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Benefits and Risks of Urban Roadside Landscape: Finding a Livable, Balanced Response

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Benefits and Risks of Urban Roadside Landscape: Finding a Livable Balanced Response

Karen K. Dixon and Kathleen L. Wolf

ABSTRACT

Placement of trees and landscape features within the urban right-of-way is often perceived by transportation officials as a safety risk. Conversely, there are many community benefits that may result from having roadside landscape, and advocates of urban forestry encourage roadside plantings. Within urban environments transportation mobility and accessibility needs should be balanced with urbanites' health and welfare. This paper reviews the many issues surrounding urban roadside landscape. It summarizes both the quantified effects of roadside landscape and proposed researchable questions that could aid communities in pursuing the balance of transportation quality and urban livability. Topics will include urban forest benefits in communities, studies of trees and traffic safety, landscape affects concerning traffic calming, self-enforcing streets, and street design. The authors provide a multidisciplinary perspective on this topic; one represents traffic engineering and the second is active in urban forestry planning and design. They collectively present the diverse issues concerning the placement of living, fixed objects adjacent to the urban roadway. The goal of this paper is 1) report the best available science on this often controversial topic, 2) to offer suggestions for ways to evaluate the safety impact of urban trees and landscape, and 3) to suggest workable solutions for tree and landscaping placement that address safety concerns of transportation professionals and integrate the interests and values of urban communities.

INTRODUCTION

Transportation corridors are major infrastructure elements of today's cities, and actions by transportation designers and planners have great influence on social ecology and community. City streets are not simply thoroughfares for motor vehicles, but must also serve as public spaces where people walk, shop, meet, and generally participate in the social and recreational activities that make urban living enjoyable. Urban foresters, designers, and planners encourage streetscape tree planting to enhance the livability of urban streets. Yet transportation professionals often discourage the placement of inflexible features near travel lanes due to safety concerns. Urban foresters, transportation professionals, and community members all recognize that the urban forest generates numerous and diverse benefits.

High-quality trees play many roles in community livability. This paper provides a summary of the research about the environmental, social, and economic benefits of the urban forest. Current roadside practices often weigh tree crash statistics against anecdotal reports of tree benefits in transportation decision-making. Discussions about trees are largely framed in terms of aesthetic values, and may not be viewed as justification for trees when weighed against long-held assumptions about safety. This paper has two other purposes. Acknowledging that any roadside fixed object presents risk, it will offer design recommendations that may enhance urban roadside safety. Second it will offer recommendations for future research concerning urban streets, vegetation and safety.

TREES AND LIVABILITY – THE EVIDENCE

Arboriculture and urban forestry are professional and scientific disciplines that have to do with city trees. Arboriculture addresses the care and stewardship of single or small groves of trees in built environments. Urban forestry is the planning and management of trees, forests, and related vegetation as systems within communities (on public and private properties) to create or add value. Urban forests are important because of their geographic extent, their proximity to people, and their impact on local economies.

In recent years the urban and community forestry paradigm has shifted from focus on beautification to one that encompasses all of the environmental, conservation, economic, and social benefits of community trees (1). This shift has been accompanied by increased local participation and new partnerships that link professionals, non-governmental organizations, industry, and government agencies. The urban forest is recognized as an important element of livable communities, supported by an extensive scientific literature.

Ecosystem Services

Natural ecosystems supply a multitude of resources and processes that benefit people. Ecosystem services and benefits include products like clean drinking water and processes like the decomposition of wastes (2). Common belief is that ecosystem services are free, invulnerable and infinitely available. Recent indications of ecological decline have prompted efforts to evaluate trade-offs between immediate and long-term human needs. Economic valuation techniques help inform decision-makers, and are helping to place ecosystem services on par with market goods and services in policy and planning.

Ecosystem services are typically perceived as being derived from wildlands or more pristine landscapes. Research in urban ecology and urban forestry indicates that nature services are also provided in built environments, and by relatively small units of nature (such as a single tree). In cities ecosystem services are conceptualized somewhat differently. For instance, "green infrastructure" refers to planned, interconnected systems of green spaces, parks and natural elements that conserve natural ecosystem values and functions (3). Historically, parks and tree plantings have been implemented in a scattered disconnected process. Just as communities plan and construct the built infrastructure of roads, sewers, and utilities, there is also a need to develop a community's natural life support system, the ecological framework needed for environmental and economic sustainability.

