: Safe System Approach for Including Trees in Urban and Suburban Roadway Contexts, which will develop a practitioner's guide for evaluating the safety effects of trees on urban and suburban roadways with a focus on posted speed limits of 35 to 50 mph. The estimated completion date is unknown.
- Reaching out to Florida DOT to learn more about potential plans to measure tree benefit attributes.
- Consulting with Missouri DOT to learn more about its Aesthetic Review Team's exploration of the benefits of trees in the median and ROW in general.
- Examining in detail the Roadside Vegetation Evaluation Toolkit (RVET) recently developed by Texas DOT to determine its relevance for Caltrans. Using geospatial data, RVET "covers five major aspects: environmental benefits, operational and maintenance measures, lifecycle costs, public perception of roads and vegetation, and public perception of aesthetics."
- Following up with Virginia DOT regarding the ongoing update of landscaping guidance and traffic calming research.
- Engaging with the current TRB committee expected to address this issue — Standing Committee on Roadside Landscape and Environmental Design, Operations and Maintenance (AKL18) — to share Preliminary Investigation findings and discuss possible follow-up research.

Table ES3. Current Caltrans Guidance

Publication or Resource (Year)	Description of Resource
Traffic Calming Guide: A Compendium of Strategies (2023)	Provides best practices, relevant standards and resources discussed in the Federal Highway Administration Traffic Calming ePrimer. Discusses traffic calming measures and other important considerations.
Chapter 900 - Landscape Architecture – Roadsides (2020)	Describes tree location requirements, including large and small trees in reference to the Clear Recovery Zone, freeways and expressways, and conventional highways.

Table ES4. Methodologies, Tools and Quantification Measures

Publication or Resource (Year)	Jurisdiction or Other Source	Excerpt from Abstract or Description of Resource
Pending Research: NCHRP 17-136: Safe System Approach for Including Trees in Urban and Suburban Roadway Contexts (Unknown)	National	Will develop a practitioner's guide for evaluating the safety effects of trees on urban and suburban roadways with a focus on posted speed limits of 35 to 50 mph.
NCHRP Report 1016: Design Guidelines for Mitigating Collisions with Trees and Utility Poles (2022)	National	Provides benefit–cost analysis examples of tree removal (isolated roadside tree and continuous group of roadside trees) and guidance on tree removal.
NCHRP Web-Only Document 336: Proposed Guidelines for Fixed Objects in the Roadside Design Guide (2022)	National	Presents recommended text for a future edition of the AASHTO Roadside Design Guide to incorporate the results of the research described in the publication cited above.
Variation in Estimates of Heat-Related Mortality Reduction Due to Tree Cover in U.S. Cities (2022)	Multiple States	Estimates spatially and temporally reductions in temperature and mortality associated with a 10% increase in tree cover in 10 U.S. cities with varying climatic, demographic, and land cover conditions.
The Unresolved Relationship Between Street Trees and Road Safety (2019)	Colorado	Describes the GIS mapping of both tree canopy and street-tree locations for the city and county of Denver; analyzes association between street trees and seven years of road safety outcomes; and investigates uses of new tools for the 3D measuring of streetscapes.
Economic Impact of Ecosystem Services Provided by Ecologically Sustainable Roadside Right of Way Vegetation Management Practices (2014)	Florida	Estimates the economic value of runoff prevention, carbon sequestration, pollination and other insect services, air quality, invasive species resistance and aesthetics for Florida's State Highway System roadside ROW ecosystem using the benefits transfer method.

Publication or Resource (Year)	Jurisdiction or Other Source	Excerpt from Abstract or Description of Resource
A Method for Examining the Ecosystem Services of Roadside Trees: Springfield, Massachusetts (2016)	Massachusetts	Outlines a series of simple, easy-to-implement scientific experiments to examine various roadside types and report on the ecosystem services that these typical roadsides provide.
Quantifying the Benefits of Roadside Vegetation (2025)	Texas	Describes the Roadside Vegetation Evaluation Toolkit (RVET) for quantifying the benefits of roadside vegetation to aid transportation planners, environmental practitioners and landscape designers in evaluating roadside vegetation.
The Effect of Roadside Vegetation and Clear Zone Design on Driver Behavior (2016)	Research Report	Evaluates the relationship between clear zone design and the presence of roadside vegetation on driver speed, lateral positioning and drivers' visual scan patterns.
Roadside Vegetation Barrier Designs to Mitigate Near-Road Air Pollution Impacts (2016)	Journal Article	Examines the performance of a model to capture the effects of vegetation barriers on near-road air quality as compared to field data; explores the effects of six conceptual roadside vegetation/solid barrier configurations on near-road particle concentrations in the context of dispersion and deposition.
Carbon Storage and Sequestration by Trees in Urban and Community Areas of the United States (2013)	Journal Article	Uses urban tree field data from 28 cities and six states to determine the average carbon density per unit of tree cover. These data were applied to statewide urban tree cover measurements to determine total urban forest carbon storage and annual sequestration by state and nationally.
Quantified Tree Risk Assessment Used in the Management of Amenity Trees (2005)	Journal Article	Evaluates components of a tree failure hazard and assigned estimates of probability and describes a system to calculate the product of those probabilities to produce a numerical estimate of risk.

Table ES5. Related Domestic Research

Publication or Resource (Year)	State or Other Source	Excerpt from Abstract or Description of Resource
Frequency and Severity of Tree and Other Fixed Object Crashes in Florida, 2006-2013 (2019)	Florida	Analyzes Florida Highway Safety and Motor Vehicle records to evaluate the relative frequency of tree-related crashes compared to other fixed-object crashes; assesses the impact of roadway-, vehicle-, and driver-related factors on tree crash frequency; and compares the severity of tree crashes relative to other single-vehicle crashes.

Publication or Resource (Year)	State or Other Source	Excerpt from Abstract or Description of Resource
Daylighting Decision-Making at State Departments of Transportation: A Case Study of Roadside Tree Removal (2024)	Georgia	Explores the impact of agency silos on multiple agency goals including safety, environmental, sustainability and equity in the context of roadside tree removal.
Assessing Large-Scale Roadside Tree Removal Using Aerial Imagery and Crash Analysis: A Difference-in-Differences Approach (2024)	Georgia	Quantifies the extent of tree removal over time along the five major interstates in Georgia using aerial imagery. Uses collected pre- and post-treatment crash data to conduct a difference-in-differences analysis on sampled road segments to isolate the effect of tree removal on crash rates.
Cost-Effective Safety Treatment of Trees on Low-Volume Rural Roads (2015)	Kansas	Analyzes incremental benefit-to-cost using the Roadside Safety Analysis Program to investigate the efficacy of safety treatment alternatives for trees on roadways with volumes of less than 500 vehicles per day and speed limits of 55 mph or greater.
The Role of Street Trees for Pedestrian Safety (2018)	Massachusetts	Studies the link between street trees and the gap between pedestrians' perceptions of safety and their actual safety while walking along street corridors.
Urban Streetscape Design and Crash Severity (2015)	New York	Examines streetscape design and traffic safety in urban settings by assessing relationships between crash severity and streetscape design variables in New York City.
Safe Streets (2018)	Washington	Surveys the research on roadside vegetation benefits, and the scientific evidence concerning city trees and transportation safety.
Unclear Territory: Clear Zones, Roadside Trees and Collaboration in State Highway Agencies (2023)	Journal Article	Explores highway agency staff perceptions of trees — either as safety hazards or as beneficial environmental assets — finding that engineering leadership understands roadside tree management as a nuanced issue.
Street Trees for Bicyclists, Pedestrians and Vehicle Drivers: A Systematic Multimodal Review (2021)	Journal Article	Provides a comprehensive review of multiple databases covering 15 countries and eight research categories that identifies the links between street trees, human health and safety for pedestrians, bicyclists and vehicle drivers; depicts the principal disciplines, themes and conceptual scope of this research; and discusses the implications for urban planning and design practice and research.

Publication or Resource (Year)	State or Other Source	Excerpt from Abstract or Description of Resource
The Effects of Roadside Vegetation Characteristics on Local, Near-Road Air Quality (2019)	Journal Article	Analyzes how differing vegetation characteristics along a highway affected downwind air quality, finding that roadside vegetation needed to be of sufficient height, thickness and coverage to achieve downwind air pollutant reductions.
Roadside Vegetation Design to Improve Local, Near-Road Air Quality (2017)	Journal Article	Describes characteristics of roadside vegetation that previous research showed can result in improved local air quality, identifying characteristics that should be avoided to protect from unintended increases in nearby concentrations.
Tree Planting and Clearing Guidance with Consideration of Minimized Crash Risk (2016)	Journal Article	Develops a quantitative approach for assessing the risk of fatal and incapacitating injuries presented by various tree spacing and offsets, applicable to any roadway where tree planting or removal is being considered.

Table ES6. International Resources

Publication or Resource (Year)	Continent/ Country	Excerpt from Abstract or Description of Resource
Reduce Speed Limits to Minimize Potential Harm and Maximize the Health Benefits of Street Trees (2024)	Australia	Analyzes associations among all serious and fatal traffic crashes and street tree percentages in Sydney, Australia, adjusting for confounding factors relating to driver behavior (speeding, fatigue and use of alcohol) and road infrastructure, including alignment (e.g., straight, curved), surface condition (e.g., dry, wet, ice), type (e.g., freeway, roundabout) and speed limit.
Trees in Medians and Roadsides in the Urban Environment: Operational Instruction 19.8 (2024)	Australia	Offers guidance that provides direction to traffic engineering practitioners, landscape architects and planners when considering tree planting in raised medians and roadsides within road corridors.
Effect of Urban Street Trees on Pedestrian Safety: A Micro-Level Pedestrian Casualty Model Using Multivariate Bayesian Spatial Approach (2022)	Australia	Develops a micro-level frequency model to evaluate the effects of tree density and tree canopy cover on pedestrian injuries, accounting for pedestrian crash exposure based on comprehensive pedestrian count data from Melbourne.
Urban Trees and Human Health: A Scoping Review (2020)	Canada	Summarizes existing literature on the health impacts of urban trees that can inform future research, policy and nature-based public health interventions.

Publication or Resource (Year)	Continent/ Country	Excerpt from Abstract or Description of Resource
Investigating Streetscape Environmental Characteristics Associated with Road Traffic Crashes Using Street View Imagery and Computer Vision (2025)	China	Uses street view images and deep learning to comprehensively measure streetscape features, including roads, sidewalks, buildings, fences, trees and grass, as well as discrete elements like vehicles, pedestrians and traffic lights. Combines imagery with crash data to identify crash risks.
Not Just More, But More Diverse: Green Landscapes Along Urban Roads May Significantly Reduce Drivers' Psychophysiological Fatigue (2024)	China	Describes an on-site driving experiment that assesses psychophysiological, visual and muscular fatigue and analyzes correlation with landscape characteristics.
Toward Livable and Healthy Urban Streets: Roadside Vegetation Provides Ecosystem Services Where People Live and Move (2016)	Germany	Explores ecosystem services provided by roadside vegetation and tradeoffs with disservices, illustrating management options to support more livable streetscapes.
Does Roadside Vegetation Affect Driving Performance? Driving Simulator Study on the Effects of Trees on Drivers' Speed and Lateral Position (2015)	Italy	Investigates the effects of roadside vegetation on driving performance, including speed and road location, with respect to the centerline on a two-lane rural road.
Roadside Vegetation: The Impact on Safety (2015)	Poland	Analyzes the impact of vegetation on water erosion, winter conditions, visibility of formation line, glare effect, inhibition of energy, wind strength, presence of animal habitats and creation of specific microclimate; and calculates accident rates, controlling for environmental conditions.
Review on Urban Vegetation and Particle Air Pollution – Deposition and Dispersion (2015)	Sweden	Appraises the physical effects linking vegetation to air quality from two perspectives, deposition and dispersion, and provides recommendations on the design of urban vegetation related to air quality.
Tree Loss Impacts on Ecological Connectivity: Developing Models for Assessment (2017)	United Kingdom	Investigates the consequences of tree loss due to the removal of roadside trees on wider landscape functional connectivity.
Soil Surface Temperatures Reveal Moderation of the Urban Heat Island Effect by Trees and Shrubs (2016)	United Kingdom	Measures the effects of urban greenspaces in reducing surface temperature extremes caused by the urban heat island effect on a citywide scale.

Detailed Findings

Background

Conventional wisdom and anecdotal evidence support the proposition that landscaped and tree-lined streets provide safety and traffic calming. Benefits of trees include reduced urban heat island effect, improved air quality, habitat for vertebrates and invertebrates, sequestration of carbon, reduction of human stress and anxiety, and water quality improvements. There are, however, legitimate safety concerns that trees lining a roadway act as fixed objects and may contribute to more negative crash outcomes. Some California Department of Transportation (Caltrans) policies only identify trees as fixed objects that are potential safety concerns.

In understanding the potential risks or benefits of tree-lined roadways, it is important to consider key differences in contexts including roadway type, posted speed limits and the roadside features such as guardrails, curbs and gutters, and/or sidewalks. The land use context — rural, urban or suburban — may also determine the impacts of roadside trees.

Currently, Caltrans uses the Traffic Calming Guide and Safety Performance Estimation Tool to evaluate the appropriateness of various safety and traffic calming measures for inclusion in projects. The tool relies on quantifiable benefits, measured either in reduction in fatal and serious injuries, or reduction in speed in miles per hour, to evaluate the relative effectiveness of various countermeasures. While the Traffic Calming Guide includes trees and landscape as a potential countermeasure, data was not available at the time of its publication to provide a comparable quantifiable benefit. The Safety Performance Estimation Tool does not currently include trees as a potential countermeasure.

To gather information about these issues, CTC & Associates surveyed state departments of transportation (DOTs) about current interpretations and practices regarding the role of trees in roadside design and efforts to identify and quantify safety and traffic calming benefits of trees. A review of relevant in-progress and completed domestic and international research supplemented the findings of the survey.

Survey of Practice

An online survey distributed to the state DOT members of the following committees sought information about agency experience with identifying or quantifying the benefits of trees:

- Then-current Transportation Research Board (TRB) committees:
    - Standing Committee on Roadside Safety Design (AKD20)
    - Standing Committee on Landscape and Environmental Design (AKD40)

Note: The current TRB committee is the Standing Committee on Roadside Landscape and Environmental Design, Operations and Maintenance (AKL18).

- American Association of State Highway and Transportation Officials (AASHTO) committees:
    - Committee on Maintenance
    - Committee on Design (This committee supports the Technical Committee on Roadside Safety.)

The online survey was also distributed to transportation-related contacts at selected Canadian municipalities and provinces:

- City of Edmonton, Alberta
- City of Moncton, New Brunswick
- City of Toronto, Ontario
- City of Vancouver, British Columbia
- City of Winnipeg, Manitoba
- Manitoba Transportation and Infrastructure
- New Brunswick Transportation and Infrastructure
- Ontario Transportation Maintenance Management
- Saskatchewan Design and Construction Division

Survey questions are provided in Appendix A.

The survey received responses from 24 individuals representing 19 states and two Canadian jurisdictions:

- City of Moncton (Canada)
- Saskatchewan Ministry of Highways (Canada)
- Alaska
- Arizona
- Arkansas
- Connecticut
- Florida
- Hawaii
- Indiana
- Kansas
- Kentucky
- Michigan
- Missouri
- Nevada
- New Hampshire
- New York
- Oregon
- Rhode Island
- Virginia
- Washington
- Wisconsin

Two responses each were received from three state DOTs:

- *New York*: Office of Design (*Design*) and Landscape Architecture Bureau (*Landscape Architecture*).
- *Rhode Island*: Environmental Division (*Environmental*) and Administrative Services (*Administrative*).
- *Wisconsin*: Bureau of Highway Maintenance (*Maintenance*) and Division of Transportation System Development (*DTSD*).

Survey responses are presented below in five topic areas:

- Tree-planting policies and guidance.
- Factors influencing tree-planting decisions.
- Other factors influencing placement of roadside trees.
- Responsibility for maintenance.
- Considering the benefits of trees.

Tree-Planting Policies and Guidance

Responding agencies' policies, procedures or tools that guide the planting of roadside trees are highlighted in Table 1. Selected details are offered along with a link to each resource.

Following the table are selected excerpts of agency guidance that offer further examples of agency practices, and brief descriptions of other agencies' statements or overarching policies that do not favor tree planting.

Table 1. Agency Tree-Planting Policies, Procedures or Tools

State/Country (Jurisdiction)	Guidance or other Resource
Canada (City of Moncton)	Moncton Subdivision Development: Procedures, Standards and Guidelines. See Chapter 3: Tree Planting and Establishment (page 35 of the manual, page 63 of the PDF). This document is under review; the agency is contemplating an allowable percentage of trees on a street and adding mulch as a landscaping option.
Canada (Saskatchewan)	RSMM 550-10: Setbacks, Roadside Management Manual. Provides guidelines and procedures for setbacks along highways.
Arizona	Roadside Development program website includes Roadside Vegetation Management Guidelines, which address cutting trees and provide limited information on tree planting.
Florida	• Landscape Policy • Section 105, Aesthetic Design, 2025 FDOT Design Manual • Part 2, Chapter 5, Aesthetic Effects of the Project Development and Environment Manual **Note**: Florida DOT avoids planting trees within lateral offsets, clear zones and recovery zones.
Indiana	• Landscape Planting Index. Twelve standard drawing specifications for tree planting • Tree pruning guides. Seven standard drawing specifications for tree pruning
Kansas	• Policy: Non-Highway Use of Right-of-Way for Gateway/Welcome Features Landscaping and Artwork. See Guidelines for Landscaping on Transportation Facility ROW (page 11) and guidelines for plantings (Attachment F, page 39). • Section 908, Trees, Shrubs and Other Plants, Specifications for State Road and Bridge Construction. Provides materials and tree planting requirements.
Kentucky	Complete Streets, Roads and Highways Manual. See **Selected Excerpts from Agency Guidance** following the table for additional information.
Michigan	Michigan Design Manual (Road Design). See **Selected Excerpts from Agency Guidance** following the table for additional information.
Missouri	MoDOT Engineering Policy Guide Category 808: Planting Trees, Shrubs and Other Plants states that roadside plantings including trees, are placed in roadside parks, in rest areas, for screening unsightly areas and for enhancement of roadway locations where future development will not require their removal.
New York	Chapter 28, Landscape Architecture and Community Design for Transportation, Highway Design Manual
Virginia	Landscaping design guidelines are currently being updated. (See the **Note** following the table.)
Washington	Roadside Policy Manual. See Roadside Policies—Treatment--Vegetation (2.3.2), Roadside Restoration—Treatments—Vegetation (4.2.2) and Appendices: • B: Maintenance Tree Removal and Replacement Chart • C: Tree Replacement Flowchart • D: Tree Replacement Calculator Tool Integrated Roadside Vegetation Management Plans. Plans for different areas include sensitive area locations and intended maintenance.
Wisconsin	• Chapter 27, Planting and Aesthetic Design, Facilities Development Manual. See **Selected Excerpts from Agency Guidance** following the table for additional information. • Section 632, Furnishing and Planting Plant Materials, 2025 Standard Specifications

Note: The *Virginia DOT* respondent shared this perspective on the agency's landscape design policies:

> Last July, [Virginia DOT] initiated a task to review and update the organization's landscape policy and design guidelines with collaboration across statewide [d]istricts and [d]ivisions. This task is in progress. The responses are based on guidance being developed for the updated Landscape Design Guidelines. Land use context influences scoping for planting components to be included in a transportation project.