Another, and related, concept concerning urban nature services are "biotechnology" functions (4). There are numerous U.S. national and state regulatory programs concerning environmental quality and human health. Research indicates that urban trees, in adequate quantity and location, offer a cost effective approach for urban communities to meet environmental standards, such as clean air and water.

Precipitation and Stormwater

Impervious surfaces concentrate and direct precipitation. Hard surfaces will generate two to six times more runoff than a natural surface (5). Adverse effects include increased flooding, erosion, sedimentation, water pollution, stream channel instability and loss of both in-stream and streamside habitat. Trees intercept a significant amount of rainfall in their canopies, where it evaporates and does not contact the ground. Understory vegetation and soils aid filtration and direct water into ground storage. Alternatively, impervious surfaces like pavement provide little water detention options resulting in potential downstream flooding during extreme conditions. Thus trees can reduce the rate and magnitude of storm water runoff, and improve surface water quality.

Planting trees in built areas provide cost savings as storm water drainage systems are built at considerable expense to handle peak flows. In particular, trees have a relatively large impact on runoff during small frequent storm events (5). For example, urban forest rain interception was studied in Sacramento, California (6). The city's utility department requires that the first 19mm of run-off be retained on site for flood control and water quality protection. A combination of vegetation and on-site infiltration basins proved to be an effective approach to reduce off-site transport of water.

Air Quality

Urban vegetation directly and indirectly affects local and regional air quality by removing air pollution and altering the urban atmospheric environment (4). Urban forests have a positive impact on air quality through adsorption of pollutants by vegetation canopy, sequestration of atmospheric carbon dioxide in woody biomass, reduction of summertime air temperatures and associated ozone formation, and energy savings that reduce power plant emissions (7).

A net effect of increased tree cover in urban areas is a reduction in ozone concentrations (4). While most vehicle emissions are in the form of tailpipe exhaust, approximately 16% are in the form of evaporative emissions when vehicles are not operating (that is, from engine hoses and fuel tanks). Such emissions contribute to the formation of ground level ozone. Evaporative emissions are sensitive to local air temperature. Such emissions may be more severe in locations where vehicles are concentrated, and where temperatures are high. Trees that shade pavement can reduce asphalt temperatures by as much as 36°F, and fuel tank temperatures by nearly 7°F (8).

Climate and Heat Island Effects

Increased concentrations of greenhouse gases are now generally accepted as a cause of climate change. Trees can reduce atmospheric carbon dioxide (CO_2), the dominant greenhouse gas, by directly storing carbon (C) as they grow. Large healthy trees sequester about 93 kg C/yr as compared to 1 kg C/yr for small trees (4). In addition, urban trees can also reduce CO_2 emissions from power plants by reducing energy use as they lower temperatures and shade buildings during the summer, and block winds in winter (9).

Perhaps a more immediate concern in cities is heat island effect, a condition of excessive accumulation of heat associated with impervious surfaces. The reflection rate of paving is important as higher reflectance means cooler temperatures. Black pavements, the hottest, have solar reflectances of 5 to 10%. Lighter pavements are at 25% or higher. In the peak of summer in warm climate areas, temperatures of asphalt and automobile surfaces can reach as high as 170°F. In addition, paving materials act as thermal batteries, accumulating heat during the day and releasing it at night generating wide daily fluctuations in temperature (10).

Hot pavement transfers heat to the air that flows over it – the hotter the pavement, the hotter the air will become. Absorption, retention, and reissuing of heat by paving materials produces a dome of elevated air temperatures 5 to 8°C greater over a city, compared to adjacent rural areas (10). Heat island effects have been detected in cities as small as 1,000 in population.

Parking lots can become thermal hot-spots, elevating air temperatures in sections of a city by as much as 20 to 40°C (11). The on-site effects of paving and heat are soon felt. At high parking lot temperatures, paint, plastics and rubber deteriorate. Asphalt thermally decomposes in repeated sessions of high heat, becoming friable and brittle, thereby shortening its functional life (8).

Vegetation canopies can cool paving by direct shading of the ground surface. They also cool paved areas indirectly through transpiration of water through leaves and exposed soils (12). A study of day temperatures at a mall in Alabama (11) found parking lot temperatures at 49°C. However, planters containing trees recorded at 32°C, and nearby small groves of trees recorded 17°C less than nearby parking lots.

Tree planting is one of the most cost-effective means of mitigating urban heat islands (11, 12). Air temperature differences of approximately 2 to 4°C have been observed across urban areas having variable tree cover, with approximately 1°C of temperature difference being associated with 10% canopy cover difference (13). Studies in Sacramento CA suggest that 50% shading of paved areas would reduce hydrocarbon emissions citywide by 1 to 2% which is equivalent to government emission reductions goals for non-transportation sources (such as waste burning and vehicle scrap practices) (14).

Human Dimensions of Urban Nature

Another vein of research has focused on improvements in human welfare and well-being that are associated with city trees. Empirical studies spanning some twenty years have pursued an understanding of human response to nearby nature. While the urban forest does provide beautification and aesthetic benefits, the human experience of nature appears to be of much greater scope.

Landscape Assessment

Landscape assessment studies have been used in natural resource management since the 1960s to explore public perceptions and values associated with landscapes. Generally, people of all ages and cultural backgrounds prefer natural views to built settings. The presence of trees generally enhances public judgment of visual quality in cities (15, 16, 17). Trees are highly valued components of urban settings, and unkept nature in urban settings is less preferred than wellmaintained nature.

Roadside plants contribute to highway visual quality. In a California study (18) people judged simulations of proposed residential development for scenic quality. Drivers described roadside development as “cluttered” and “ugly,” while “pleasant” and “beautiful” were descriptions of highly vegetated highway corridors. Van passengers recorded attractiveness ratings for urban roadside views in Minnesota (19); highest values were awarded to road segments having nature features, and well-designed plantings and structural elements. Other research found that the presence of perimeter foreground vegetation, wildlife and openness, and flowers were significant indicators of public ratings of scenic beauty for urban roadside landscapes (20). A national study found that drivers prefer urban highway landscapes having large trees that screen adjacent commercial properties; scenes with “commercial windows were less preferred but provide a compromise for business owners who desire visibility (21, 22).

Landscape assessment theory includes psychological dynamics that are associated with visual quality, such as affect, cognition and behavior (23). For instance, roadside character can affect route choice. Drivers chose a scenic parkway route to a shopping center more often than a nonscenic expressway route, despite the parkway route having more stops and taking more time (24). Drivers enjoyed views of nature and reported feelings of relaxation while on the parkway route.

Health and Functioning

Cognitive psychologists have studied the restorative capacities of natural settings. Work that demands focused attention (such as professional tasks or studying) for a lengthy period can result in mental fatigue, which can be expressed as irritability, physical tiredness, and inability to concentrate. Brief interludes in natural settings have been found to be restorative (23). Studies demonstrate the importance of nature and mental functioning. Inner-city girls with more natural views at home have greater concentration and self-discipline (25). Desk workers who have a view of nature report greater job productivity and satisfaction, and reduced absenteeism (26).

Nature experience and human physiology are linked. Hospital patients who have a view of nature recover faster from surgery and require less pain medication (27). Views of nature reduce physiological stress response (16). Preliminary research suggests that urban forests contribute to more walkable cities and increase recreation benefits (28, 29). More active lifestyles combat obesity, improve cardiovascular health, and increase longevity (30).

Community Development

Positive meanings and values are associated with the urban forest (31, 32), with consequences for community economics. In a series of studies of consumer response to downtown business districts, shoppers report increased patronage and purchasing behavior in districts having a quality urban forest. Using contingent valuation methods (CVM) in trees and business studies, consumers report being willing to pay 9 to 12% more for goods and services in business districts having a quality urban forest (33).

People express more positive emotions and judgments for urban places having trees. Such cues may influence patronage behavior. Retailing studies have compared "atmospherics" against shoppers’ behavior. Indoor features such as product layout, music, and store lighting contribute to store image, which influences patrons' perceptions. Shoppers accept higher prices for goods in stores having attractive settings and positive staff. Visual quality of the outdoor environment appears to also impact price behavior (34).

A study of driver response to community views from a high-speed road yielded similar results (21). More extensive community greening was associated with positive consumer inferences and higher price points, ranging from 7 to 20%. The greener place was characterized as being a more appealing place for shoppers, including positive merchant interactions and product quality.