Selected Excerpts from Agency Guidance

Examined in more detail below are publications that address the tree-planting practices of three state DOTs: Kentucky, Michigan and Wisconsin.

Kentucky Transportation Cabinet

Selected portions of the agency's Complete Streets, Roads and Highways Manual (see **Related Resource** below) address tree planting:

- *Page 24 of the manual, page 36 of the PDF*: An example rendering of a planned Complete Street retrofit in Danville, Kentucky, demonstrates how traffic calming and pedestrian-focused elements and amenities, including curb extensions, street trees, lighting and marked crossings bring safety and character to this downtown street.
- *Page 58 of the manual, page 70 of the PDF*: Trees, landscaping and amenities that support the comfort of roadway users, reflect the character of the surrounding land use, and provide health and environmental benefits are appropriate on streets, roads and highways throughout Kentucky. However, the placement of landscaping and amenities must not block the view of other users along a roadway.
- *Page 107 of the manual, page 118 of the PDF*: A section on Planting and Green Space Recommendations advises:

  > Typical planting recommendations, including placement and species selection, will vary widely based on site-specific constraints, land use context, soil composition, and the presence of water. Green spaces, particularly shade trees, are important to the character of the corridor, improve comfort of pedestrians, bicyclists and/or other micromobility users, and may also help reduce urban heat island effects. Street trees typically require a minimum of 6 feet of space to remain healthy with sufficient nutrients and water. Smaller plantings may require less space, but a minimum of 4 feet of space is recommended since plantings and green space require regular maintenance. When plantings and green spaces are part of a Complete Streets project, separate maintenance agreements should be developed for their care.

Related Resource

Complete Streets, Roads and Highways Manual: A Guide to Implementing Safe and Equitable Transportation Strategies for Facilities in Rural and Urban Kentucky, Kentucky Transportation Cabinet, August 2022.
https://transportation.ky.gov/BikeWalk/Documents/Complete%20Streets,%20Roads,%20and%20Highways%20Manual.pdf
From the overview and purpose: In the past, transportation design often favored single-occupancy motor vehicles, moving as many cars as quickly as possible through the network. However, some people choose or need to use alternatives to single-occupancy motor vehicles throughout the Commonwealth. Nearly one-third of Kentucky residents do not have a driver's license to operate single-occupancy motor

vehicles. The KYTC [Kentucky Transportation Cabinet] Complete Streets Policy ("Policy") is the directive from KYTC at the administrative level to promote Complete Streets, creating safe transportation options for users of all ages and abilities through the planning, design, construction, operation, and maintenance of Complete Streets

Michigan Department of Transportation

Chapter 7 of the agency's Design Manual (Road Design) (see **Related Resource** below) describes circumstances under which "it may be necessary to retain trees that otherwise would be considered for removal. *From page 14 of the PDF (Section 7.01.1 B)*:

> **B. Treatment/Consideration of Obstacles Inside the Calculated Project Clear Zone**
> Where the following conditions exist, it may be necessary to retain trees that otherwise would be considered for removal.
>
> 1. At landscaped areas, parks, recreation or residential areas or where the functional and/or aesthetic values will be lost.
> 2. Exceptional or unique trees (because of their size, species or historic value).
> 3. On designated heritage roads and low speed roads (including low speed urban areas).
> 4. At locations where cumulative loss of trees would result in a significant change in character of the roadside landscape.
> 5. Behind nontraversable backslopes.
> 6. Behind vertical curbs, particularly in low speed areas.
> 7. Where shrubs and/or ornamental trees exist that would have a mature diameter of 4" or less at 4'-6" above ground line.
> 8. Where removal would adversely affect endangered/threatened species, wetland, water quality, or result in significant erosion/sedimentation problems.

Related Resource

Chapter 7, Appurtenances, Michigan Design Manual (Road Design), Michigan Department of Transportation, revised April 2023 (for relevant section).
https://mdotjboss.state.mi.us/stdplan/getStandardPlanDocument.htm?docGuid=4554c896-e95a-4f01-ab95-27c637e6e484
This portion of the design manual addresses, among other topics relevant to safety, the clear zone.

Wisconsin Department of Transportation

Chapter 27 of the agency's Facilities Development Manual (see **Related Resources** below) provides guidance for planting and aesthetic design and generally discusses tree planting. *From section FDM 27-1-5 Aesthetic Design*:

> A quality design is appropriate to the site, its functions and environs, and contributes to motorist safety, comfort and enjoyment. To meet these goals, the principles of landscape architecture must be considered at the beginning of the development process.

From FDM 27-1-15 Authority, citing the Wisconsin Administrative Code (see **Related Resources** below):

> The purpose of Trans 280 is to "… establish uniform procedures for increasing the number of hardy and aesthetically pleasing trees planted on highway rights-of-way…" The goals of Trans 280 include the following: "(1) plant trees to enhance roadside aesthetics, maximize oxygen production and improve air quality. (2) Promote the ecological integrity of the state's natural heritage through the

planting of native trees on state highway roadsides. (3) Tree planting should be consistent with a vegetation management plan to … (a) preserve and encourage the regeneration of native vegetation on roadsides." Trans 280 also calls for the identification and classification of vegetation and other roadside features for … "potential enhancements, including reforestation, aesthetic improvement opportunities, erosion control prevention and native vegetation opportunities."

One Wisconsin respondent (*Maintenance*) described the agency as not planting many trees, including to offset lost trees, but hopes to develop a tree-planting program to encourage trees outside of the highway project process.

Related Resources

Chapter 27, Planting and Aesthetic Design, Facilities Development Manual, Wisconsin Department of Transportation, 2022.
https://wisconsindot.gov/rdwy/fdm/fd-27-00toc.pdf
This chapter contains sections on visual impact assessment, planting design and plant materials.

Wisconsin Administrative Code, Chapter Trans 280 – Roadside Vegetation Management, 1994.
https://docs.legis.wisconsin.gov/code/admin_code/trans/280/_1
From Trans 280.01 Purpose and Scope: [T]he purpose of this chapter is to establish uniform procedures for increasing the number of hardy and aesthetically pleasing trees planted on highway rights-of-way, while maintaining highway safety.

From Trans 280.03 Goals:

(1) Plant trees to enhance roadside aesthetics, maximize oxygen production and improve air quality.

(2) Promote the ecological integrity of the state's natural heritage through the planting of native trees on state highway roadsides.

(3) Tree planting should be consistent with a vegetation management plan to:

  (a) Preserve and encourage the regeneration of native vegetation on roadsides.

  (b) Promote highway safety by establishing and maintaining clear zones that are appropriate to any given highway location.

  (c) Avoid interference with the visibility of legal adjacent land use.

Agency Policies or Practices Not Favoring Tree Planting

Three respondents briefly described their agencies' policies or practices that recommend against planting trees:

- *Arkansas DOT* rarely plants trees in the right of way (ROW).
- *New Hampshire DOT* Operations prefers:
  - "[T]rees not be planted to eliminate future needs or concerns. Eventually they will become too big or die, becoming Maintenance's responsibility to remove."
  - Cutting trees to allow solar melting of snow and ice. Shaded areas, especially from white pine trees which hold snow on limbs that blows onto the highway and prolongs the winter storm event, create cold spots and increased ice concerns on the highway.
- *Oregon DOT* typically only plants trees in the ROW to meet mitigation commitments for project delivery and is generally opposed to roadside tree planting, with the respondent noting that

trees provide cover for — and decrease the visibility of — wildlife, can be run-off-road hazards, and can die and fall across the highway.

Examining Federal Guidance

Some respondents described reliance on two AASHTO guidance documents when setting agency tree-planting policy. Selected relevant excerpts from these documents are highlighted below, followed by citations for each document under **Related Resources**.

- *A Policy on Geometric Design of Highways and Streets*, 7th edition (2018) (also referred to as the Green Book). This publication includes multiple references to trees, including the following from Section 7.2.4.1, Clear Zones:

  > A clear unobstructed roadside is highly desirable on high-speed arterials in rural areas. Where fixed objects or non-traversable slopes fall within the clear roadside zones discussed in Section 4.6, "Roadside Design," refer to AASHTO's Roadside Design Guide (6) for guidance in selecting the appropriate treatment. Where practical, fixed objects, including trees that will grow to 4 in. [100 mm] or more in diameter, should be located near the right-of-way line and should be outside the selected clear zone. Where arterials in rural areas pass through a rural town context, the designer may refer to the "Arterials in Urban Areas" discussion in Section 7.3.4

- *Roadside Design Guide*, 4th edition (2011). This publication also addressed the presence or removal of trees, including the following from Section 409, Trees:

  > The removal of individual trees should be considered when those trees are determined to be both obstructions and in a location where they are likely to be hit. Such trees often can be identified by past crash histories at similar sites, by scars indicating previous crashes, or by field reviews. Removal of individual trees will not reduce the probability that a vehicle will leave the roadway at that point, but it should reduce the severity of any resulting crash. For example, 1V:3H and flatter slopes may be traversable, but a vehicle on a 1V:3H slope usually will reach the bottom. If numerous trees are at the toe of the slope, removal of isolated trees on the slope will not significantly reduce the risk of a crash. Similarly, if the recommended clear zone for a particular roadway is 7 m [23 ft], including the shoulder, removal of trees 6 to 7 m [20 to 23 ft] from the road will not materially change the risk to motorists if an unbroken tree line remains at 8 m [26 ft] and beyond. However, isolated trees noticeably closer to the roadway may be candidates for removal. If a tree or group of trees is in a vulnerable location but cannot be removed, a properly designed and installed traffic barrier can be used to shield them. Roadside barriers should be used only when the severity of striking the tree is greater than striking the barrier. Specific information on the selection, location, and design of roadside barriers is in Chapter 5.

Federal Highway Administration (FHWA) resources also address the clear zone, which plays a role in many agencies' decision-making when planting trees.

Related Resources

A Policy on Geometric Design of Highways and Streets, 7th Edition, American Association of State Highway and Transportation Officials, 2018.
Available for purchase at https://store.transportation.org/Item/CollectionDetail?ID=180
From the product description: *A Policy on Geometric Design of Highways and Streets*, 7th Edition, 2018, commonly referred to as the Green Book, contains the current design research and practices for highway and street geometric design. This edition presents an updated framework for geometric design that is more

flexible, multimodal, and performance-based than in the past. The document provides guidance to engineers and designers who strive to make unique design solutions that meet the needs of all highway and street users on a project-by-project basis. Not only are the traditional functional classifications for roadways (local roads and streets, collectors, arterials, and freeways) presented, but also an expanded set of context classifications (rural, rural town, suburban, urban, and urban core) to guide geometric design. The completely rewritten Chapter 1: A New Framework for Geometric Design, introduces the updated approach to design, with specific design guidance throughout each chapter.

Roadside Design Guide, 4th Edition, American Association of State Highway and Transportation Officials, 2011.
Available for purchase at https://store.transportation.org/Item/CollectionDetail?ID=105
The Roadside Design Guide's table of contents and Chapter 1 are available. Relevant sections include:

- Section 4.9, Trees
- Section 10.2.3, Placement of Landscaping, Trees and Shrubs

Clear Zones, FHWA Highway Safety Programs, Federal Highway Administration, June, 2023.
https://highways.dot.gov/safety/rwd/provide-safe-recovery/clear-zones/clear-zones
From the website:

> By creating Clear Zones, roadway agencies can increase the likelihood that a roadway departure results in a safe recovery rather than a crash, and mitigate the severity of crashes that do occur.
>
> A Clear Zone is an unobstructed, traversable roadside area that allows a driver to stop safely, or regain control of a vehicle that has left the roadway. The width of the clear zone should be based on risk (also called exposure). Key factors in assessing risk include traffic volumes, speeds, and slopes. Clear roadsides consider both fixed objects and terrain that may cause vehicles to rollover.
>
> Horizontal 'clearance' must not be confused with 'clear zone'. The minimum 18 inch horizontal clearance to objects behind curbs that is specified in the AASHTO Green Book is a minimum standard offset that allows for normal traffic operations. Because curbs do not deter errant vehicles from leaving the traveled way, the minimum horizontal clearance does not provide a clear zone sufficient to accommodate errant vehicles. The recommended clear zones in the AASHTO Roadside Design Guide (RDG) are based on the design speed of the facility and the slope of the roadside and are not affected by the presence of curbs. It is recognized that providing a clear zone as recommended in the RDG may not be practical in low speed curbed facilities because of right-of-way constraints and other realities of the built environment and a design exception is not required in these cases. However, the minimum 18 inch horizontal clearance to vertical obstructions must still be met unless a design exception is approved.
> ….
>
> AASHTO Roadside Design Guide: This document provides guidance to help highway agencies develop their own standards and policies for determining the widths of clear zones along roadways based on speed, traffic volume, roadside slope and curvature. The recommended clear zone ranges are based on a width of 30 to 32 feet for flat, level terrain adjacent to a straight section of a 60mph highway with an average daily traffic of 6000 vehicles. For steeper slopes on a 70 mph roadway the clear zone range increases to 38 to 46 feet, and on a low speed, low volume roadway the clear zone range drops to 7 to 10 feet. For horizontal curves the clear zone can be increased by up to 50 percent from these figures.

Factors Influencing Tree-Planting Decisions

Survey respondents identified how various factors influence the decision whether — and where — to plant trees in agency ROW or the agency-defined clear zone. Respondents provided varying amounts of information; the respondent from *Saskatchewan Ministry of Highways* did not address these issues.

Below are highlights of overarching themes followed by summaries of survey responses organized in these topic areas:

- *Land use context*. Over half of responding agencies do not apply different practices for planting roadside trees in urban, suburban and rural contexts, while others reported differences such as reduced tree planting in rural areas and local jurisdiction factors.
- *Public interest*. Some agencies reported not considering or generally considering public interest in tree planting, while others identified factors impacting stakeholder interest:
  - Aesthetics.
  - Focus on urban areas.
  - Local government preferences or requests.
  - Neighborhood character or context.
- *Roadway type or classification*. Local, collector and slower-speed roads were more commonly reported to include tree plantings.
- *Posted speed limit or actual driving speed*. Some respondents cited clear zones as determinative and others reported planting trees on roads with speed limits of 45 mph or less.
- *Roadside features (includes guardrails, barriers, curbs and/or gutters or sidewalk)*. Many agencies indicated guardrails and barriers were conducive to planting more trees. Curbs and gutters elicited more mixed responses.

Alaska Department of Transportation and Public Facilities

Criteria	Description
Land Use Context	No distinction.
Public Interest	Public interest is not always considered.
Roadway Type or Classification	Trees are planted on both arterial and collector roads.
Posted Speed Limit or Actual Driving Speed	Speed limits of 45 mph or below.
Roadside Features	Trees are planted behind curbs and gutters.

Arizona Department of Transportation

Criteria	Description
Land Use Context	Practices are based on presence of irrigation water. The agency follows local agency guidelines and requirements for large urban areas.
Other Land Use Considerations	Avoids planting within the clear zone per AASHTO guidelines. Trees planted within the ROW are consistent with guidelines established by the agency's Roadside Development Group, which describe various context sensitive factors as location, setting, environmental mitigation, aesthetics, public perception and adjacent land use.

Criteria	Description
Public Interest	Public interest is a primary consideration, especially in urban areas.
Roadway Type or Classification	Planting practices vary between rural highways and urban freeways.
Posted Speed Limit or Actual Driving Speed	Planting practices vary based on roadway design speeds and average daily traffic volume. Planting is increased where drivers typically stop or drive at lower speeds and decreased on higher speed roads.
Roadside Features	Planting design, location and placement of trees always considers roadside features including maintenance of those features.

Arkansas Department of Transportation

The agency does not plant trees within the ROW in accordance with the AASHTO Roadside Design Guide. Municipal governments can request tree planting permits following Arkansas DOT's environmental guidelines and clear zone policy. The municipal governments would be responsible for tree planting cost and maintenance.

Connecticut Department of Transportation

Criteria	Description
Land Use Context	A "street tree approach" is used in urban areas where there special soil treatments may be needed. The agency is interested in exploring Silva Cell, described by a DeepRoot Green Infrastructure, LLC brochure as a "modular suspended pavement system that uses soil volumes to support large tree growth and provide powerful on-site stormwater management through absorption, evapotranspiration and interception." In suburban and rural areas, trees are planted for reforestation, revegetation or a singular or small shade tree grouping outside of the clear zone or in a protected area.
Other Land Use Considerations	Historic properties may be a consideration in tree planting.
Public Interest	Public interest increases agency efforts and frequency of tree plantings and other design considerations that may be conducive to tree plantings.
Roadway Type or Classification	Plantings are more likely along slower-speed urban roadways or smaller town main streets than other roadway types.
Posted Speed Limit or Actual Driving Speed	Urban or main streets with speed limits under 30 mph are more likely to receive plantings than roadways with faster speeds or in rural areas, unless protected by guiderails or other barriers.

Criteria	Description
Roadside Features	• Curbs and gutters have little to no impact on tree planting decisions. • Guiderails and barriers allow roadside tree plantings on higher speed roadways. • Trees are planted where feasible near sidewalks, given roadway speed and other safety factors.

Florida Department of Transportation

Criteria	Description
Land Use Context	• Plantings in urban or suburban areas will be coordinated with the local jurisdiction, with the local agency taking over maintenance. • Focus in rural areas is typically larger grouping of trees along intersections and pedestrian crossings.
Other Land Use Considerations	Tree planting is indirectly addressed in Chapter 105, Aesthetic Design, in the FDOT Design Manual.
Posted Speed Limit or Actual Driving Speed	Posted speed limits may impact if and where tree planting occurs.
Roadside Features	While trees aren't planted within lateral offsets, clear zones and recovery zones, trees are considered where on-street parking is present and for providing shade along shared-use paths. Relevant provisions from the 2025 FDOT Design Manual: • FDM 212.11 Clear Sight Triangles • FDM 215.2.3 Clear Zone Concept • FDM 215.2.4 Lateral Offset • FDM 222.2.1.1 Sidewalk Width: "Consider providing tree wells where on street parking is present." • FDM 224.18 Shade Considerations discusses providing trees for shade along shared-use paths.

Hawaii Department of Transportation

Criteria	Description
Land Use Context	No distinction.
Public Interest	Considers the need for trees for shade and for beautification purposes.
Roadway Type or Classification	Hawaii does not plant trees on high-speed, access-controlled roadways.
Roadside Features	Plants trees behind guardrails or in low-speed areas with curbs.

Indiana Department of Transportation

Indiana DOT has no formal guidance for distinctions between urban and rural contexts, nor posted, design or actual driving speeds. The respondent commented that “trees in rural areas would likely be offset farther from the roadway than those in urban areas,” highlighting that the higher speeds on rural roadways translate to a “larger clear zone.” The agency has no guidance related to road features and planting trees, however, consideration of appropriate recovery area/clear zone may limit the appropriateness of planting new trees. Requests for permits for planting trees must include letters of community support.

Kansas Department of Transportation

The Kansas DOT respondent provided additional criteria about sight distance at intersections: no shrubs, ground cover or decorative grasses that reach a mature height of more than 36 inches above the roadway will be planted within the clear sight distance triangles of an intersection, interchange, ramp terminal or gore area.

Criteria	Description
Land Use Context	No distinction.
Public Interest	Not considered in planting decisions.
Roadway Type or Classification	Trees are prohibited in medians on roads with speeds greater than 45 mph.
Posted Speed Limit or Actual Driving Speed	Speeds are only a factor in median plantings.
Roadside Features	Though uncommon, trees otherwise considered obstacles could potentially be left if located behind a barrier.

Kentucky Transportation Cabinet

Criteria	Description
Land Use Context	Landscaping and tree placement are tailored to the specific characteristics of the area, whether urban, suburban or rural.
Other Land Use Considerations	To ensure road design aligns with local needs, land use and community preferences, the agency’s tree planting approach is highly context sensitive.
Public Interest	Public input or DOT assessment may identify areas where landscaping and aesthetics are considered beneficial.
Roadway Type or Classification	• Local and minor collector roads are considered appropriate for tree planting. • In rural contexts where vehicle speeds are typically higher, tree planting density is reduced, and lateral offsets are increased to enhance safety.
Posted Speed Limit or Actual Driving Speed	Speed limits between 25 and 45 mph are amenable to trees.
Roadside Features	Trees normally planted alongside curbs, gutters and sidewalks.

Michigan Department of Transportation

Criteria	Description
Land Use Context	No distinction.
Public Interest	• Context Sensitive Solutions design principles include preferences of local stakeholders. • Local agencies give input on new project landscaping and can request tree planting permits apart from a road project.
Roadway Type or Classification	If space allows, trees may be included regardless of roadway type.
Posted Speed Limit or Actual Driving Speed	Design speeds dictate whether trees are planted and depends on the clear zone. If crashes occur frequently in a location outside the clear zone, tree removal may be warranted and planting prohibited.
Roadside Features	Plantings are of sufficient distance from roadside features so as not to interfere with them.

Missouri Department of Transportation

Criteria	Description
Land Use Context	Guided by Engineering Policy Guide, Category 808 Planting Trees, Shrubs and Other Plants: Plantings are placed in roadside parks, in rest areas, for screening unsightly areas, and for enhancement of roadway locations where future development will not require their removal (Section 808.1).
Roadway Type or Classification	Plantings along U.S. and state routes.
Posted Speed Limit or Actual Driving Speed	Speed limits appropriate for trees vary based on road functional classification.

Nevada Department of Transportation

Criteria	Description
Land Use Context	Roadsides in urban areas and interchanges will receive a higher level of treatment, including trees, under Landscape and Aesthetics Corridor Plans.
Public Interest	Considered and accommodated if there is a plan for long-term maintenance and all safety guidelines are met.
Type or Classification of Road	Any road type or functional class with adequate space for safety reasons can accommodate trees.
Posted Speed Limit or Actual Driving Speed	Plantings are appropriate where adequate space exists outside clear zone for safety, rather than speed limits.

Criteria	Description
Roadside Features	• Guardrails and barriers provide flexibility in allowing for trees as both tree and driver are protected. • Curb, gutter or sidewalk will not allow enough protection from crashes with trees unless clear zone calculations allow for them.

New Hampshire Department of Transportation

Criteria	Description
Land Use Context	No distinction.
Public Interest	Public concerns include changes to neighborhood character.
Roadway Type or Classification	Local collectors.
Posted Speed Limit or Actual Driving Speed	45 mph or lower.
Roadside Features	Roadside features may or may not be present where trees are planted.

New York State Department of Transportation (Design)

Criteria	Description
Land Use Context	Planting practices are inversely related to local tree density.
Public Interest	Agency tries to accommodate stronger public interest in having trees in more densely populated areas.
Roadway Type or Classification	Road type and functional classification may indirectly impact tree-planting decisions based on ROW widths and anticipated operating speeds.
Posted Speed Limit or Actual Driving Speed	Planting is typically acceptable at 30 mph posted speeds. Between 35 and 40 mph, more caution and careful positioning is needed to preserve sight distance or avoid fixed objects.
Roadside Features	• Where barriers are required for other reasons, the shielded area they provide is often used to permit planting or natural growth of trees outside of the barrier's deflection distance. • Curbs and gutters are not considered adequate shielding. • Trees near sidewalks are only considered if there is enough clear area to permit trees beyond the clear zone.

New York State Department of Transportation (Landscape Architecture)

Criteria	Description
Land Use Context	For curbed roadway segments, trees can be planted closer to the roadside and may be beneficial for screening and separation of pedestrians and bicyclists from vehicular traffic. For aesthetics, planting in urban and suburban contexts may result in different tree species selection, size and quality (for example, specimen trees).
Public Interest	Defers to AASHTO Green Book criteria.

Criteria	Description
Roadway Type or Classification	Roadway types are considered in planting that is consistent with the AASHTO Green Book.
Posted Speed Limit or Actual Driving Speed	Speed limits are considered in planting that is consistent with the AASHTO Green Book.
Roadside Features	Follows criteria in the AASHTO Green Book.

Oregon Department of Transportation

The agency only plants trees on ROW under project mitigation commitments. No distinctions are made between urban and rural contexts. Trees are planted on the downslope side if there is one, behind a guardrail if one is present and outside the clear zone. Planting will not be done in a location where a tree has the potential to fall onto the highway.

Rhode Island Department of Transportation (Administrative)

This respondent reported no distinctions are made between urban and rural contexts and that roadside barriers or other protections remove the trunk diameter restrictions for trees planted within the clear zone without positive protection. Public requests are considered on a case-by-case basis.

Rhode Island Department of Transportation (Environmental)

Criteria	Description
Land Use Context	No distinction
Public Interest	Tries to accommodate requests for replacement trees or screening/buffer trees.
Roadway Type or Classification	Highways and state roads within a municipality involve varied considerations; for example, larger canopy trees may be selected for highways while sidewalks with nearby buildings may require more columnar trees.
Posted Speed Limit or Actual Driving Speed	Posted speeds impact clear zone determinations where trees are not typically planted.
Roadside Features	• Trees cannot be planted in medians with mountable curbs. • If there is a minimum of 5 feet behind a guardrail, then trees may be considered. • Roadside barriers or other protections remove tree trunk diameter restrictions when trees are planted within the clear zone.

Virginia Department of Transportation

The agency considers maintenance requirements in determining whether and where to plant trees. The landscaping guidelines in development will establish three planting zones with suggestions for intensity of planting and frequency of maintenance as a general guideline.

Criteria	Description
Land Use Context	Generally, there are different maintenance approaches or frequencies for the roadway context of urban, suburban, rural. Land use context influences scoping for planting components in a transportation project.
Public Interest	Enhanced planting design practices can be requested in locality-initiated projects and are negotiated during the project scoping phase.
Roadway Type or Classification	Seven corridor character types/functional classifications have separate planting considerations. Clear zones, transition zones and unrestricted zones are influenced by corridor character types and design speed.
Posted Speed Limit or Actual Driving Speed	Speed influences the width of the clear zone and placement of trees relative to travel lanes.

Washington State Department of Transportation

Criteria	Description
Land Use Context	Guidelines provide different policies for tree planting in forested, open and built character areas.
Public Interest	• Trees are planted to mitigate vegetation removal during construction. • Tree placement always considers public interest and neighboring property owners' needs.
Roadway Type or Classification	Trees are not planted on roadways with less than 30 feet of ROW or in areas where trees do not naturally occur in the landscape.
Posted Speed Limit or Actual Driving Speed	Street trees are incorporated in the clear zone where appropriate on lower speed, urban roadways.
Roadside Features	Barriers are required for planting trees near the road.

Wisconsin Department of Transportation (DTSD)

Criteria	Description
Land Use Context	Depends on funding and maintenance agreements with the local government. More likely to plant in urban areas (for example, roundabouts and street trees).
Public Interest	Considers public input but does not guarantee outcomes.
Roadway Type or Classification	The Facilities Development Manual identifies road types appropriate for trees.
Posted Speed Limit or Actual Driving Speed	Posted speed limits impact tree plantings.
Roadside Features	Sometimes posted speed takes priority over roadside features.

Wisconsin Department of Transportation (Maintenance)

Criteria	Description
Land Use Context	Each situation is different.
Other Land Use Considerations	Environmental commitments may factor into tree planting decisions.
Public Interest	Municipalities occasionally request trees be planted as part of an improvement project. Generally, community sensitive design is used.
Roadway Type or Classification	Most tree planting takes place on mega projects — those with a cost of at least $500 million and use federal funds.
Posted Speed Limit or Actual Driving Speed	Safety clear zones are established by driving speeds.
Roadside Features	These features help determine safe zones for tree placement.

City of Moncton (Canada)

An increasing trend of smaller lots and more duplexes or townhomes with driveways reduces the space available for street trees.

Criteria	Description
Land Use Context	Trees are not generally planted in a rural context.
Public Interest	Not considered.
Roadway Type or Classification	Roadway classification is considered with respect to ROW.
Posted Speed Limit or Actual Driving Speed	Speed limits help establish safety clear zones.
Roadside Features	Sidewalks integrated with curbs impact the type and number of trees planted.

Changes in Tree-Planting Practices

While over half of the responding agencies have not changed tree-planting practices over the years, other agencies have modified their approach to planting trees as part of a transportation construction project:

- *Florida DOT* is moving away from a focus on palm trees to a more balanced approach of trees native to the local environment.
- *Kentucky Transportation Cabinet* has gradually increased the inclusion of landscaping in transportation projects. In the past, most road projects featured little to no landscaping, but this approach has evolved over time to allow for more aesthetic and environmental enhancements.
- *Michigan DOT* has increased efforts to replant as many trees as possible given project site constraints.
- *Washington State DOT* now has a formula for planting trees as mitigation for removal during construction and/or certain maintenance operations. The 2022 revision of the agency's Roadside Policy Manual includes clarified language addressing "how the Roadside Policy aligns with current Agency emphasis areas (i.e., preservation and management of assets, system resilience, promoting the health of pollinators)."

Other state DOTs identified concerns leading to reductions to tree planting:

- **General budget** constraints (*Arizona* and *Wisconsin (DTSD)*).
- **Maintenance** concerns, budgets or other shortfalls (*Alaska*, *Arizona*, *Hawaii* and *Wisconsin (DTSD)*).
- **Pavement root damage** potential (*Hawaii*).
- **Project timelines** insufficient for tree establishment period (*Wisconsin (DTSD*)).
- **ROW needs** driving the determination of whether to plant trees in projects (*Alaska*).
- **Water availability** concerns (*Hawaii*).

The *Rhode Island* (*Environmental*) respondent noted that while landscape contracts had been successful with tree planting, the agency decided not to use separate landscape contracts about a decade ago. Currently, however, the agency is trying to get a landscape contract out to bid.

Other Factors Influencing Placement of Roadside Trees

In this section, other factors that can influence the placement of roadside trees are addressed in three topic areas:

- Characteristics of planted trees.
- Distance from the road edge.
- Roadside slope.

Characteristics of Planted Trees

Certain characteristics of trees contribute to their selection and how they are placed in agency ROW or the clear zone:

- *Tree trunk diameter*: The most common size among respondents for planting in the clear zone is 4 inches or less.
- *Species*: Many respondents select drought-tolerant species that are well adapted or native to the location but roadside conditions may favor using non-native trees in certain locations. Salt tolerance is also considered for survivability in the ROW. Other agencies rely on species lists, guidance, other agencies or local governments for tree selection.
- *Planting density*: Several respondents noted that the planting purpose or context dictates planting density. For example, higher planting density is typically used in lower-speed areas. While lower-density plantings are used in areas where visibility is needed for security and maintenance, higher-density planting may be done in areas where screening is needed.

Table 2 summarizes specific agency practices. Feedback from respondents describing more general practices follows the table.

Table 2. Characteristics of Planted Trees

State/Country (Jurisdiction)	Tree Trunk Diameter	Species	Planting Density
Canada (City of Moncton)	Not provided	Different species based on boulevard width	In accordance with tree-spacing standards

State/Country (Jurisdiction)	Tree Trunk Diameter	Species	Planting Density
Arizona	4-inch limit within clear zone, per the agency's Roadway Design Guidelines and AASHTO guidelines	Native or drought-adapted species	Varies depending on context: • Goal for formal urban freeway landscapes is approximately 1,350 plants per freeway mile with roughly 10% for trees. • No density goals for rural non-formal highways; native seed mixes are used without irrigation water.
Connecticut	4 inched or above is considered a fixed object	Natives, naturalized and some non-natives if proven successful in the environment and have no invasive tendencies	Depends on the planting purpose: • 30 – 50 feet spacing for shade/canopy trees • 10 – 30 feet spacing for reforestation
Florida	4- to 6-inch caliper trees are generally planted outside of clear or recovery zones. Frangible plant material with a mature diameter less than 4 inches is planted in the medians.	• Site-specific and guided by local jurisdictional agencies. • Native plant material generally planted as determined by the project landscape architect.	• Site-specific depending on local environment and site conditions. • Larger grouping of trees generally planted in a rural highway setting.
Hawaii	6-inch limit when mature	Not applicable	Not applicable
Indiana	Less than or equal to 4 inches	No species requirements but requires that seedlings be purchased from sources with have an Active Nursery Dealer License issued by the Indiana Department of Natural Resources (DNR). Indiana DNR maintains a tree species list.	Not provided
Kansas	4 inches when mature	American Hornbeam, Washington Hawthorn and Norway Spruce	Depends on tree type
Michigan	4 inches and smaller must be kept out of the clear zone	Considers species' salt tolerance and survivability in the ROW. Native species are considered but sometimes the roadside conditions favor using non-native trees. See also: • Michigan DOT Plant Selection Manual • Michigan DOT Plant Selection Database	Depends upon the project goal; replacing a large quantity of trees may require closure spacing to achieve higher replacement numbers.

State/Country (Jurisdiction)	Tree Trunk Diameter	Species	Planting Density
Nevada	All trees will be planted outside the clear zone regardless of tree trunk diameter.	Only well-adapted or native drought tolerant species are used. Multiple tree lists are used to select the correct size, disease resistance and branching structural strength.	No specific density guidelines; professional discretion considers canopy sizes and potential obstructions.
New Hampshire	2 to 3 inches	Salt-resistant species of native hardwood and softwood	10- to 15-foot spacing
New York (Design)	Depending on setting, may limit to smaller species.	Generally limits to native species often with smaller mature size.	Strives for healthy spacing at maturity.
New York (Landscape Architecture)	Generally smaller diameter trees, especially in absence of follow-up maintenance.	Native species where possible; streetscapes may use non-natives if survival rates are better.	Consider If screening or special permits are required.
Oregon	Not provided	Will not plant alder, ash, poplar/cottonwood or big leaf maple due to brittleness and susceptibility to breaking in ice storms and the emerald ash borer.	Planted for easy maintenance and long-term growth outlook
Rhode Island (Administrative)	Up to 4 inches if planted within clear zone	Not applicable	Not applicable
Rhode Island (Environmental)	Assumes all trees may grow to 4 inches or greater, therefore trees are not in the clear zone of highways because they are not considered breakaway.	Native species in the right setting; also allows use of ornamentals	Not provided
Virginia	Concern is with mature trunk size of canopy trees outgrowing the planting area and causing operational and maintenance issues.	General guidance for preferred species is provided in a preferred plant list and standardized meadow seed mixes based on physiographic region of the state.	The landscaping design guidelines in development will establish three planting zones with gradation of planting density: clear zone, transition zone and unrestricted zone.
Washington	Trunk diameters greater than 4 inches are not planted within 30 feet of traffic.	Uses only native species that will not be a risk to traffic upon maturity. The agency avoids fast-growing tree species like cottonwood and alder that may be a liability when mature.	Depends on context: • Less density where visibility is needed for security and maintenance. • More density where screening is needed.
Wisconsin (DTSD)	Under 4 inches diameter at breast height (DBH) when fully grown	Requirement of 4-inch DBH at maturity excludes most trees	Have not considered
Wisconsin (Maintenance)	Considered during design	Native species preferred; many seminative tree species are also used	Mature tree size determines spacing and number of trees planted.

Three respondents described more general practices in lieu of providing specific information about tree size, species and planting density:

- All trees are selected by the agency's landscape architect (*Alaska*).
- Tree selection is on a case-by-case basis, tailored to the specific conditions and context of each project. While there is no agencywide guidance on roadside tree species, District 5 based in Louisville has established its own guidelines — an Excel workbook titled *Approved Trees District 5* that includes four tabs describing small to large trees with heights and widths, and a list of approved trees that includes 26 tree species with mature trunk sizes ranging from 1 to 8 inches.

  Planting density varies based on context:
  - Higher planting density, such as every 25 feet, is typically used in lower-speed areas.
  - Spacing is increased in high-risk areas or "hot spots," such as the outside of horizontal curves, near entrances and at bus stops (*Kentucky*).

  Note: These KYTC District 5 guidance documents have been provided to Caltrans separately.
- Many plants have a size and trunk diameter specifications in plans. Size and number are checked when a shipment arrives, and any deficiencies rejected and noted. Each plant should be measured in accordance with directions on the relevant plans. All plants must be certified free of insects and disease by the Missouri Department of Agriculture (*Missouri*).

Distance from the Road Edge

Clear zone considerations were the most common factor identified by responding agencies when determining how far from the road edge to plant trees. Respondents also reported other factors such as prescribed distance (2 to 30 feet), lateral offset requirements, and state or federal guidance. *Alaska DOT* has no applicable requirements for distance from trees to road edge. The factors identified by the remaining respondents are summarized in Table 3.