Hedonic analysis uses sales prices of comparable properties to isolate the increment of market value contributed by a specific attribute. Local governments can capitalize on increased values through greater property tax assessments or excise taxes on property sales

The presence of trees has been found to increase the selling price of a residential unit from 1.9% (35) to 3 to 5% (36) to 7% (37). In a study of Philadelphia's revitalizing neighborhoods, houses adjacent to street tree plantings were found to gain a 9% price premium (38). In addition, neighborhood commercial corridors in "excellent" condition (including a green streetscape) are correlated with a 23% net rise in home value within ¼ mile of the corridor, and an 11% net rise for those within ½ mile (38). In an Ohio study rental rates of commercial office properties were about 7% higher for sites having a quality landscape that included trees (39).

Driver Response

Early transportation publications promoted trees. In 1949 Neale proposed that "trees have undoubtedly saved many lives and prevented many accidents in intangible ways," observing that well-spaced trees might improve driver comfort by providing relief from the sun and wind, help keep drivers alert, and can cut cross-glare (40). Zeigler also reported benefits: shade, windbreaks, visual buffer, physical protection for pedestrians from run-off-the-road vehicles, and contributions to historic character (41).

Few of these benefits have been scientifically evaluated, but there are compelling studies that hint at the possibilities. For example, commuting may be one of the most stressful experiences of urban life. Increased blood pressure, higher illness rates, lowered job satisfaction, absenteeism and lower performance on cognitive tasks are all related to longer or more difficult commutes (42). Stress response is documented for all driving experiences, though intensity varies depending on road and traffic conditions (43).

Views of nature provide restorative effects and reduce stress response (44, 45). One study specifically looked at the effects of roadside character on stress (46). Simulator drivers who saw built-up, strip-mall style roadsides showed slower recovery from introduced stressors. Drivers viewing roadside nature scenes returned to normal, baseline conditions faster. An "immunization effect" was discovered; exposure to a natural roadside setting decreased the magnitude of stress response in a later task.

In another study, highway drivers with views of natural roadsides displayed higher frustration tolerance (47), a known precursor of road rage. Reports of speed reductions or traffic calming are of great interest and have some empirical support. In a simulator study identical street pairs, presented with and without trees, were used to test the effect in a drive-through virtual environment (48). Individual driving speeds were significantly reduced in the suburban settings. Faster drivers and slower drivers both drove slower with the presence of trees.

Green Values

Trees have been perceived as expendable elements in the paved matrix of cities, largely due to concerns of driver safety. Today more than 80% of the U.S. population lives in urbanized areas. Trees in contemporary communities contribute intangible non-market values that (often inconspicuously) improve the health and welfare of urban residents.

TREES AND SAFETY RISK

Risk is a complex social phenomenon. It has both technical and psychology dimensions (49). From a technical standpoint, risk is a probabilistic expression of the occurrence of an outcome, such as the probability of an individual being diagnosed with cancer after exposure to a toxic chemical. From a psychological perspective, risk perception is the concern that an individual or community has about a danger of modern life. Risk perception is rarely consistent with risk probability. Scientific studies can clarify risk communication; below is a summary of current knowledge.

Technical Risk

Transportation officials often warn of the statistical likelihood of crash and injury. In absolute terms trees do pose a risk to drivers. Crashes totaled 6,316,000 in the U.S. in 2002; more than 43,000 people died, and 13,000 were killed in single-vehicle crashes, many involving trees (50). Yet the overall incidence of tree-related crashes and injury are rarely communicated within the broader context of U.S. driving behavior. If translated to multi-year trends (51), the average driver has a crash about once per decade, usually causing minor property damage. The corresponding rate for fatal crashes is about one per 4,000 years.

Use of a "clear zone" or lateral roadside space free of rigid obstacles is a major policy response to annual crash statistics. The objective is to improve road safety by prohibiting obstacles that run-off-the-road drivers might encounter during a crash event, thereby reducing the severity of the event. In the United States, the *Roadside Design Guide (RDG)* (52) published by the American Association of State Highway and Transportation Officials (AASHTO) promotes this clear zone. Most of the research supporting the clear zone concept occurred at rural locations. The *RDG* also recognizes that the urban environment is unique and so encourages roadside clearance where feasible, but also acknowledges that entire clear zone regions may be infeasible due to urban land use needs.