Table 3. Factors Determining Distance of Trees from Road Edge

Factor	Jurisdiction and Description
Clear Zone	*Connecticut*. Trees must be outside of clear zone if not protected by guiderail. *Hawaii*. Two feet from curb edge on low-speed facilities and/or outside the clear zone. *Indiana.* Setbacks are based on clear zone or reduced clear zone as defined for resurfacing, restoration and rehabilitation (3R) projects. *Kansas.* Outside the clear zone or in medians. *Michigan*. Based on agency clear zone guidelines. *Nevada.* Distances dictated by clear zone, site visibility and all AASHTO and FHWA requirements. *New York (Design).* Distances based on clear zone and speeds. *Oregon*. No trees in clear zone. *Rhode Island (Administrative)*. As far as practical from to maximize clear zone; ROW space often limited. *Virginia*. Clear zones or lateral offsets for tree placement based on design speed and/or roadside features; landscape design guidelines will include typical offset distances from sidewalk/curb. *Wisconsin (Maintenance).* Distance of trees from road edge established via clear zones.

Factor	Jurisdiction and Description
General Agency Guidance	*Canada (City of Moncton)*. Trees typically planted at a boulevard's midpoint. *Canada (Saskatchewan Ministry of Highways)*. RSMM 550-10 Setbacks specifies setbacks for buildings, structures and trees for different road classes. *Michigan*. Clear zone guidelines in the Michigan Design Manual (Road Design): • Section 7.10, Landscaping Guidelines in MDOT Right-of-Way • Section 10.04.04H, Mitigation of Impacts During Construction > Tree Removal and Replacement *Virginia*. Clear Zone or lateral offsets for tree placement are established based on design speed and/or roadside features; Landscape Design Guidelines to note typical offset distance for trees from sidewalk/curb. *Wisconsin (DTSD)*. Guidance defines the distance based on many factors such as speed, distance from the edge of pavement, cut or fill slope, and roadway type or functional class.
General Federal Guidance	*Nevada.* Distances dictated by clear zone, site visibility and all AASHTO and FHWA requirements. *New York (Landscape Architecture*). Based on the clear zone calculations from the AASHTO Green Book. *Washington*. Based on federal guidelines regarding design speed and horizontal alignment
Lateral Offsets	*Florida*. Lateral offset charts based on posted roadway speeds. *Kentucky*. Lateral offset based on speed and context, but distance maximized where feasible. Urban areas with 25 mph speed limits use enhanced lateral offsets of at least 4 feet; at least 6 feet or trees excluded entirely in hot spots (where vehicles are more likely to leave the roadway). *Virginia*. Clear zones or lateral offsets for tree placement based on design speed and/or roadside features; landscape design guidelines will include typical offset distances from sidewalk/curb.
Prescribed Distance	*Arizona*. 30-foot minimum clearance on flat slopes. *Hawaii.* 2 feet from curb edge on low-speed facilities and/or outside the clear zone. *Kansas*. 6 feet from back of curb. *Missouri.* 30 feet from pavement's edge for trees with a trunk of 4 inches or more. *Missouri DOT* provided additional context for determining planting location, which is typically guided by planting plans. Precise plant locations are not generally required for highway work, though accurate locations may occasionally be necessary. In addition to avoiding straight lines and geometrically regular patterns, the resident engineer interprets the plans to consider local conditions, such as accommodating utility lines, and maintaining sight distances and drainage requirements. Plant location adjustments must consider the final appearance at plant maturity. *New Hampshire*. 20 feet.

Roadside Slope

Agencies may also consider roadside slope when determining if, where and what to plant along the roadside. While the *New York State DOT* (*Design*) respondent indicated that slope is not a factor in determining where trees are planted, the *New York State DOT* (*Landscape Architecture*) respondent reported applying clear zone calculations from the AASHTO Green Book. *Virginia DOT's* guidance provides for variation of the clear zone width based on slope conditions. The *City of Moncton* is generally flat so roadside slope is not an issue.

Other survey respondents identified criteria considered when determining to place trees on roadside slopes:

- **Selected by landscape architect during the design phase** (*Alaska, Florida* and *Wisconsin (Maintenance)*). In *Alaska*, all installations known to the respondent are in medians or flat areas behind sidewalks.
- **Slope ratio limits for trees**:
    - Up to 2:1 (*Connecticut, Michigan* and *Nevada*). *Nevada DOT* reports success retaining soil in front of and behind trees.
    - Up to 4:1 (*New Hampshire* and *Arizona*). *Arizona DOT* plants trees farther away from the travel lane the steeper the slope and considers design speed, traffic volume and roadway geometrics criteria.
    - From 10(H):1(V) to 6 (H):1(V) (*Kentucky*).
- **Slope type:**
    - Backslope over fore slope (*Indiana*).
    - Cut or fill slope (*Wisconsin (DTSD)*).
    - Downslopes generally have wider clear zone, depending on context (*Washington*).

In *Michigan*, mowing on steep slopes is a safety concern so the agency has been experimenting with using trees and shrubs to revegetate steep slopes. *Michigan DOT* and Michigan State University recently completed the Slope Restoration on Urban Freeways project identifying best practices for planting shrubs and perennials on the slopes near the many depressed freeways in metro Detroit.

Figure 1 illustrates the clear zone distance employed by Michigan DOT on recoverable slopes.

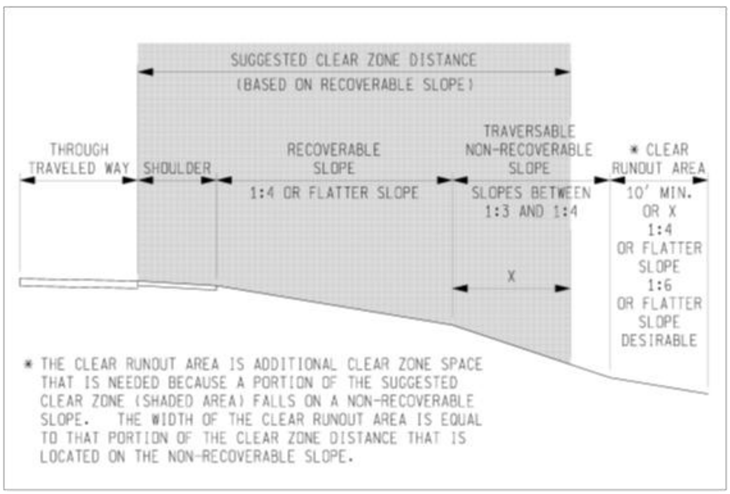

Figure 1. Michigan DOT Clear Zone Distance Based on Recoverable Slope

(*Source*: Michigan Design Manual (Road Design).)

Responsibility for Maintenance

For many responding agencies, local governments are responsible for the maintenance of planted trees, often through maintenance agreements. In some jurisdictions, maintenance responsibilities are shared. A few state DOTs reported sole responsibility for tree maintenance.

Local Government Tree Maintenance

Respondents from eight jurisdictions described tree maintenance responsibilities that are assumed by local entities, with some providing details regarding local agency tree maintenance:

- In municipalities or on university properties, the road owner performs tree maintenance (*Alaska*).
- Trees planted at a city's request via permit are maintained by the requesting city (*Arkansas*).
- Cities maintain roadsides within city boundaries (*Washington*).
- City parks department maintains trees (*City of Moncton*).

Five responding agencies have executed maintenance agreements with local entities (*Connecticut*, *Indiana, New York, Rhode Island* and *Wisconsin*):

- *Connecticut DOT* indicated that tree plantings as part of state projects, while typically designed to be low maintenance, require a maintenance agreement with the host municipality. Likewise, trees along state highways are considered to need little maintenance in *Rhode Island* (*Environmental*). If a state road goes through a town or city, that municipality would be responsible for maintenance through an agreement (*Administrative* and *Environmental*).
- *Indiana DOT* executes a joint-use maintenance agreement between the state DOT and the municipality where the project is located.
- *New York State DOT* contractors are usually responsible for maintaining planted material for at least one year. In urban or suburban areas, local governments or homeowners may have maintenance agreements to care for the plantings (*Landscape Architecture*). The agency's *Design* respondent also noted that maintenance responsibility is generally passed to a local entity. DOT staff do not maintain trees (*Landscape Architecture*) other than removal of unsafe, dead or dying trees (*Design*).
- In *Wisconsin*, counties perform all highway maintenance, including removal and pruning of trees. Maintenance contracts for trees usually are for one to two years (*DTSD* and *Maintenance*).

Shared Maintenance Responsibility

Seven responding state DOTs share tree maintenance responsibilities under a variety of arrangements that define respective duties.

<u>Agreements</u>

- Maintenance responsibility maps designating specific landscape areas are contained within interagency or joint project agreements negotiated by *Arizona DOT* and local public agencies during project design development or post construction.
- Memorandums of understanding (MOU) or memorandums of agreement (MOA) with local agencies are used by *Florida DOT* and *KYTC.* Where KYTC retains maintenance responsibility, low-maintenance trees allow the agency to perform little or no ongoing maintenance on them. KYTC's intent, however, is for the local government to maintain roadside trees and landscaping.
- *Michigan* and *Virginia* DOTs typically maintain trees unless a local agency agreement to maintain an enhanced landscape design is requested. In *Virginia*, enhanced landscape maintenance is negotiated in accordance with the agency's Comprehensive Roadside Management Program.

General Practices

- Landscape installation contractors are typically responsible for maintenance after planting for a two-year establishment period, before *Florida DOT* takes over maintenance.
- Most trees in *Nevada* are maintained by the DOT, unless the trees were planted by a developer or a community is willing to maintain them. Communities can plant more trees if they maintain them. Similarly, in *New Hampshire*, maintenance crews or local interested parties maintain the trees and the agency strives for low or no tree maintenance.

State DOT Tree Maintenance

A few respondents noted that tree maintenance responsibilities reside with DOT staff (*Hawaii*, *Kansas* and *Missouri*). *Missouri DOT* protocol for contractor tree planting includes DOT inspection, replacement of dying plants, and resident engineer documented approval before tree responsibility moves from the contractor to the DOT. Contractors may need to replace rejected trees the following planting season.

Finally, the *Oregon DOT* respondent noted that tree survival is low, and the agency lacks resources for tree maintenance. Friends' groups may receive DOT permission to plant trees in approved ROW locations. Typically, *Saskatchewan Ministry of Highways* will not plant trees and maintaining any trees is the landowners' responsibility.

Considering the Benefits of Trees

Survey respondents were queried about their agencies' interest in quantifying or measuring the safety benefits or traffic calming impacts of trees planted in ROWs or clear zones. While there was significant interest indicated by 14 survey respondents, most have not attempted to quantify or measure safety benefits. Respondents from two state DOTs — Florida and Virginia — provided information on early attempts to quantify or measure the safety or traffic calming benefits of trees.

Florida Department of Transportation

When describing efforts to quantify or measure the safety benefits or traffic calming impacts of trees planted in the ROW or clear zone, the Florida DOT respondent noted that "[w]hile our procedures have language to measure such attributes, in practice this has proven very elusive to quantify." Three guidance documents (see **Related Resources** below) that mention safety benefits of landscaping are described briefly below.

- FDOT's one-page Landscape Policy includes a reference to measuring benefits of landscaping in general. The department is directed to, among other things:
    - Develop and commit to aesthetics, landscape opportunities, and landscape conservation and protection concepts early in programming, planning and designing of transportation facilities.
    - Promote awareness of the many benefits of transportation landscapes enjoyed by the public and within the [d]epartment.
    - ***Measure the costs and benefits*** (emphasis added).
- The Aesthetic Design section of the FDOT Design Manual, Section 105.6, Safety and Scenic Beauty, states:

  > The general principles of aesthetic design include form, scale, order and proportion. Due to the need for uniformity in roadway design, there is often a lack of contrast and variety. This

can contribute to driver monotony, a real safety concern. By integrating aesthetic design principles throughout the design process, the need for uniformity can be balanced with the need for variety and interest.

- Part 2, Chapter 5, Aesthetic Effects of the Project Development and Environment Manual notes that "FDOT considers Aesthetic Effects (AE) during project development because it influences community cohesion, community values and can affect the travel experience. As such, FDOT identifies practical and feasible opportunities to improve project aesthetics during project delivery" and includes multiple references to trees.

Florida DOT has no procedures or metrics in place to acquire data to quantify traffic calming or safety before and after planting. If such data were available, the respondent reported, the agency could use it "to identify locations where landscape installations would increase roadway safety."

Related Resources

Landscape Policy, Topic 000-650-011-d, Florida Department of Transportation, January 29, 2020.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/roadway/landscape-architecture/fdot-procedure-000-650-011.pdf
From the policy: It is the policy of the Florida Department of Transportation to conserve, protect, and enhance Florida's natural resources and scenic beauty when planning, constructing, and maintaining the State Transportation System. Under this policy, Florida can have:

- Safe, attractive and high-quality transportation facilities that reflect and recognize the beauty and nature of Florida.
- Corridors with landscapes that improve air and water quality, benefit ecosystems and enhance communities.
- A transportation system that attracts and supports diverse economic opportunities and tourism.

Section 105, Aesthetic Design, FDOT Design Manual, Florida Department of Transportation, January 2025.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/roadway/fdm/2025/2025fdm105aesthetics.pdf?sfvrsn=c1aa960e_1
This section discusses components of and general guidelines for aesthetic design. *From 105.3 Policies*:

> Section 334.044 (26) Florida Statutes:
> "The department shall have the powers and duties to...conserve the natural roadside growth and scenery; and to provide for the implementation and maintenance of roadside conservation, enhancement, and stabilization programs."

Part 2, Chapter 5, Aesthetic Effects, Project Development and Environment Manual, Florida Department of Transportation, July 2024.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/environment/pubs/pdeman/2024/pt2ch5-073124_clean.pdf?sfvrsn=44d3e6f1_1
From the purpose: Transportation actions can affect communities and influence aesthetic qualities. The FDOT Landscape, Policy No. 000-650-011 was created to conserve, protect, and enhance Florida's natural resources and scenic beauty when planning, constructing, and maintaining the State Transportation System. FDOT considers Aesthetic Effects (AE) during project development because it influences community cohesion, community values, and can affect the travel experience. As such, FDOT identifies practical and feasible opportunities to improve project aesthetics during project delivery.

Virginia Department of Transportation

Virginia DOT is currently researching the traffic calming effects of street trees to potentially expand their use within the clear zone for specific corridor character categories. While no preliminary or final conclusions have been drawn from the exploration, the respondent shared the research team's May 2025 interim findings, which included this excerpt from the interpretive summary:

> Generally, it seems that the benefits of trees on traffic calming are primarily related to their (subconscious) effects on driver awareness. By reducing the optical width of the roadway (i.e., making it seem visually narrower to drivers) trees make the road seem narrower, which decreases driver speeds. They also increase the visual complexity of the road just enough to increase driver attentiveness without being visually overwhelming or distracting. And they are thought to reduce stress, which reduces the likelihood that drivers will engage in unsafe behaviors. These are all very much in line with how accepted traffic calming strategies work; there is just minimal quantified clearly correlated data to back the use of street trees specifically for this purpose.

The research team highlighted selected statistical data identified in relevant papers or journal articles:

> Some statistics consolidated from the few papers that looked at this: Crashes on streetscapes fully covered by tree canopy are 51% less likely to result in injury or death than those on streetscapes without trees. Even for arterial roads, which have a higher rate of severe crashes, presence even of 40% tree canopy may offset this hazard. As the visual width of the street reduces, the odds of a severe crash do too (by 9% for each unit reduction in the ratio of streetscape height to width. Proportions with a factor of 10 or more almost eliminate the likelihood of a crash).

Note: The author of the interim findings cited the following publication as the source of this data:

> "Urban Streetscape Design and Crash Severity," Chester Harvey and Lisa Aultman-Hall, *Transportation Research Record 2500*, pages 1-8, 2015 (see page 60 of this Preliminary Investigation for the citation).

Agency Interest in Quantifying Benefits of Trees

While 14 survey respondents expressed interest in quantifying or measuring the safety benefits or traffic calming impacts of trees planted in the ROW or clear zone, none identified efforts underway to do so. The Connecticut DOT respondent, for example, described a general understanding that street trees provide benefits and would like more information.

Many of these survey respondents described reasons for interest in the potential safety and other benefits of trees and some provided observations or comments. Presented below is respondent feedback in three topic areas:

- Informing tree-planting decisions.
- Supporting speed management strategies.
- Anecdotal evidence of tree-planting benefits.

Informing Tree-Planting Decisions

Several respondents reported interest in data on safety and traffic calming benefits of trees to Inform and justify decisions regarding if and where to plant roadside trees (*Alaska*, *Nevada, Washington* and *Wisconsin* (*DTSD* and *Maintenance*)). As the *Indiana DOT* respondent commented, "Overcoming the long-standing message that all trees are hazards and should be removed is difficult to reframe without supporting data."

Some respondents offered specific reasons for seeking benefit data:

- To support the production of various pre-design or Design Concept Reports during formative project development (*Arizona*).
- To measure and understand the noise reduction effects of trees along high-speed roadways adjacent to neighborhoods (*Arkansas*).
- To inform the agency's Aesthetic Review Team's exploration of the benefits of trees in the median and ROW in general (*Missouri*).
- To address environmental concerns with endangered bat species (*Wisconsin (DTSD)*).
- To understand trees' potential for traffic calming (*Saskatchewan Ministry of Highways*).

Supporting Speed Management Strategies

Three respondents expressed interest in quantitative data to support trees as a speed control strategy:

- Trees can make a roadway "feel" like a lower speed is appropriate and may encourage drivers to change their behavior (*Indiana*).
- Current "context" conversations within the agency, including what to do in transition areas, would benefit from guidance or information on speed control measures (*Kansas*).
- If planting trees closer to traveled lanes reduces speeds, quantified data would be very useful for decision-making regarding tree planting locations (*Michigan*).

Anecdotal Evidence of Tree-Planting Benefits

Survey respondents indicated if their agencies had gathered anecdotal or other evidence regarding a range of potential benefits associated with the presence of roadside trees:

- Aesthetic value
- Carbon sequestration or other air quality impact
- Driver behavioral changes
- Erosion control or stormwater management
- Reduced urban heat island effects
- Speed reduction
- Temperature or climate regulation

Responses are summarized in Table 4, followed by brief descriptions of the anecdotal or other evidence and general comments offered by respondents.

Table 4. Considering the Anecdotal Benefits of Trees

State/Country (Jurisdiction)	Aesthetic Value	Carbon Sequestration or Other Air Quality Impact	Driver Behavioral Changes	Erosion Control or Stormwater Management	Reduced Urban Heat Island Effects	Speed Reduction	Temperature or Climate Regulation
Canada (City of Moncton)	X	X			X	X	
Alaska	X		X				
Arizona	X	X	X	X	X		
Hawaii	X	X					
Michigan	X		X	X			
Nevada	X	X	X	X			
New Hampshire	X						

State/Country (Jurisdiction)	Aesthetic Value	Carbon Sequestration or Other Air Quality Impact	Driver Behavioral Changes	Erosion Control or Stormwater Management	Reduced Urban Heat Island Effects	Speed Reduction	Temperature or Climate Regulation
Rhode Island (Environmental)				X			
Washington		X					
Wisconsin (DTSD)	X	X		X	X		X
Wisconsin (Maintenance)		X			X		X
Total	**8**	**7**	**4**	**5**	**4**	**1**	**2**

Aesthetic Value

Respondents offered general statements regarding trees benefiting street aesthetics (*City of Moncton*) and making a road seem more "livable" as opposed to a throughfare (*Alaska*), noting the "assumption is that the roadside looks better" with trees and other plants than without (*Hawaii*).

Other respondents cited community interest in tree aesthetics:

- Aesthetics is an important consideration in tree planting due to public awareness of the benefits of trees and public or homeowner complaints when trees adjacent to the ROW are removed (*Michigan*).
- Positive community feedback over the years regarding tree planting is evidence of tree benefits (*Nevada*).
- The public's and environmentalists' interest in roadside trees remaining uncut doesn't consider that the slopes were "bare vegetated slopes" when highways were constructed and trees will naturally grow back without the expense of planting them (*New Hampshire*).

The *Wisconsin* (*DTSD*) respondent noted that the recognition that trees have aesthetic value "doesn't hold well for making [trees] a priority."

Carbon Sequestration, Other Air Quality Impacts and Reduced Urban Heat Island Effects

Respondents reported being generally aware of or interested in the air quality and/or urban heat island benefits of trees (*Hawaii, Nevada, Wisconsin (Maintenance)* and *City of Moncton*). The *Wisconsin* (*DTSD*) respondent noted that while the agency has no evidence, landscape architects are becoming educated on these topics as well as temperature or climate regulation.

A City of Phoenix, Arizona, two-page fact sheet quantifies the benefits of trees, including carbon sequestration (see Figure 2 for a link to this publication).

GROWING A HEALTHIER COMMUNITY

KEY TREES – PHOENIX

LACEBARK ELM
Ulmus parvifolia
height 40'-60'
canopy 35'-40'

TEXAS HONEY MESQUITE
Prosopis spp
height 12'-20'
canopy 35'-45'

ARIZONA ASH
Fraxinus velutina
height 35'-45'
canopy 30'-40'

DESERT IRONWOOD
Olneya tesota
height 20'-40'
canopy 40'-80'

PALO VERDE
Parkinsonia spp
height 13'-20'
canopy 30'-50'

DESERT WILLOW
Chilopsis linearis
height 15'-40'
canopy 30'-50'

CHINESE PISTACHE
Pistacia chinensis
height 45'-65'
canopy 35'-45'

ALEPPO PINE
Pinus halepensis
height 50'-80'
canopy 75'-85'

LIVE OAK
Quercus virginiana
height 40'-60'
canopy 50'-80'

EUCALYPTUS / GUM
Eucalyptus spp
height 50'-90'
canopy 40'-65'

Total Annual Value in Urban Tree Benefits: $40.25 million/year
Combined values for annual benefits provided for pollution removal, carbon sequestration, carbon avoidance, energy savings, and storm water avoidance.

Total Structural Value in Urban Trees: $3.842 billion
Structural Value is the standing value of each tree plus the carbon it stores.

SUMMARY OF KEY FINDINGS

Key Highlights

AIR QUALITY
The City of Phoenix urban tree population as a whole stores 305,000 tons of carbon and removes 35,400 tons of carbon from our air each year (valued at $2.52 million/year). Trees remove enough carbon to offset 10,412 cars per year - based on a 25mpg car traveling 12,000 miles/year and producing 14 lbs of CO_2 per gallon of gas.

POLLUTION REMOVAL
Trees within the City of Phoenix intercept 1,770 tons/year of air pollution (valued at $5.76 million/year).

STORMWATER RUNOFF
Trees within the City of Phoenix reduce stormwater runoff by 91.7 million cubic feet per year. That is enough water to fill approximately 23,000 swimming pools (based on an average pool size of 4,000 cubic feet); valued at $6.11 million/year.

ENERGY USE
It is estimated in the City of Phoenix that trees reduce energy-related costs from residential buildings by $22.9 million annually.

PROVIDE SHADE
Trees in the City of Phoenix account for 9% shade within the city. That is shade equivalent to 107,166,640 umbrellas or approximately 186,000 football fields.

Project DESERT CANOPY ARIZONA
Growing a Healthier Community

Produced in cooperation with the USDA Forest Service, which is an equal opportunity service provider and employer

DATA	PHOENIX
Number of Trees	3,166,000
Project Study Area	384.5 sq mi (996 sq km) 246,064 acres
City Land Area	519 sq mi (1,344 sq km) 332,160 acres
Number of Species Sampled	60
Tree Cover	9.0% – 12.9 trees/acre
Most Common Species	Velvet Mesquite 8.3% California Palm 7.5% Sweet Acacia 6.7%
Percentage of Trees less than 6" DBH* DBH is the diameter at 4.5 feet above ground	44.8%
Pollution Removal	1,770 tons/year ($5.76 million/year)
Carbon Sequestration	35,400 tons/year ($2.52 million/year)
Carbon Storage	305,000 tons ($21.7 million/year)
Avoided Carbon Emissions	$2.96 million/year
Oxygen Production	89,200 tons/year
Building Energy Savings	$22.9 million/year
Avoided Stormwater Runoff	91,700,000 cu ft ($6.11 million/year)
Replacement Values	$3.82 billion ($1,207/tree)

Figure 2. First Page of the City of Phoenix Fact Sheet on the Benefits of Trees.

(*Source*: City of Phoenix, Arizona.)

Washington State DOT produced the interpretive panel on carbon storage and roadside fire resilience presented in Figure 3 as one of four panels that will be installed at a rest area as part of the agency's 4-mile Roadside Research Lab demonstration site along I-5 south of Olympia. The respondent noted that the agency expects to share information with the public about this project after all four panels are installed at the rest area.

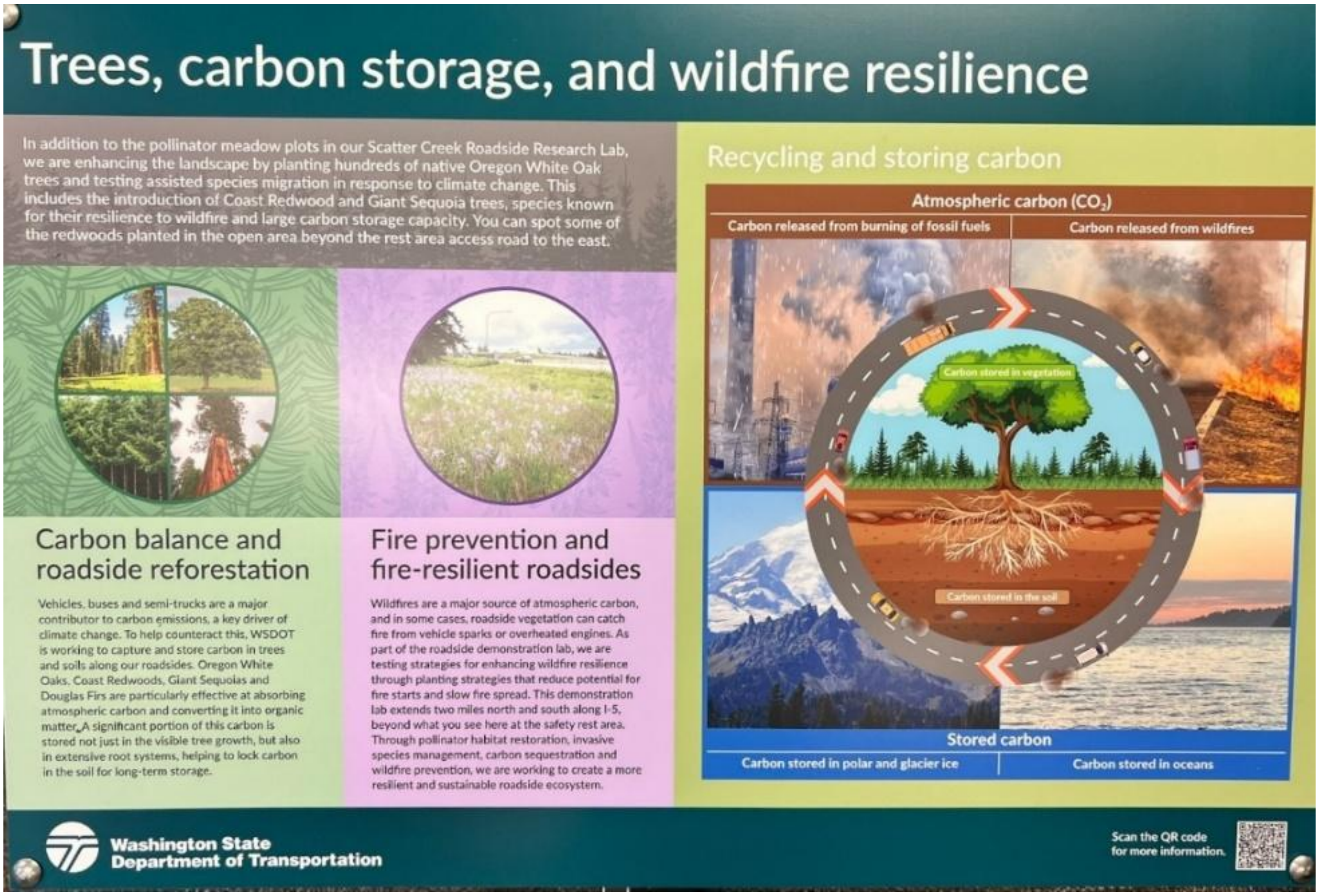

Figure 3. Washington State DOT Interpretive Panel on Trees in Fire-Resilient Roadsides.

(*Source*: Washington State Department of Transportation.)

Erosion Control or Stormwater Management

The *Rhode Island* (*Environmental*) respondent mentioned the general knowledge that tree cover slows water reaching the ground and root systems help with erosion. The *Wisconsin DOT* (*Maintenance*) respondent noted that the agency has used trees for stormwater applications.

Michigan and *Nevada* respondents commented that vegetation, in general, stabilizes slopes and decreases erosion to support the longevity of highway infrastructure.

Speed Reduction and Other Driver Behavioral Changes

Agency responses regarding interest in planting trees as a speed reduction strategy are summarized in the Supporting Speed Management Strategies section above. The *City of Moncton* respondent observed that the inner urban core has a high percentage of mature street trees and experiences low speeds, and notes that other data may be available through speed studies.

The *Alaska* respondent offered an anecdotal observation regarding a project that included, in addition to trees, other features such as continuous sidewalks, turn lanes and raised medians:

> I drive slower personally and have seen that the landscaped project near my house creates more uniform driving.

Michigan DOT follows FHWA guidance on landscaping on roundabouts that encourages the planting of tall shrubs or trees in the central island to emphasize that the road doesn't go straight through. The agency also considers headlight glare, which can be a concern, when planting trees. The *Nevada* respondent recognized that trees, and aesthetics in general, improve the driver experience by not only calming traffic but calming the drivers themselves.

Closing Comments

Several survey respondents indicated keen interest in this Preliminary Investigation (*Alaska, Arizona, Michigan* and *Nevada*). The *Washington State DOT* respondent suggested that the relevant TRB committee would also be interested in Preliminary Investigation findings.

The *New York State DOT* (*Design*) respondent described the difficulty in measuring generally intangible benefits and directly correlating benefits to tree plantings. Finally, the *Kentucky Transportation Cabinet* respondent offered these closing comments recommending against the use of trees as a traffic calming measure:

> While trees and other roadside features can help calm traffic and reduce vehicle speeds, they also present significant hazards. Vehicles that leave the roadway and strike trees often result in severe injuries or fatalities. Using trees as protective barriers for pedestrians and bicyclists is a misguided approach and fuels division among professionals in the highway business.
>
> Pedestrian safety must be improved without increasing the risk of vehicle-related fatalities. Rather than relying on trees to influence driver behavior, roadway geometry should be the primary tool for managing speed and enhancing safety for all users. Proven design strategies — such as raised intersections, speed tables, and chicanes — are effective in calming traffic while maintaining a safer roadside environment. Use these tools — not trees — to protect pedestrians and promote safer streets for everyone.

Related Research and Resources

A literature search of publicly available domestic and international in-progress and published research identified publications that are organized into the following topic areas:

- Current Caltrans guidance.
- Methodologies, tools and quantification measures.
- Related domestic research.
- International resources.

Current Caltrans Guidance

Traffic Calming Guide: A Compendium of Strategies, California Department of Transportation, 2023.
https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/traffic-calming/final-traffic-calming-guide_v2-a11y.pdf
From the introduction:

> Traffic calming strategies should be implemented at locations along the State Highway System (SHS) where vehicle speed will have a negative impact on the non-motorized modes of travel. The Traffic Calming Guide provides best practices, relevant standards and resources discussed in the FHWA Traffic Calming ePrimer. The traffic calming measures encompass various strategies including law enforcement, public education, as well as temporary and permanent highway features that become part of the highway infrastructure. Other important considerations should include the accommodation of emergency response services and the guidance published in Design Information Bulletin 93, Evacuation Route Design Guidance. The State Highway System should be reviewed from a holistic perspective and discussed with local agency partners and communities when working with adjacent private and public access.

See page 87 of the publication, page 88 of the PDF, for information on street trees and landscaping.

Chapter 900, Landscape Architecture – Roadsides, Highway Design Manual, California Department of Transportation, July 2020.
https://dot.ca.gov/-/media/dot-media/programs/design/documents/chp0900-a11y.pdf
The excerpt below is from Section 904.5, Locating Trees, which begins on page 9 of the PDF:

> Trees must be located to not visually restrict existing roadside signs and signals.
>
> Locate trees to maintain a minimum vertical clearance of 17 feet from the pavement to the lower foliage of overhanging branches over the traveled way and shoulder. Locate trees to maintain a minimum vertical clearance of 8 feet from sidewalks or walkways to the lower foliage of overhanging branches for pedestrian passage.
>
> For sidewalks and pedestrian plazas, design tree wells with a minimum of 2 feet from the tree trunk to the edge of the tree well to protect pavement from tree root displacement. Include root barriers to protect the pavement surrounding the tree well. Allow for an appropriate soil volume when designing tree wells.
>
> Without exception, do not plant large trees over gas lines or under overhead utilities and/or structures. Coordinate with local utility provider or District Utility Engineering for guidance.
>
> (1) Large Trees. Large trees are defined as plants which at maturity have trunks 4 inches or greater in diameter, measured 4 feet above the ground. Examples of large tree species are Coast

Redwood (Sequoia sempervirens), Coast Live Oak (Quercus agrifolia), and Deodar Cedar (Cedrus deodara).

(2) Small trees. Small trees are defined as smaller trees or plants usually considered shrubs but trained in tree form that will develop up to a 4-inch diameter trunk at maturity. Examples of small trees are Crape Myrtle (Lagerstroemia indica), and Bottlebrush (Callistemon sp.) trained in standard form.

(3) Clear Recovery Zone (CRZ). Locate trees to be outside the CRZ. The CRZ provides an area for errant vehicles the opportunity to regain control. Refer to Index 309.1(2) for additional information and requirements of the CRZ.

Setbacks are measured from the edge of traveled way to the face of tree trunk. Situate trees to accommodate the anticipated mature tree size.

(a) Freeways and Expressways. On freeways and expressways, including interchange areas, there should be 40 feet or more of clearance between the edge of traveled way and large trees; but, a minimum clearance of 30 feet must be provided where trees may become a fixed object to errant vehicles. However, large trees may be planted within the 30-foot limit if they cannot be reached by an errant vehicle. For example, on cut slopes above a retaining wall, in areas shielded behind concrete barriers, metal beam guardrail, thrie beam, etc. which has been placed for reasons other than tree planting. Additionally, exceptions to the 30-foot setback may also be considered on cut slopes which are 2:1 or steeper. The minimum tree setback in these cases should be 25 feet from the edge of traveled way.

Special considerations should be given to providing additional clearance in potential recovery areas. Setback distances greater than 30 feet should be provided at locations such as on the outside of horizontal curves and near ramp gores.

Large trees should not be planted in unprotected areas of freeway medians or expressway medians except for separated roadways with medians of sufficient width to meet the plant setback requirements for tree planting.

(b) Conventional Highways. When locating large trees on conventional highways comply with the requirements in Table 904.5.

Methodologies, Tools and Quantification Measures

The publications cited in this section provide measures of the safety associated with tree removal or identify ways to quantify the benefits associated with trees in the landscape. A 2025 Texas DOT (TxDOT) study that "introduces the Roadside Vegetation Evaluation Toolkit (RVET) for quantifying the benefits of roadside vegetation" may be of particular interest to the Caltrans panel (see page 55 for the citation).

Citations are further organized as national research, state research and resources, and other research.

National Research

Pending Research: NCHRP Project 17-136: Safe System Approach for Including Trees in Urban and Suburban Roadway Contexts, start date: unknown; expected completion date: unknown.

Note: The project website indicates this: *A research contractor has been selected for the project. The contracting process is underway.*

Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5684

From the objective: The objective of this research is to develop a practitioner's guide for evaluating the safety effects of trees on urban and suburban roadways with a focus on posted speed limits of 35 to 50 mph.

The practitioner's guide will include a framework for the sustainable placement, maintenance, removal and replanting of trees and complementary features in roadway environments. This research will consider the needs of all users of the transportation system and support implementation of the Safe System approach.

NCHRP Report 1016: Design Guidelines for Mitigating Collisions with Trees and Utility Poles, Ingrid B. Potts and Douglas W. Harwood, 2022.
Publication available at https://nap.nationalacademies.org/download/26777/
This publication provides benefit–cost analysis examples of tree *removal* (isolated roadside tree and continuous group of roadside trees). As the authors note in Chapter 3, "[AASHTO's Roadside Design Guide] Chapter 4 provides the following guidance on tree removal:

- Removing a tree will not reduce the probability that a vehicle will leave the roadway at that point, but it should reduce the severity of any resulting crash. For example, 1V:3H and flatter slopes may be traversable, but a vehicle on a 1V:3H slope usually will reach the bottom.
- If numerous trees are at the toe of the slope, removal of isolated trees on the slope will not significantly reduce the likelihood of a crash.
- If the recommended clear zone for a particular roadway is 23 ft, including the shoulder, removal of trees 20 to 23 ft from the road will not materially change the risk to motorists if an unbroken tree line remains at 26 ft and beyond. However, isolated trees noticeably closer to the roadway may be candidates for removal.
- If a tree, or group of trees, is in a vulnerable location but cannot be removed, a properly designed and installed traffic barrier can be used to shield it. Roadside barriers should be used only when the severity of striking the tree is greater than striking the barrier."