Recent Studies

A national study analyzed 2002 U.S. crash data to determine the scope of tree crashes (53). Tree collisions numbered about 1.9% of all traffic crashes, and 46% of these were severely injurious or fatal. Of 229 billion household vehicle trips in the U.S. in 2001, approximately 141,000 of the trips resulted in crashes with trees. While 62% of annual miles traveled are in urban areas, 61% of crashes with trees occur in rural areas. Notably little data about vegetation are collected in standardized crash reports, and this oversight is unfortunate, as analysis of the national database informs overarching transportation policy and design revisions.

Studies with a local or regional focus do not generally indicate that urban trees are consistently or significantly posing safety risk, and some suggest that they may be providing safety benefits to road operation and pedestrian use. A study for a limited number of downtown urban arterials in Toronto, Canada found that street landscape improvements reduced crashes by 5 to 20% and boosted pedestrian use of urban arterials (54). Trees could not be directly linked to the results, but it was observed that the presence of a well-defined road edge might cause drivers to be more attentive and cautious.

A before-and-after study of landscaped medians and other streetscape improvements on urban arterials in Washington State concluded that tree variables had relatively little impact on the prediction of crash rates (55). A shift in crash locations occurred, with fewer mid-block and increased intersection crashes due to installations of median curbs and plantings. Results are not consistent as a California study found that in medians of major urban and suburban highways were associated with more collisions and increased severity of outcomes, though some of the associations were not strong statistically (56).

A Florida study compared a section of road that had landscaping and other livability features at nearly identical roads (57). The investigator reported, "by any meaningful safety benchmark— total mid-block crashes, injuries, or fatalities—there can be little doubt that the livable section is the safer roadway." Pedestrian and bicyclist injuries were likewise fewer in the improved road sections. A study of Texas urban arterial and highway sites compared pre- and post-planting over 3 to 5 year time spans, and found a decrease in crash rates after landscape improvements were installed (58). Investigators noted, "the landscape not only contributes to greater aesthetic compatibility between the urban environment and the highway but may contribute to a safer street."

Finding space for trees in a constricted right-of-way may mean reducing lane width. Narrower lane width is generally assumed to reduce safety for motor vehicles and bicycles. One project investigated the relationship between lane width and safety for roadway segments and intersection approaches, and found no general indication that the use of lanes narrower 12 feet on urban and suburban arterials increases crash frequencies (59).

DESIGN SOLUTIONS

Confronted with public demand for and societal benefits of the street tree, a workable set of engineer-friendly evidence-based design guidelines are needed. These guidelines should take into account the positive effects of the street tree as experienced by all road users. Many jurisdictions currently maintain landscaping guidelines; however these standalone documents often are not integrated into transportation project design. Landscaping is often treated as a supplemental activity following roadway design. Integrated design standards that incorporate street trees, utilities, street furniture, etc. as components of the overall street design are essential for ultimately designing a cohesive urban roadway environment.

It may be appropriate for a jurisdiction to also maintain supplemental landscaping standards that specify information about placement, species choice, the size and spacing of underground root zones, canopy height and reach, and regional plant characteristics. Given the variability of geography and plant materials, region-specific guidelines may be appropriate.

In addition to integrated design standards, there are two general approaches to design solutions that better incorporate trees into streetscapes. One is to improve the engineering technologies and urban forest practices associated with placing trees in streets of traditional design.

Arboriculture science can contribute knowledge about trees and roadside environments in ways that improve forest health and human health alike, contributing to urban livability in multiple ways. Collaboration between urban foresters and transportation officials can lead to better solutions for tree planting along city streets. Professional and scientific groups such as the International Society of Arboriculture and the Society of Municipal Arborists can contribute to improved planting strategies and urban roadside vegetation management.

The second approach is to recognize that the roadway functions as a system and one key component of that system is the streetscape. The traditional perception that the primary benefit of landscaping is to enhance beauty needs to be refined to recognize the added environmental, economic, and societal benefits of items such as street trees in the design of the roadway corridor. This does not mean that safety should be compromised, but that the engineering and landscaping community should work harder to identify strategies to safely incorporate street trees.

Systemic Strategies
A design response is to revisit the traditional standards of streetscapes and re-conceptualize their purpose to serve the needs of neighborhoods and communities in more diverse ways. In recent years, the transportation community has struggled to comprehensively incorporate pedestrian and bicycle activity in the overall design of urban roads. Though significant progress has occurred toward this multi-modal approach, the only successful way to achieve good multi-modal transportation is to design access as a system. This same systemic approach should be extended to all components of the urban transportation corridor.