Related Resource:

NCHRP Web-Only Document 336: Proposed Guidelines for Fixed Objects in the Roadside Design Guide, Ingrid B. Potts, Douglas W. Harwood, 2022.
Publication available at https://nap.nationalacademies.org/download/26776
Presented below are excerpts from Appendix B. Recommended Text for Potential Use in a Future Edition of the AASHTO Roadside Design Guide. *From page 126 of the report, page 134 of the PDF*:

> This appendix presents text recommended for use in a future edition of the AASHTO RDG [Roadside Design Guide] (AASHTO 2011) to incorporate the results of this research. Potential inserts concerning both utility poles and trees are presented. The recommended RDG text does not attempt to present the full details of the crash prediction method developed in the research, but rather makes reference to the design guidelines document that presents all of the information that a designer would need to apply the method.
>
> ….
>
> **Insert at the end of RDG Section 4.9 (Trees)**
> Roadside improvement programs for removing trees should identify opportunities to reduce tree-related crashes and prioritize potential projects. The highest priorities for improvement projects should focus on trees that are located close to the roadway traveled way on higher volume and higher speed roads and are not shielded by guardrail or other traffic barriers. A

crash prediction method that can provide quantitative estimates of annual crashes likely to occur involving an individual tree or a group of trees is presented as part of the design guidelines in NCHRP Report 1016 (11).

….

While the benefit-cost examples described above, and presented in the design guidelines (11), use typical or representative input data, these inputs vary substantially from site to site, so the most reliable results will be obtained from analyses that use site-specific roadway characteristics, tree location, and improvement cost data. A spreadsheet tool is available with the design guidelines for performing such analyses efficiently.

While tree-related crashes are a key roadside design issue, transportation agencies must recognize in developing strategies for reducing the potential for tree-related crashes that trees are a desirable feature of the landscape and have an important aesthetic value to communities and, indeed, to motorists. The presence of trees makes a community attractive to residents and visitors. Motorists enjoy driving through natural landscapes, and trees are an important element of such landscapes. Trees also make urban communities appear attractive and well planned. At the same time, the potential for motorist deaths and injuries in collisions with trees is a substantial traffic safety issue that deserves to be addressed. Transportation agencies should consult with communities and motorist organizations in developing policies to reduce tree-related crashes. Alternatives to tree removal, such as provision of traffic barriers between the roadway and trees, should be considered, where appropriate.

State Research and Resources

Multiple States

"Variation in Estimates of Heat-Related Mortality Reduction Due to Tree Cover in U.S. Cities," Paramita Sinha, Robert C. Coville, Satoshi Hirabayashi, Brian Lim, Theodore A. Endreny and David J. Nowak, *Journal of Environmental Management*, Vol. 301, January 2022.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S0301479721018132?via%3Dihub
From the abstract: Heat-related mortality is one of the leading causes of weather-related deaths in the United States. With changing climates and an aging population, effective adaptive strategies to address public health and environmental justice issues associated with extreme heat will be increasingly important. One effective adaptive strategy for reducing heat-related mortality is increasing tree cover. Designing such a strategy requires decision-support tools that provide spatial and temporal information about impacts. We apply such a tool to estimate spatially and temporally explicit reductions in temperature and mortality associated with a 10% increase in tree cover in 10 U.S. cities with varying climatic, demographic, and land cover conditions. Two heat metrics were applied to represent tree impacts on moderately and extremely hot days (relative to historical conditions). Increasing tree cover by 10% reduced estimated heat-related mortality in cities significantly, with total impacts generally greatest in the most populated cities. Mortality reductions vary widely across cities, ranging from approximately 50 fewer deaths in Salt Lake City to about 3800 fewer deaths in New York City. This variation is due to differences in demographics, land cover, and local climatic conditions. In terms of per capita estimated impacts, hotter and drier cities experience higher percentage reductions in mortality due to increased tree cover across the season. Phoenix potentially benefits the most from increased tree cover, with an estimated 22% reduction in mortality from baseline levels. In cooler cities such as Minneapolis, trees can reduce mortality significantly on days that are extremely hot relative to historical conditions and therefore help mitigate impacts during heat wave conditions. Recent studies project highest increases in heat-related mortality in the cooler cities, so our findings have important

implications for adaptation planning. Our estimated spatial and temporal distributions of mortality reductions for each city provide crucial information needed for promoting environmental justice and equity. More broadly, the methods and model can be applied by both urban planners and the public health community for designing targeted, effective policies to reduce heat-related mortality. Additionally, land use managers can use this information to optimize tree plantings. Public stakeholders can also use these impact estimates for advocacy.

Colorado

The Unresolved Relationship Between Street Trees and Road Safety, Wesley E. Marshall, Yaneev Golombek, Nicholas Coppola and Bruce Janson, Mountain-Plains Consortium, July 2019.
https://www.ugpti.org/resources/reports/downloads/mpc19-376.pdf
From the abstract: Part 1 relies on advances in remote sensing to map both tree canopy and street-tree locations in GIS for the entirety of the city and county of Denver, Colorado. We then statistically test the association between street trees and seven years of road safety outcomes while controlling for factors known to be associated with crash outcomes. Despite 50 years as standard design practice, our results suggest that the expected safety benefit of roadside clear zones — at least with respect to street trees in an urban context — may be overstated.
….

Part 2 investigates the usefulness of 3D volumetric pixels (voxels) and USGS [U.S. Geological Service] Quality Level 2 (QL2) LiDAR data to measure features in streetscapes. As the USGS embarks on a national LiDAR database with the goal of covering the entire United States with QL2 data or better, this paper investigates uses of QL2 LiDAR for the 3D measuring of streetscapes.

Florida

Economic Impact of Ecosystem Services Provided by Ecologically Sustainable Roadside Right of Way Vegetation Management Practices, George L. (Les) Harrison, Florida Department of Transportation, March 2014.
https://rightofway.erc.uic.edu/wp-content/uploads/2018/05/2A4-FDOT-ecosystem-services-roadsides-report.pdf
From the abstract:

> The economic value of runoff prevention, carbon sequestration, pollination and other insect services, air quality, invasive species resistance and aesthetics was estimated for Florida's State Highway System roadside right-of-way (ROW) ecosystem using the benefits transfer method. Regardless of whether these benefits are classified as ecosystem services or functions, the sum total value of these benefits was conservatively estimated at nearly a half billion dollars. Utilizing sustainable vegetation management practices more than doubles the total value. And incorporating Wildflower Areas (WAs; remnant native plant communities as well as wildflower plantings) nearly triples the value of these benefits. While roadside ROW vegetation historically has been treated as a financial liability to fulfill main FDOT functions, information in this report provides evidence that roadside ROW vegetation is an asset. The cost of vegetation management, at least $33.5 million in 2011-12, is more than offset by the value of only carbon sequestration, a service that potentially could generate income for FDOT via the sale of carbon credits. And implementing sustainable management practices will reduce vegetation management costs nearly 30 percent. Understanding the economic benefits of the roadside ROW ecosystem and sustainable management practices will allow the department to measure outcomes and establish performance targets. Findings in this report serve as an incentive for FDOT to gradually implement innovative, broad scale, ecologically

> sustainable roadside ROW vegetation management practices and expand the number and acreage of WAs.

The author examined the impacts of trees on air quality on page 13 of the report, page 21 of the PDF:

> ***Air quality***. Roadside trees and turf can improve air quality by removing air pollutants such as particulate matter, ozone, nitrogen and sulfur dioxide, and carbon monoxide (Macdonald, Sanders, & Supawanich, 2008). While the value of this ES [ecosystem service] has not been estimated for roadside ROW ecosystems, the value of this service been studied in urban environments, but only for trees. For example, in Modesto, Calif. trees provided about $1.4 million in air quality improvement (Macdonald, Sanders, & Supawanich, 2008). About 47 lb/yr of pollutants at a value of $117 was removed by 879 street trees in Iowa (Thompson, Nowak, Crane, & Hunkins, 2004), while in Chicago the 806 MT [metric tons] of pollutants removed per year by its urban forest was valued at $6.4 million (Nowak, Crane, Stevens, & Fisher, 2010).

Massachusetts

A Method for Examining the Ecosystem Services of Roadside Trees: Springfield, Massachusetts, Ross Kahn, April 2016.
https://www.itreetools.org/documents/326/Method_for_Examining_the_Ecosystem_Services_of_Roadside_Trees_RKahn.pdf
From the project background: This article outlines a series of simple, easy- to- implement scientific experiments to examine various roadside types and report on the ecosystem services that these typical roadsides provide. There are four distinct quantitative components included in this study and four roadside types: major arterial roadways, minor arterial roadways with no tree setback, collector streets, and a local residential street setting. The initial investigation was conducted in Springfield, Massachusetts, and the roadside types examined are representative of the roadside types crossing the City. Research and field observation provided information on the structure of the roadsides, including the underground and overhead utilities, drainage systems, greenspace components and shade tree canopy.

Texas

Quantifying the Benefits of Roadside Vegetation, Kyeong Rok Ryu, Joowon Im, June Young Park, Alireza Shamshiri, Steven Tanner McCullough and Shikha Somani, Texas Department of Transportation, January 2025.
https://library.ctr.utexas.edu/hostedpdfs/uta/0-7162-1.pdf
From the abstract: Transportation agencies and state DOTs have established roadside vegetation programs to enhance sustainability, quality of life and the aesthetics of the transportation systems. However, a comprehensive toolkit to quantify the benefits and risks of various roadside vegetation types and applications has been largely lacking across the nation, including Texas. This study introduces the Roadside Vegetation Evaluation Toolkit (RVET) for quantifying the benefits of roadside vegetation to address this gap, aiding transportation planners, environmental practitioners, and landscape designers within TxDOT in evaluating roadside vegetation. Incorporating extensive geospatial data, the RVET covers five major aspects: environmental benefits, operational and maintenance measures, lifecycle costs, public perception of roads and vegetation, and public perception of aesthetics. The RVET will assist the statewide implementation of improved roadside vegetation management within the TxDOT system, enhancing the health and safety of Texans. This study delivers a comprehensive evaluation of roadside vegetation, providing valuable insights for stakeholders through detailed measurements across five major modules.

Other Research

The Effect of Roadside Vegetation and Clear Zone Design on Driver Behavior, Michael A. Knodler and Cole D. Fitzpatrick, Safer-Sim University Transportation Center, January 2016.
http://safersim.nads-sc.uiowa.edu/final_reports/UM_1_Y1_Report.pdf
From the abstract: Roadside vegetation provides a myriad of environmental and psychological benefits to drivers. Research has shown that, although natural landscapes cause less stress and frustration to the driver, the same vegetation may increase the severity of run-off-the-road crashes. This study evaluates the relationship between clear zone design and the presence of roadside vegetation on driver speed, lateral positioning, and drivers' visual scan patterns. A driving simulator was utilized to test six combinations of clear zone sizes and roadside vegetation densities. Participants' driving performance was measured throughout the virtual drive. While there were no statistically significant differences between drivers' speeds, the speed trends that were found correlate to statistically significant observations in previous research, further validating the effect of clear zone size on driver speed. Along left curves, drivers drove closer to the centerline when there were trees near the edge of the road. Based upon the recorded drivers' eye movements, the horizontal scan pattern did not significantly change between combinations, suggesting that drivers use their peripheral vision to monitor potential hazards.

"Roadside Vegetation Barrier Designs to Mitigate Near-Road Air Pollution Impacts," Zheming Tong, Richard W. Baldauf, Vlad Isakov, Parikshit Deshmukh and K. Max Zhang, *Science of the Total Environment,* Vol. 541, pages 920-927, January 2016.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S0048969715307270
From the abstract: With increasing evidence that exposures to air pollution near large roadways increases risks of a number of adverse human health effects, identifying methods to reduce these exposures has become a public health priority. Roadside vegetation barriers have shown the potential to reduce near-road air pollution concentrations; however, the characteristics of these barriers needed to ensure pollution reductions are not well understood. Designing vegetation barriers to mitigate near-road air pollution requires a mechanistic understanding of how barrier configurations affect the transport of traffic-related air pollutants. We first evaluated the performance of the Comprehensive Turbulent Aerosol Dynamics and Gas Chemistry (CTAG) model with Large Eddy Simulation (LES) to capture the effects of vegetation barriers on near-road air quality, compared against field data. Next, CTAG with LES was employed to explore the effects of six conceptual roadside vegetation/solid barrier configurations on near-road size-resolved particle concentrations, governed by dispersion and deposition. Two potentially viable design options are revealed: a) a wide vegetation barrier with high Leaf Area Density (LAD), and b) vegetation–solid barrier combinations, i.e., planting trees next to a solid barrier. Both designs reduce downwind particle concentrations significantly. The findings presented in the study will assist urban planning and forestry organizations with evaluating different green infrastructure design options.

"Carbon Storage and Sequestration by Trees in Urban and Community Areas of the United States," David J. Nowak, Eric J. Greenfield, Robert E. Hoehn and Elizabeth Lapoint, *Environmental Pollution*, Vol. 178, pages 229-236, 2013.
https://www.fs.usda.gov/nrs/pubs/jrnl/2013/nrs_2013_nowak_001.pdf
From the abstract: Carbon storage and sequestration by urban trees in the United States was quantified to assess the magnitude and role of urban forests in relation to climate change. Urban tree field data from 28 cities and [six] states were used to determine the average carbon density per unit of tree cover. These data were applied to statewide urban tree cover measurements to determine total urban forest carbon storage and annual sequestration by state and nationally. Urban whole tree carbon storage densities average 7.69 kg C m2 of tree cover and sequestration densities average 0.28 kg C m2 of tree

cover per year. Total tree carbon storage in U.S. urban areas (c. 2005) is estimated at 643 million tonnes ($50.5 billion value; 95% CI ¼ 597 million and 690 million tonnes) and annual sequestration is estimated at 25.6 million tonnes ($2.0 billion value; 95% CI ¼ 23.7 million to 27.4 million tonnes).

"Quantified Tree Risk Assessment Used in the Management of Amenity Trees," Michael J. Ellison, *Journal of Arboriculture*, Vol. 31, Issue 2, pages 57-65, March 2005.
https://doi.org/10.48044/jauf.2005.007
From the abstract: A system of tree risk assessment is proposed that expands concepts developed by others and enables a probability of significant harm to be applied to tree failure risk. By evaluating the components of a tree failure hazard and assigning to them estimates of probability, the proposed system enables the skilled tree inspector to calculate the product of those probabilities to produce a numerical estimate of risk. The use of quantification in the assessment of tree hazards enables property owners and managers to operate, as far as is reasonably practicable, to a predetermined limit of reasonable or acceptable risk.

Related Domestic Research

Publications in this section are further organized as state research and resources and other resources.

State Research and Resources

Florida

"Frequency and Severity of Tree and Other Fixed Object Crashes in Florida, 2006-2013," Jeffery W. Van Treese II, Andrew K. Koeser, George E. Fitzpatrick, Michael T. Olexa and Ethan J. Allen, *Arboriculture and Urban Forestry*, Vol. 45, Issue 2, pages 65-74, March 2019.
https://doi.org/10.48044/jauf.2019.006
From the abstract:

> Roadside trees provide benefits to drivers such as traffic calming, roadway definition and driver stress reduction. However, trees are also one of several roadway infrastructure elements commonly involved in single-vehicle crashes. In this study, Florida Highway Safety and Motor Vehicle records were analyzed to: evaluate the relative frequency of tree-related crashes compared to other fixed-object crashes; assess the impact of roadway-, vehicle-, and driver-related factors on tree crash frequency; and compare the severity of tree crashes relative to other single-vehicle crashes. In accessing 3,033,041 crash records from 2006 to 2013 (all complete years), we identified 323,581 single-vehicle accidents (10.6%) and 47,341 tree-related accidents (1.6%). Trees were the third most common fixed object hit in urban single-vehicle accidents and the second most common fixed object hit in rural single-vehicle accidents. Driver gender, vehicle type, light conditions, weather conditions and land use all were correlated with the frequency. Additionally, the injuries associated with tree crashes were more severe than all other single-vehicle crash types except vehicle rollovers.

The authors noted the following in concluding the article with implications for planning:

> While potential risks such as second-hand smoke inhalation offer no benefit to those subjected to it, roadside trees differ in that they can do both harm and good. In fact, excessive tree removal has its risks. In a study on the effects of drastic urban tree removal following infestations of the highly destructive emerald ash borer, researchers found that areas that lost tree canopy over a 17-year period experienced an additional 6,113 deaths related to respiratory illness and an additional 15,080 deaths linked to cardiovascular-related deaths (Donovan et al. 2013). Even the act of removing trees itself increases the likelihood of death, as forestry is consistently ranked one of the most dangerous

occupations (National Safety Council 2017). As such, roadside tree removal or retention decisions are a balance of risk versus benefit. Removal efforts should focus on high-risk and low-value trees, leaving trees with lower risks and higher benefits. Ultimately, risk is situation-specific, and the character of the road and land use must be considered in evaluating trees as crash hazards.

Georgia

“Daylighting Decision-Making at State Departments of Transportation: A Case Study of Roadside Tree Removal,” Ellen O. White, *Transportation Research Interdisciplinary Perspectives*, Vol. 28, November 2024.
https://www.sciencedirect.com/science/article/pii/S2590198224002410
From the abstract: Transport agencies worldwide must operate with multiple strategic goals: safety, mobility, sustainability and equity. In support of these goals, they employ experts from a wide range of disciplines, which often operate in silos. In many instances, the silos can undermine agency goals. In this case study, I investigate the state department of transportation in the US state of Georgia, which cleared thousands of acres of roadside trees beginning in 2018 without public or environmental review. The agency’s stated aim was to enhance roadside safety. I interviewed staff in various agencies across Georgia to discover how this happened when the environmental costs were so great and when the agency employs so many experts in environmental and ecology roles. The findings justify a renewed focus on multidisciplinary efforts and training, enhanced federal regulations for DOT maintenance actions, and a call for more interdisciplinary transportation research.

“Assessing Large-Scale Roadside Tree Removal Using Aerial Imagery and Crash Analysis: A Difference-in-Differences Approach,” Ellen O. White and Marcia S. Meixler, *Landscape and Urban Planning*, Vol. 244, April 2024.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S0169204623002992
From the abstract: In this paper, we quantified the extent of tree removal within a 60 m buffer along the five major interstates in Georgia, using aerial imagery from the United States Department of Agriculture (USDA) Farm Service Agency’s National Agricultural Imagery Project (NAIP). We used supervised image classification and change detection on aerial imagery between 2015 and 2021. We also collected pre- and post-treatment crash data and conducted a difference-in-differences analysis on sampled road segments to isolate the effect of tree removal on crash rates.

Results showed that 28.4 sq km of previously forested land in the interstate corridors were cleared of trees, 25% of the total forested land in the corridors. Tree crash fatalities did not decrease.

Findings provide insight into approaches to roadside safety like tree removal while helping assess impacts and plan for next steps. The lack of evidence for reduced tree crash fatalities indicate that transport agencies should consider measures other than large-scale tree removal to prevent fatal crashes with trees.

Kansas

“Cost-Effective Safety Treatment of Trees on Low-Volume Rural Roads,” Karla A Lechtenberg, Cody Stolle, Ronald K. Faller and Kevin Schrum, *Transportation Research Record 2472*, Issue 1, pages 194-202, May 2015.
Publication available at https://www.researchgate.net/publication/282521583_Cost-Effective_Safety_Treatment_of_Trees_on_Low-Volume_Rural_Roads
From the abstract: Generally, trees are naturally occurring fixed objects that are found along many roadways and that potentially pose safety risks to errant motorists. Unfortunately, trees have been

responsible for numerous fatal and serious injury crashes during run-off-road events. This study included an incremental benefit-to-cost (B-C) analysis that used the Roadside Safety Analysis Program to investigate the efficacy of safety treatment alternatives for trees on roadways with volumes of less than 500 vehicles per day (vpd) and speed limits of 55 mph (88.5 km/h) or greater. The study was based on a parametric analysis of site characteristics from a field survey in Kansas. It used four tree groupings, three tree diameters and four lateral offsets from the roadway to configure 120 scenarios. Three safety treatment methods were considered: (a) a do-nothing option representing the baseline condition; (b) tree removal, with cost estimates coming from reliable sources; and (c) a crashworthy guardrail system. For various reasons, the guardrail system was no more cost-effective than the do-nothing or tree removal options. B-C ratios were used to recommend tree removal on the basis of several pertinent variables. In all cases, B-C ratios for tree removal were never less than 1.0, which indicated limited justification for keeping the trees. Tree removal was considered the safest and primary alternative when trees were far from other fixed obstacles. Because these guidelines are based solely on B-C analyses, the road designer or engineer is encouraged to use them as a foundation for making safety improvements but also to consider site-specific investigation and analysis.

Massachusetts

The Role of Street Trees for Pedestrian Safety, Robert L. Ryan, Theodore S. Eisenman and Alicia F. Coleman, Massachusetts Department of Transportation, February 2018.
https://rosap.ntl.bts.gov/view/dot/64848/dot_64848_DS1.pdf
From the abstract: This research report studies the link between street trees and the gap between pedestrians' perceptions of safety and their actual safety while walking along street corridors. Prior to this report, there was little research highlighting the relationship between street trees and pedestrian safety. The research team undertook two projects to understand the role of street trees and pedestrian safety: (1) An analysis of 181 pedestrian intercept surveys across streets with varying street tree cover; and (2) A GIS mapping analysis that measured urban design variables and street tree characteristics alongside recorded pedestrian-vehicle crashes. Overall, street trees did positively impact pedestrian safety, but the impact was small and further research is needed. These findings support the work of previous research and contain relevant information for street redesign standards and planning, especially Complete Streets guidance and technical assistance. Street trees can serve as an option for applying Complete Streets principles into smaller-scale projects to improve pedestrian mobility and community livability, especially in environmental justice areas. There may also be ways to leverage street tree advocacy and streetscape redevelopment projects through existing funding programs, and promote inter-agency collaboration and public-private partnerships.

New York

"Urban Streetscape Design and Crash Severity," Chester Harvey and Lisa Aultman-Hall, *Transportation Research Record 2500*, Issue 1, pages 1-8, January 2015.
Citation at https://journals.sagepub.com/doi/10.3141/2500-01
From the abstract: Streetscape design is increasingly acknowledged as a tool for improving traffic safety and livability in urban settings. While traditional highway safety engineering promotes removing obstacles from and widening roadside clear zones to reduce collision potential, a contrasting framework proposes that smaller, more enclosed streetscapes may encourage slower, less risky driving and therefore improve both livability and safety. Such a strategy may have particular relevance along urban arterials, where large clear zones may be impractical because of complex adjacent land uses and where the promotion of livable spaces is an increasing focus. This study examined streetscape design and traffic safety in urban settings by assessing relationships between crash severity and streetscape design variables in New York City. A method based on a geographic information system was used for the

precise capture of streetscape design measurements at the locations of more than 240,000 crashes. Logistic regression models indicated that crashes on smaller, more enclosed streetscapes were less likely to result in injury or death compared with those on larger, more open streetscapes. These results point to in-fill development and street tree planting as safety countermeasures that are consistent with additional livability goals such as walkability, high-quality design of the public realm, and provision of natural amenities.

Washington

Safe Streets, Green Cities: Good Health, University of Washington, last modified August 2018.
https://depts.washington.edu/hhwb/Thm_SafeStreets.html
From the introduction: City streets are not just thoroughfares for motor vehicles; they serve as public spaces where people walk, shop, meet and participate in activities that make urban living enjoyable. Conventional guidelines for transportation safety regard trees as roadside fixed-objects that constitute driving hazards but urban foresters, designers, and planners encourage tree planting to enhance the livability of urban streets. This article surveys the research on roadside vegetation benefits, and the scientific evidence concerning city trees, and transportation safety.

Other Research

"Unclear Territory: Clear Zones, Roadside Trees and Collaboration in State Highway Agencies," Ellen Oettinger White, *Transportation Research Part D: Transport and Environment*, Vol. 118, May 2023.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S1361920923000470?via%3Dihub
From the abstract: The American Association of State Highway and Transportation Officials (AASHTO) issues guidance for highway agencies to maintain clear zones adjacent to the roadbed, free of trees, to reduce the severity of run-off-the-road crashes. Some departments of transportation (DOTs) are clearing trees beyond the standard clear zone for road safety, creating friction between units of different disciplines.

Following an analysis of roadside tree literature, I use semi-structured interviews with agency staff to illuminate how perceptions of trees—either as safety hazards or as beneficial environmental assets—are considered by practitioners at state highway agencies. Results indicate that engineering leadership understands roadside tree management as a nuanced issue.

The benefits of trees are understood by most staff though are rarely a sufficient counterweight for perceived safety issues. Maintenance staff are motivated more by budgets or contracts than by research or federal guidance. An interdisciplinary staff structure, robust communication practices, and stronger environmental policy can improve DOT collaboration.

"Street Trees for Bicyclists, Pedestrians and Vehicle Drivers: A Systematic Multimodal Review," Theodore S. Eisenman, Alicia F. Coleman and Gregory LaBombard, *Urban Science*, Vol. 5, Issue 3, August 2021.
https://www.mdpi.com/2413-8851/5/3/56
From the abstract: Multimodal Complete Streets have emerged as a prominent aspiration of urban planning to ensure safe access for all users of streets including pedestrians, bicyclists, motorists and transit users. Concurrently, municipal leaders are pursuing ambitious tree planting initiatives. These co-arising trends are potentially good news, as trees are important elements of livable cities and Complete Streets. Yet, street trees may have different health and safety benefits and disbenefits for various circulation modes. To advance a multimodal approach to research and practice, we undertook a systematic literature review with goals to (1) identify the scholarly literature addressing links between

street trees, human health and safety for pedestrians, bicyclists and vehicle drivers; (2) depict the principal disciplines, themes and conceptual scope of this research; and (3) discuss the implications for urban planning and design practice and research. This review drew upon 13 scholarly databases and yielded 63 relevant articles spanning 15 countries, of which 49 constituted original research. The systematic analysis covers eight research categories. Findings show exponential growth in related scholarship over the past two decades, especially for pedestrians. Journals oriented toward interdisciplinary planning and public health and safety are leading this rise, and benefits far outweigh disbenefits. Yet, there are multimodal tensions especially as it relates to the role of street trees in relationship to drivers and pedestrians. Implications for research and practice are discussed, with an eye towards governance, design and equity.

"The Effects of Roadside Vegetation Characteristics on Local, Near-Road Air Quality," Parikshit Deshmukh, Vlad Isakov, Akula Venkatram, Bo Yang, K. Max Zhang, Russell Logan and Richard Baldauf, *Air Quality, Atmosphere and Health*, Vol. 12, pages 259-270, 2019.
Citation at https://doi.org/10.1007/s11869-018-0651-8
From the abstract: A study was conducted along a highway with differing vegetation characteristics to identify if and how the changing characteristics affected downwind air quality. The results indicated that roadside vegetation needed to be of sufficient height, thickness and coverage to achieve downwind air pollutant reductions. A vegetation stand which was highly porous and contained large gaps within the stand structure had increased downwind pollutant concentrations. These field study results were consistent with other studies that the roadside vegetation could lead to reductions in average, downwind pollutant concentrations by as much as 50% when this vegetation was thick with no gaps or openings. However, the presence of highly porous vegetation with gaps resulted in similar or sometimes higher concentrations than measured in a clearing with no vegetation. The combination of air quality and meteorological measurements indicated that the vegetation affects downwind pollutant concentrations through attenuation of meteorological and vehicle-induced turbulence as air passes through the vegetation, enhanced mixing as portions of the traffic pollution plume are blocked and forced over the vegetation, and through particulate deposition onto leaf and branch surfaces. Computational fluid dynamic modeling highlighted that density of the vegetation barrier affects pollutant levels, with a leaf area density of 3.0 $m^2\ m^{-3}$ or higher needed to ensure downwind pollutant reductions for airborne particulate matter. These results show that roadside bushes and trees can be preserved or planted along highways and other localized pollution sources to mitigate air quality and human health impacts near the source if the planting adheres to important characteristics of height, thickness, and density with full coverage from the ground to the top of the canopy. The results also highlight the importance of planting denser vegetation and maintaining the integrity and structure of these vegetation barriers to achieve pollution reductions and not contribute to unintended increases in downwind air pollutant concentrations.

"Roadside Vegetation Design to Improve Local, Near-Road Air Quality," Richard Baldauf, *Transportation Research Part D: Transport and Environment*, Vol. 52, Part A, pages 354-361, May 2017 (author manuscript).
https://pmc.ncbi.nlm.nih.gov/articles/PMC6060415/
From the abstract: As public health concerns have increased due to the rising number of studies linking adverse health effects with exposures to traffic-related air pollution near large roadways, interest in methods to mitigate these exposures have also increased. Several studies have investigated the use of roadside features in reducing near-road air pollution concentrations since this method is often one of the few short-term options available. Since roadside vegetation has other potential benefits, the impact of this feature has been of particular interest. The literature has been mixed on whether roadside vegetation reduces nearby pollutant concentrations or whether this feature has no effect or even

potentially increases downwind air pollutant concentrations. However, these differences in study results highlight key characteristics of the vegetative barrier that can result in pollutant reductions or increase local pollutant levels. This paper describes the characteristics of roadside vegetation that previous research shows can result in improved local air quality, as well as identify characteristics that should be avoided in order to protect from unintended increases in nearby concentrations. These design conditions include height, thickness, coverage, porosity/density, and species characteristics that promote improved air quality. These design considerations can inform highway departments, urban and transportation planners, and developers in understanding how best to preserve existing roadside vegetation or plant vegetative barriers in order to reduce air pollution impacts near transportation facilities. These designs can also be used to mitigate impacts from other air pollution sources where emissions occur near ground-level.

"Tree Planting and Clearing Guidance with Consideration of Minimized Crash Risk," Christine E. Carrigan, T. Olaf Johnson and Malcolm H. Ray, *Transportation Research Record 2588,* Issue 1, pages 110-115, January 2016.
Citation at https://journals.sagepub.com/doi/abs/10.3141/2588-12
From the abstract: Improvement projects are increasingly introducing landscape elements to add aesthetic appeal to the projects. Though effective for improving aesthetics, the introduction of trees on the roadside may increase the risk of fatal or incapacitating crashes. In general, the goal of roadside design is to minimize, in so far as is practical, the chance of fatal or incapacitating injury crashes on the roadside. It may not be possible to minimize that risk to the level implied in AASHTO's *Roadside Design Guide* while capturing the benefits provided by trees, but it is still desirable to understand the risk presented by the presence of trees and balance that risk with the aesthetic benefits. The widely adopted benefit–cost methods currently used in the *Roadside Design Guide* present a significant challenge with respect to the consideration of trees. Many purported benefits of trees have not been or cannot be quantified in dollars; this lack makes the traditional unit of measurement (i.e., dollars) in a benefit–cost analysis unavailable. This paper presents a quantitative approach for assessing the risk of fatal and incapacitating injuries presented by various tree spacing and offsets. This approach can be applied to any roadway where tree planting or removal is being considered, to quantify the risk of the current and proposed tree locations such that informed decisions can be made about the risk introduced by trees and whether the risks outweigh the benefits.

International Resources

Australia

Trees in Medians and Roadsides in the Urban Environment: Operational Instruction 19.8, Department for Infrastructure and Transport, Government of South Australia, August 2025.
https://www.dit.sa.gov.au/__data/assets/pdf_file/0005/396104/Operational_Instruction_19_8_Trees_in_Medians_and_Roadsides_in_the_Urban_Environment_v11.pdf
From the scope: This Operational Instruction has been developed to provide direction to traffic engineering practitioners, landscape architects and planners when considering tree planting in raised medians and roadsides within the Department for Infrastructure and Transport's (the Department) road corridors. The Department's approach to planting and maintenance of trees and vegetation in urban road corridors aims to balance the safety risk to road users with the Department's and the community's goals for an attractive, shady, liveable city that encourages use of active travel and public transport. The requirements of this Operational Instruction have been informed by multi-criteria assessment against the key principles and objectives (described in section 2).

"Reduce Speed Limits to Minimize Potential Harm and Maximize the Health Benefits of Street Trees," Xiaoqi Feng, Michael Navakatikyan and Thomas Astell-Burt, *Land*, Vol. 13, Issue 11, November 2024. https://www.mdpi.com/2073-445X/13/11/1815
From the abstract: Urban greening is threatened by the concern that street trees increase traffic-related injury/death. Associations between all serious and fatal traffic crashes and street tree percentages were examined in Sydney, Australia. Associations were adjusted for confounding factors relating to driver behavior (speeding, fatigue, and use of alcohol) and road infrastructure, including alignment (e.g., straight, curved), surface condition (e.g., dry, wet, ice), type (e.g., freeway, roundabout), and speed limit. Models indicated that 10% more street trees were associated with 3% and 20% higher odds of serious or fatal injuries and 20% tree collisions on roads of any speed, respectively. However, further analysis stratified by speed limit revealed contrasting results. Along roads of 70 km/h or greater, 10% more street trees were associated with 8% higher odds of serious or fatal injury and 25% higher odds of death. Comparable associations were not found between street trees and serious or fatal injuries along roads below 70 km/h. Reducing speed limits below 70 km/h saves lives and may mitigate risks of serious or fatal traffic accidents associated with street trees, enabling greener, cooler, healthier cities.

"Effect of Urban Street Trees on Pedestrian Safety: A Micro-Level Pedestrian Casualty Model Using Multivariate Bayesian Spatial Approach," Manman Zhu, N.N. Sze and Sharon Newnam, *Accident Analysis and Prevention*, Vol. 176, October 2022.
Citation at https://doi.org/10.1016/j.aap.2022.106818
From the abstract: In the past decades, trees were considered roadside hazard. Street trees were removed to provide clear zone and improve roadside safety. Nowadays, street trees are considered to play an important role in urban design. Also, street tree is considered a traffic calming measure. Studies have examined the effects of urban street trees on driver perception, driving behaviour and general road safety. However, it is rare that the relationship between urban street trees and pedestrian safety is investigated. In this study, a micro-level frequency model is established to evaluate the effects of tree density and tree canopy cover on pedestrian injuries, accounting for pedestrian crash exposure based on comprehensive pedestrian count data from a state in Australia, Melbourne. In addition, effects of road geometry, traffic characteristics and temporal distribution are also considered. Furthermore, effects of spatial dependency and correlation between pedestrian casualty counts of different injury severity levels are accounted [for] using a multivariate Bayesian spatial approach. Results indicate that road width, bus stop, tram station, on-street parking and 85th percentile speed are positively associated with pedestrian casualty. In contrast, pedestrian casualty decreases when there is a pedestrian crosswalk and increases in tree density and canopy. Also, time variation in pedestrian injury risk is significant. To sum up, urban street trees should have favorable effect on pedestrian safety. Findings are indicative to optimal policy strategies that can enhance the walking environment and overall pedestrian safety. Therefore, sustainable urban and transport development can be promoted.

Canada

"Urban Trees and Human Health: A Scoping Review," Kathleen L. Wolf, Sharon T. Lam, Jennifer K. McKeen, Gregory R.A. Richardson, Matilda van den Bosch and Adrina C. Bardekjian, *International Journal of Environmental Research and Public Health*, Vol. 17, No. 12, 2020.
https://doi.org/10.3390/ijerph17124371
From the abstract: The urban forest is a green infrastructure system that delivers multiple environmental, economic, social and health services, and functions in cities. Environmental benefits of urban trees are well understood, but no review to date has examined how urban trees affect human health. This review provides a comprehensive summary of existing literature on the health impacts of urban trees that can inform future research, policy, and nature-based public health interventions. A systematic search used keywords representing human health, environmental health and urban forestry.

Following screening and appraisal of several thousand articles, 201 studies were conceptually sorted into a three-part framework. Reducing Harm, representing 41% of studies, includes topics such as air pollution, ultraviolet radiation, heat exposure, and pollen. Restoring Capacities, at 31%, includes attention restoration, mental health, stress reduction, and clinical outcomes. Building Capacities, at 28%, includes topics such as birth outcomes, active living, and weight status. The studies that were reviewed show substantial heterogeneity in purpose and method yet indicate important health outcomes associated with people's exposure to trees. This review will help inform future research and practice, and demonstrates why urban forest planning and management should strategically promote trees as a social determinant of public health.

China

"Investigating Streetscape Environmental Characteristics Associated with Road Traffic Crashes Using Street View Imagery and Computer Vision," Han Yue, *Accident Analysis and Prevention*, Vol. 210, February 2025.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S0001457524003968?via%3Dihub
From the abstract: Examining the relationship between streetscape features and road traffic crashes is vital for enhancing roadway safety. Traditional field surveys are often inefficient and lack comprehensive spatial coverage. Leveraging street view images (SVIs) and deep learning techniques provides a cost-effective alternative for extracting streetscape features. However, prior studies often rely solely on semantic segmentation, overlooking distinctions in feature shapes and contours. This study addresses these limitations by combining semantic segmentation and object detection networks to comprehensively measure streetscape features from Baidu SVIs. Semantic segmentation identifies pixel-level proportions of features such as roads, sidewalks, buildings, fences, trees and grass, while object detection captures discrete elements like vehicles, pedestrians and traffic lights. Zero-inflated negative binomial regression models are employed to analyze the impact of these features on three crash types: vehicle-vehicle (VCV), vehicle–pedestrian (VCP) and single-vehicle crashes (SVC). Results show that incorporating streetscape features from combined deep learning methods significantly improves crash prediction. Vehicles have a significant impact on VCV and SVC crashes, whereas pedestrians predominantly affect VCP crashes. Road surfaces, sidewalks and plants are associated with increased crash risks, while buildings and trees correlate with reduced vehicle crash frequencies. This study highlights the advantages of integrating semantic segmentation and object detection for streetscape analysis and underscores the critical role of environmental characteristics in road traffic crashes. The findings provide actionable insights for urban planning and traffic safety strategies.