Some demonstration and pilot examples of such ideas can be found throughout the world. Below are design proposals for future development and debate. Some have been installed to a limited extent; others are intended to expand discussion in communities.

Urban Control Zones
Many urban roadside environments are crowded with potential hazards. The task of identifying which objects pose the greatest risk to users of the road can be daunting for a jurisdiction with limited resources. The Florida Department of Transportation (FDOT) developed the *Utility Accommodation Manual* (60). This document's purpose is to provide direction for ways to reasonably accommodate utilities in state transportation facility rights-of-way. The FDOT included a concept in this document known as *Control Zones* for consideration at facilities with limited or no access control. Though the emphasis of their document was utility pole placement, this concept could be expanded for evaluating an urban roadside environment in its entirety. The FDOT Manual defines control zones as:

> *"areas in which it can be statistically shown that accidents are more likely to involve departure from the roadway with greater frequency of contact with above ground fixed objects."*

Example control zones include those that contain objects hit more than 2 times within 3 consecutive years; objects located within the return radii and horizontal offset distance at an intersecting street; objects located within 3 feet of a driveway flare; and objects located along the outside edge of a horizontal curve for roads with operating speeds greater than 35 mph.

This control zone for utility pole placement could be expanded to an *urban control zone* for urban roadside design. Locations more prone to departure crashes could be treated by requiring obstacle-free-zones at these locations for a given setback distance, while locations not characterized by run-off-road crashes could have less rigid setback criteria.

Functional Offset and Sight Distance Criteria
The AASHTO *RDG* (52) encourages adherence to the clear zone concept, but recognizes it may be infeasible to achieve these wide obstacle free zones in the restricted urban environment. Most street tree guidelines provide criteria regarding sight distance so that a driver's view will not be obstructed by the canopy of a tree or mounded landscaping treatments. These sight distance criteria should be further defined to address bicycle, pedestrian, and drivers of vehicles at driveways.

When a jurisdiction cannot achieve the clear zone, often they do not know a reasonable compromise object offset value. The Ohio Department of Transportation developed the *Roadside*

Safety Landscaping Guidelines (61). This document recommends planting offsets based on the operating speed of the facility. For example, for urban roads that operate at 35 mph or less, they permit 1 foot from the face of the curb to the foliage, 5 feet from the face of the curb to the center of a small tree, and 10 feet from the curb face to a large tree. As operating speeds increase these offset values also increase. For example, for urban roads with speeds greater than 45 mph, the foliage, small tree, and large tree offsets extend to 10 feet, 20 feet, and 25 feet respectively.

Kloeden, et al. (62) published a study for crashes that occurred from 1985 through 1996 in Southern Australia. They did not separate crashes into urban versus rural categories; however, they did perform evaluations based on the speed zones associated with the crash locations. TABLE 11 depicts the distance to roadside hazards for fatalities that occurred during the study period for speed zones of 50 mph or less. This Australia study found that 58.6% of roadside hazard fatalities were due to trees. More than 78% of the fatal crashes into trees occurred within 10 feet of the road. A better understanding of similar crash statistics in the United States could help refine acceptable placement standards for unobstructed trees.

TABLE 11 Offsets to Roadside Hazards in Fatalities

South Australia 1985-1996 for Speed Zones Less that 50 mph – Source (62)

Distance of Roadside Hazard from Road feet	Number of Crashes	Percentage [%]	Cumulative Percentage [%]
0	34	22.2	22.2
3.3	38	24.8	47.1
6.6	30	19.6	66.7
9.8	18	11.8	78.4
13.1	12	7.8	86.3
16.4	5	3.3	89.5
19.7	3	2.0	91.5
23.0	1	0.7	92.2
26.2	3	2.0	94.1
29.5	1	0.7	94.8
32.8	3	2.0	96.7
45.9	2	1.3	98.0
49.2	2	1.3	99.3
52.5	1	0.7	100.0
Total	513	100.0	

Note: Crashes involving multiple fatalities are only counted once in this table.

Plant Layering
The New Zealand *Guidelines for Highway Landscaping* (63) recommend plant layering where plants are grouped according to height with smaller, more forgiving plants positioned lateral to the road in front of larger plantings. This plant layering approach permits the use of roadside landscaping and, as indicated in the guide, will:

- Allow wider clear zones to rigid objects;
- Permit the inclusion of large trees into the roadside design;
- Allow appropriate sight distance; and
- Permit visually appealing plant compositions.