"Not Just More, But More Diverse: Green Landscapes Along Urban Roads May Significantly Reduce Drivers' Psychophysiological Fatigue," Wenyan Xu, Jibo He and Bin Jiang*, Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 103, pages 273-289, May 2024.
Citation at
https://www.researchgate.net/publication/380104375_Not_just_more_but_more_diverse_Green_landscapes_along_urban_roads_may_significantly_reduce_drivers'_psychophysiological_fatigue
From the abstract: The impact of roadside greenness on driving fatigue in real urban settings has been insufficiently investigated, presenting a critical knowledge gap for researchers, policymakers, professionals and the public. In this onsite driving experiment, 34 urban residents completed seven driving tasks on different urban road routes in a randomized order with one-day intervals. A total of 238 tasks were conducted, each lasting an hour, assessing psychophysiological, visual and muscular fatigue. A cardiovascular activity monitor (BioHarness) continuously measured the driver's heart rate, with lower rates indicating reduced psychophysiological fatigue. Visual and muscular fatigue were self-reported using a Visual Analog Scale questionnaire administered before, at the midpoint, and after completing the driving task. Deep transfer learning semantic segmentation analyzed road landscape characteristics

and traffic conditions recorded from the drivers' view. Statistical analysis demonstrated that higher mean and variation in greenness significantly predicted lower psychophysiological fatigue after adjusting for multiple covariates. These results indicate that enhancing both the quantity and diversity of green landscapes along urban roads is vital for reducing driver's psychophysiological fatigue. This study reveals that roadside landscapes in urban settings are not trivial decorations, and they should be considered an essential component of transportation infrastructure.

Germany

"Toward Livable and Healthy Urban Streets: Roadside Vegetation Provides Ecosystem Services Where People Live and Move," Ina Säumel, Frauke Weber and Ingo Kowarik, *Environmental Science and Policy*, Vol. 62, Issue 6, pages 24-33, June 2016.
Publication available at
https://www.researchgate.net/publication/285131637_Toward_livable_and_healthy_urban_streets_Roadside_vegetation_provides_ecosystem_services_where_people_live_and_move
From the abstract: Fostering ecosystem services in urban road corridors is an important challenge for urban planning and governance because residents are often exposed to environmental pressures in these ubiquitous open spaces. We here aim at illustrating multiple ecosystem services that may be underpinned by roadside vegetation. Previous work is broadly scattered in papers from the natural and social sciences and biased by a focus both on regulating services (temperature regulation, air filtration, carbon sequestration) and also on trees. We provide a first synthesis that illustrates (i) the multi-functional capacity of green elements in streetscapes to deliver various ecosystem services; (ii) the relevance of planted and wild-grown herbaceous vegetation as well as trees; and (iii) trade-offs between certain ecosystem services as well as risks related to disservices. Trees and herbaceous road vegetation can mitigate adverse environmental conditions in road corridors, which is particularly important in vulnerable neighborhoods that are undersupplied with green spaces. Enhancing the amenity value of streetscapes might also positively influence public health by promoting physical activity. However, significant knowledge gaps exist, e.g. on the contribution of biodiversity to ecosystem services and on the valuation of green street components by different sociocultural groups. Our synthesis illustrates management options that can support planning and governance approaches toward more livable streetscapes by fostering ecosystem services and counteracting disservices.

Italy

"Does Roadside Vegetation Affect Driving Performance? A Driving Simulator Study on the Effects of Trees on Drivers' Speed and Lateral Position," Alessandro Calvi, *Transportation Research Board 94th Annual Meeting,* January 2015.
Publication available at
https://www.researchgate.net/publication/273313882_Does_Roadside_Vegetation_Affect_Driving_Performance_A_Driving_Simulator_Study_on_the_Effects_of_Trees_on_the_Driver's_Speed_and_Lateral_Position
From the abstract: This study investigated the effects of roadside vegetation on driving performance on a two-lane rural road. Forty-four participants drove along seven different roadside tree configurations implemented in a driving simulator. Configurations were characterized by two offsets of trees from the road edge (1.5 m and 4.0 m) and three spacings between trees (10.0 m, 17.5 m and 25.0 m) located on the roadside of a 6.0 m wide two-lane rural road. One additional configuration, without trees, was used as the baseline condition. The investigation was developed over five geometric elements: sharp/gentle, left/right curves and tangent. The driver's lateral position and speed were subsequently collected. Compared to the baseline condition, it was found that when trees were close to the road edge drivers tended to significantly decrease their speed and moved towards the centerline of the road. On the

contrary, when the offset of trees increased, drivers adopted higher speeds, increasing the distance from the road edge but with a lower left lateral displacement. This occurred along all five geometries, especially on sharp curves. Tree spacing did not affect the driver's speed but significantly influence the lateral position: drivers moved further away from the road edge when tree spacing decreased. The results demonstrate that drivers balance the useful guidance information that roadside trees provide with the risk associated with their presence: when trees are far, the sense of guidance is predominant and drivers adopt higher speeds; when trees are close, they are seen as a risk by drivers who consequently slow down and move further away from them. Such driving behaviour has direct impacts on the safety implications of roadside trees which are discussed in this paper.

Poland

"Roadside Vegetation: The Impact on Safety," Katarzyna Kocur-Bera and Małgorzata Dudzińska, *Engineering for Rural Development*, Vol. 14, pages 594-600, January 2015.
Publication available at https://www.researchgate.net/publication/282680798_Roadside_vegetation_-_The_impact_on_safety
From the abstract: Trees and other vegetation, called "roadside vegetation," are found along a road lane and have different functions. This paper provides the analysis of the impact of vegetation on water erosion, winter conditions, visibility of formation line, glare effect, inhibition of energy, wind strength, presence of animal habitats and creation of specific microclimate. Apart from typical ecological functions, they also impact the risk for people involved in the traffic flow. These influences have both a positive and negative impact on the safety of vehicle flow on roads. The paper uses the method of data analysis, and accident rates were calculated with the participation of environmental conditions — driving into a tree, hitting an animal, rainfall, snowfall, blinding sun and strong wind gusts. The main conclusions of the study include: (1) roadside vegetation has many positive characteristics and also influences the safety of road users, (2) taking into consideration different environmental conditions, most road accidents are caused by driving into a tree, (3) the overall number of road accidents in Poland influenced by environmental conditions is decreasing despite the growth in the number of vehicles, (4) by employing the standards of woodlot shaping, it is possible to retain the positive influence of the vegetation on the space and, simultaneously, make the space safe for road users.

Sweden

"Review on Urban Vegetation and Particle Air Pollution – Deposition and Dispersion," Sara Janhäll *Atmospheric Environment*, Vol. 105, pages 130-137, March 2015.
https://www.sciencedirect.com/science/article/pii/S1352231015000758?via%3Dihub
From the abstract: Urban vegetation affects air quality through influencing pollutant deposition and dispersion. Both processes are described by many existing models and experiments, on-site and in wind tunnels, focusing [for example] on urban street canyons and crossings or vegetation barriers adjacent to traffic sources. There is an urgent need for well-structured experimental data, including detailed empirical descriptions of parameters that are not the explicit focus of the study.
This review revealed that design and choice of urban vegetation is crucial when using vegetation as an ecosystem service for air quality improvements. The reduced mixing in trafficked street canyons on adding large trees increases local air pollution levels, while low vegetation close to sources can improve air quality by increasing deposition. Filtration vegetation barriers have to be dense enough to offer large deposition surface area and porous enough to allow penetration, instead of deflection of the air stream above the barrier. The choice between tall or short and dense or sparse vegetation determines the effect on air pollution from different sources and different particle sizes.

United Kingdom

"Tree Loss Impacts on Ecological Connectivity: Developing Models for Assessment," Roslyn C. Henry, Stephen C.F. Palmer, Kevin Watts, Ruth J. Mitchell, Nick Atkinson and Justin M.J. Travis, *Ecological Informatics*, Vol. 42, pages 90-99, November 2017.
https://www.sciencedirect.com/science/article/pii/S157495411730211X
From the abstract: Trees along linear features are important landscape features, and their loss threatens ecological connectivity. Until recently, trees outside of woodlands (TOWs) were largely unmapped however; the development of innovation mapping techniques provides opportunities to understand the distribution of such trees and to apply spatially explicit models to explore the importance of trees for connectivity. In this study, we demonstrate the utility of models when investigating tree loss and impacts on connectivity. Specifically, we investigated the consequences of tree loss due to the removal of roadside trees, a common management response for diseased or damaged trees, on wider landscape functional connectivity. We simulated the loss of roadside trees within six focal areas of the south east of the UK. We used a spatially explicit individual-based modelling platform, RangeShifter, to model the movement of 81 hypothetical actively dispersing woodland breeding species across these agriculturally fragmented landscapes. We investigated the extent to which removal of trees, from roadsides within the wider landscape, affected the total number of successful dispersers in any given year and the number of breeding woodlands that became isolated through time. On average roadside trees accounted for < 2% of land cover, but removing 60% of them (~ 1.2% of land cover) nevertheless decreased the number of successful dispersers by up to 17%. The impact was greatest when roadside trees represented a greater proportion of canopy cover. The study therefore demonstrates that models such as RangeShifter can provide valuable tools for assessing the consequences of losing trees outside of woodlands.

“Soil Surface Temperatures Reveal Moderation of the Urban Heat Island Effect by Trees and Shrubs,” J.L. Edmondson, I. Stott, Z.G. Davies, K.J. Gaston and J.R. Leake, *Scientific Reports*, Vol. 6, 2016. https://doi.org/10.1038/srep33708

From the abstract: Urban areas are major contributors to air pollution and climate change, causing impacts on human health that are amplified by the microclimatological effects of buildings and grey infrastructure through the urban heat island (UHI) effect. Urban greenspaces may be important in reducing surface temperature extremes, but their effects have not been investigated at a city-wide scale. Across a mid-sized UK city we buried temperature loggers at the surface of greenspace soils at 100 sites, stratified by proximity to city centre, vegetation cover and land-use. Mean daily soil surface temperature over 11 months increased by 0.6 °C over the 5 km from the city outskirts to the centre. Trees and shrubs in non-domestic greenspace reduced mean maximum daily soil surface temperatures in the summer by 5.7 °C compared to herbaceous vegetation, but tended to maintain slightly higher temperatures in winter. Trees in domestic gardens, which tend to be smaller, were less effective at reducing summer soil surface temperatures. Our findings reveal that the UHI effects soil temperatures at a city-wide scale, and that in their moderating urban soil surface temperature extremes, trees and shrubs may help to reduce the adverse impacts of urbanization on microclimate, soil processes and human health.

Contacts

CTC engaged with the individuals below to gather information for this investigation.

State Agencies

Alaska

Lauren Little
Chief Engineer, Statewide
Alaska Department of Transportation
907-378-5911, lauren.little@alaska.gov

Arizona

Kirk Kiser
Professional Landscape Architect, Central District Landscape Development
Arizona Department of Transportation
602-768-4596, kkiser@azdot.gov

Alexa Lopezlira
Environmental Planning Group
Arizona Department of Transportation
928-679-0741, alopezlira@azdot.gov

Arkansas

Hannah LyBrand
Staff Engineer, Roadway Design
Arkansas Department of Transportation
479-360-7141, hannah.lybrand@ardot.gov

Connecticut

Matthew Verry
Transportation Supervising Landscape Architect
Connecticut Department of Transportation
860-594-3349, matthew.verry@ct.gov

Florida

Allie Caldwell
Complete Streets Coordinator
Florida Department of Transportation
850-414-4330, carey.caldwell@dot.state.fl.us

Hawaii

Ross Hironaka
Highway Design Engineer
Hawaii Department of Transportation
808-692-7570, ross.hironaka@hawaii.gov

Indiana

Elizabeth Mouser
Standards and Policy Director
Indiana Department of Transportation
317-232-6775, emouser@indot.in.gov

Kansas

Jeff Sims
Senior Road Design Leader
Kansas Department of Transportation
785-296-2093, Jeff.sims@ks.gov

Kentucky

Jeff Jasper
Program Manager, Project Development
Kentucky Transportation Cabinet
502-229-0819, jeff.jasper@uky.edu

Michigan

Jaime Nauta
Landscape Architect, Roadside Development
Michigan Department of Transportation
517-285-7376, mailto:Nautaj@michigan.gov

Missouri

Kirby F. Woods, Jr.
Roadside Design Specialist
Missouri Department of Transportation
573-450-2475, Kirby.WoodsJr@modot.mo.gov

Nevada

John L’Etoile
Landscape Architect Supervisor
Nevada Department of Transportation
775-888-7337, jletoile@dot.nv.gov

New Hampshire

Alan Hanscom
State Maintenance Engineer
New Hampshire Department of Transportation
603-271-2693, alan.g.hanscom@dot.nh.gov

New York

Terry Hale
Senior Engineer, Office of Design
New York State Department of Transportation
518-485-7009, Terry.Hale@dot.ny.gov

Christine Colley
Landscape Architect, Office of the Environment
New York State Department of Transportation
518-485-9313, christine.colley@dot.ny.gov

Oregon

Patti Caswell
Maintenance Environmental Program Manager, Maintenance and Operations
Oregon Department of Transportation
503-913-9221, patti.caswell@odot.oregon.gov

Rhode Island

Susan Votta Tantimonico
Landscape Architect, Environmental Division
Rhode Island Department of Transportation
401-921-1114, susan.votta@dot.ri.gov

Sean Raymond
Assistant Director of Administrative Services
Rhode Island Department of Transportation
401-563-4204, Sean.Raymond@dot.ri.gov

Virginia

Emmett Heltzel
State Location and Design Engineer
Virginia Department of Transportation
804-786-0121, Emmett.Heltzel@VDOT.Virginia.Gov

Washington

Ray Willard
Landscape Architect, Maintenance Operations
Washington State Department of Transportation
360-705-7865, ray.willard@wsdot.wa.gov

Wisconsin

Erik Emerson
Standards Development Engineer, Roadside Design
Wisconsin Department of Transportation
(608)266-2842, erik.emerson@wi.gov

Mark Polega
Landscape Architect, Bureau of Highway Maintenance
Wisconsin Department of Transportation
608-266-6791, mark.polega@dot.wi.gov

Christa Schaefer
Landscape Architect, Division of Transportation System Development
Wisconsin Department of Transportation
608-266-3943, Christa.schaefer@dot.wi.gov

Canadian Agencies

City of Moncton, New Brunswick

Radya Rifaat
Transportation Engineer, Engineering
City of Moncton, New Brunswick, Canada
506-877-4264, radya.rifaat@moncton.ca

Saskatchewan

Jeffrey Holland
Traffic Engineering Standards
Saskatchewan Ministry of Transportation, Canada
306-787-8353, jeffrey.holland@gov.sk.ca

Appendix A: Survey Questions

An online survey was distributed to state transportation agency members of two American Association of State Highway and Transportation Officials (AASHTO) and two Transportation Research Board (TRB) committees:

- AASHTO Committee on Maintenance
- AASHTO Committee on Design. This committee supports the Technical Committee on Roadside Safety.
- TRB Standing Committee on Landscape and Environmental Design (AKD40)
- TRB Standing Committee on Roadside Safety Design (AKD20)

The online survey was also distributed to appropriate transportation-related contacts at selected Canadian municipalities and provinces:

- City of Edmonton, Alberta
- City of Moncton, New Brunswick
- City of Toronto, Ontario
- City of Vancouver, British Columbia
- City of Winnipeg, Manitoba
- Manitoba Transportation and Infrastructure
- New Brunswick Transportation and Infrastructure
- Ontario Transportation Maintenance Management
- Saskatchewan Design and Construction Division

Caltrans Survey on Identifying Quantified Safety and Traffic Calming Benefits of Trees

Tree-Planting Practices

1. Please briefly describe the factors your agency considers when deciding if and where to plant trees in agency rights of way or in the clear zone as defined by your agency.

   Land use context:
   Roadway type or functional classification:
   Posted speed limit or actual driving speeds:
   Presence of roadside features such as guardrails, barriers, curbs and/or gutters or sidewalks:
   Public interest:
   Other (Please describe.):

2. Please briefly describe how your agency uses the criteria below when deciding to place a roadside tree.

   Tree trunk diameter:
   Distance from road edge:
   Roadside slope:
   Planting density:
   Species:
   Other (Please describe.):

3. Does your agency apply different practices for the planting of roadside trees in urban, suburban and rural contexts?

   - No
   - Yes (Please describe agency practices.)

4. Who maintains the trees after installation? This could be your agency's maintenance crews, a local government agency or another entity.
5. Have your agency's tree-planting practices changed over the years?
    - No
    - Yes (Please describe how your agency's tree-planting practices have changed and why.)
6. Does your agency have policies, procedures or tools to guide the planting of roadside trees?
    - No
    - Yes (Please provide links to publications describing this guidance. Send any files not available online to susan.johnson@ctcandassociates.com.)

(Required) 7. Has your agency attempted to quantify or measure the safety benefits or traffic calming impacts of trees planted in rights of way or the clear zone?

- Yes (Skipped the respondent to **Quantifying or Measuring the Benefits of Trees** and **Wrap-Up**.)
- No (Skipped the respondent to **Considering the Benefits of Trees** and **Wrap-Up**.)

Quantifying or Measuring the Benefits of Trees

1. Please describe your agency's efforts to quantify or measure the safety benefits or traffic calming impacts of trees planted in rights of way or the clear zone.
2. Please describe the metrics that resulted from this quantification effort.
3. How has, or how will, your agency use the results of this quantification effort?
4. Please describe the challenges your agency experienced when attempting to quantify or measure the safety or traffic calming benefits of trees.
5. Please provide links to documents associated with your agency's quantification of the safety benefits or traffic calming impacts of trees. Send any files not available online to susan.johnson@ctcandassociates.com.
6. Please describe any anecdotal or other evidence your agency has gathered regarding the benefits of roadside trees using the categories below.

    Aesthetic value:
    Carbon sequestration or other air quality impact:
    Driver behavioral changes:
    Erosion control or stormwater management:
    Reduced urban heat island effects:
    Speed reduction:
    Temperature or climate regulation:
    Other (Please describe.):

Considering the Benefits of Trees

1. Does your agency have any interest in quantifying or measuring the safety benefits or traffic calming impacts of trees planted in rights of way or the clear zone?
    - No
    - Yes (Please describe your agency's interest and how the data gathered from a quantification effort might be used.)

2. Please describe any anecdotal or other evidence your agency has gathered regarding the benefits of roadside trees using the categories below.

    Aesthetic value:
    Carbon sequestration or other air quality impact:
    Driver behavioral changes:
    Erosion control or stormwater management:
    Reduced urban heat island effects:
    Speed reduction:
    Temperature or climate regulation:
    Other (Please describe.):

<u>Wrap-Up</u>

Please use this space to provide any comments or additional information about your previous responses.