Perceptual Placement Strategies
In a study of how people conceptualize urban environments, Kevin Lynch (64) found that features such as architecturally-unique buildings, key viewsheds, and other environmental stimuli serve as central reference points by which individuals orient themselves and cognitively map their travel progress. The observation that such features emerged prominently in the way individuals visualize their travel activity suggests that environmental features provide drivers with important cues regarding appropriate driving behavior. The use of environmental factors to help inform drivers of safe operating conditions has received little attention in the literature (65), although the field of traffic psychology has begun to strongly encourage such practices as a key strategy for enhancing transportation system safety (66). The New Zealand *Guidelines for Highway Landscaping* (63) encourages agencies to use highway planting to help drivers understand the road ahead. Plantings are recommended to help with curve delineation, headlight glare reduction, visual containment, and speed awareness and stimulation.

In 2001, the City of Las Vegas, Nevada, developed a guide for neighborhood traffic management, based on a community survey where respondents rated pictures of various street cross sections (67). The most popular images were tree-lined streets in residential areas and commercial buildings placed close to the road in business districts. Both trees and buildings provide a sense of enclosure that frame the street and narrow the driver's field of vision. The Las Vegas guide further suggests that when the buildings are set further back from the street, the roadway appears to be wide and conducive to excessive speeds. The "enclosed" environment helps to mitigate speeding. In New Zealand, this "enclosed" environment is captured using a vertical elements technique where the height of vertical features is designed to be greater than the street width to provide an optical appearance of a narrow street (63). These vertical elements can include trees, light poles, and other elements as long as the man-made objects are frangible, and trees or shrubs do not interfere with sight lines and have narrower trunks.

Forest/Vegetation Strategies
In addition to consistent tree placement strategies, it may be appropriate to develop placement exceptions for various tree selections based on species type, biomechanics of plants upon impact, tree flexibility, etc. In addition, as the transportation community has developed impact attenuation devices for roadside protection, it is similarly possible that this strategy can be extended to streetscape features. For example, specific vegetation types naturally can function as energy absorption devices. In addition, the industry could develop unique planters with materials or construction strategies that enable them to also function as attenuation devices or even enable them to "breakaway" upon impact.

CONCLUSIONS

Communities striving for healthy neighborhoods and economic vibrancy identify numerous positive values associated with the urban forest, including street tree effects. The integration of street trees into the urban roadside system offers many advantages to the surrounding community including enhanced property value, environmental benefits, and the well recognized aesthetic enhancements. The safety concerns regarding street tree placement are real and cannot be ignored. As a result, it is essential that transportation professionals work closely with urban foresters to identify strategies to systematically design roadway corridors with streetscape features as critical components.

Local decision makers and transportation planners may acknowledge the need for community values to be reflected in urban roadway design, but the difficulty lies in implementation. Community values have not been systematically incorporated into the transportation engineering process or in design standards. Meanwhile, some transportation designers are calling for more dramatic innovations. Psychological traffic control is the proposed theory that physical elements (including trees) can be arranged within the road corridor to promote social interactions that generate a sense of shared space and prompt appropriate driving speeds and behaviors.

This issue should not be simply framed as one of safety versus aesthetics or environment, but rather one of how trees can be effectively incorporated into a safe roadside design that integrates engineering, community values, and environmental services. Future research efforts could substantially enhance the safe implementation of street trees. We present a broader research framework that is a meta-level approach to city trees and safety research:

- Improved data collection concerning vegetation in national and state accident databases, and a strategic program of analysis,
- Before-and-after studies to assess collision consequences of installing or removing street and median trees, as well as locational factors,
- Model development and refinement concerning access points and intersections, including turning movement, as higher rates of tree crashes appear to be associated with directional change by travelers,
- Development and testing of aesthetically pleasing and effective barriers and other preventive treatments to protect out-of-control vehicles,
- Study of breakaway and energy absorption responses to vehicle impacts of varied kinds and arrangements of vegetation, and
- Safety assessments of comprehensive street strategies that address community livability on many levels (e.g. complete streets, home zones).

Better understanding of trees and urban roads will contribute to transportation systems that are safer, handle traffic volumes efficiently and are perceived as community assets.

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