

# Urban Trees and Traffic Safety: Considering U.S. Roadside Policy and Crash Data

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**Abstract.** In the mid to late 20th century, U.S. transportation agencies focused on traffic planning and design practices intended to achieve high levels of traffic capacity and safety for roads at lowest cost. Intangible values of the roadside such as community character and environmental systems were often overlooked, including the urban forest. Context Sensitive Solutions is a U.S. national policy intended to better incorporate local community values into transportation planning processes and products. The starting point for community-based roadside design is adequate research. This study analyzed national traffic collision data to address concerns about urban trees and traffic safety, including crash incidence and severity. Distinctions of urban and rural conditions were explored using descriptive, comparative, and predictive analysis methods. The findings acknowledge the serious consequences of tree crashes but distinguish urban/rural situations. Circumstances of tree crashes in urban settings are not well understood. Conclusions address future applications of flexible transportation design. The clear zone philosophy has been widely applied in rural settings but may need modification to better incorporate community values in urban design. Future research needs include testing of trees as a mitigation technology in safe roadside design and risk assessment as a community expression of value.

**Key Words.** Context sensitive solutions; risk; roadside; safety; transportation; urban forestry.

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Automotive transportation systems are primary infrastructure elements of modern cities, and actions of the transportation industry have great influence on ecology and community. Transportation officials have reviewed roadside materials for potential safety risk, because run-off-the-road collisions are significant contributors to driver injuries and death. Transportation policy and design guidelines have evolved to address crash incidence and create safer driving conditions.

Urban streetscapes and roadsides are the places where urban forestry intersects with transportation policy. Communities have come to realize that the urban forest generates local environmental, economic, and social benefits. Yet, in many instances, transportation officials will limit or exclude urban trees because of safety concerns.

Do policies about trees in urban streetscapes reflect best available science? This article serves two purposes. First, it summarizes policies that address roadside trees and guide decision-making of transportation officials. This article also describes an empiric analysis of U.S. national collision data. The results more accurately describe tree crash outcomes and can enhance discussions about the merits and risk of having trees in urban roadsides.

## POLICY, STANDARDS, AND DATA

Road systems emerged in the United States early in the 20th century to serve local and regional commerce. After World War II, the network of interstate highways was instituted for expanded commerce and national security purposes. Trans-

continental highway building brought with it national oversight. Guidelines and standards for transportation systems, and associated safety precautions, are promulgated at the national level and are often adopted (with some modification) by state and local agencies. Federal funds for local transportation projects may obligate communities to comply with national standards.

Policy about roadside landscape and urban forests is embedded within prodigious documentation concerning transportation design. When negotiating on behalf of roadside trees, it is helpful to understand the derivation of engineering practices. An overview is provided.

The American Association of State Highway Transportation Officials (AASHTO) was established in 1914 and adopted the first set of geometric design policies in 1945. Geometric design refers to the design of the visible dimensions of a highway or road to create a facility form that meets functional and operational needs, including road location, alignment, and intersections.

The fifth edition of the AASHTO Policy on the Geometric Design of Highways and Streets (AASHTO 2004a), generally referred to as the "Green Book," contains current guidelines and has also been adopted by the Federal Highway Administration (FHWA). The Green Book provides uniform criteria for highway and road design, providing safety and operational consistency for highways and roads throughout the United States. Guidelines also address streetscape materials such as signage, street lighting, and traffic signals.

Geometric guidelines have focused on achieving the highest levels of safety and capacity for a road at the lowest cost. Such goals have been accomplished by building wider lanes and shoulders along with straighter and flatter alignments. Engineering economics, a mainstay of engineering education and practice, focuses on solving problems based on benefit-to-cost ratio or lowest life cycle cost of solutions.

Two issues emerge with regard to trees and the guidelines. First, transportation designers may fail to heed the flexibility implied and framed by the Green Book and implement recommendations (and local derivations) as “standards.” Transportation officials are encouraged to mitigate the effects of environmental impacts using “thoughtful design processes” (AASHTO 2004a) as standards have been “less rigorously derived” for urban settings (AASHTO 2004b). Second, most geometric design criteria apply to high-speed and rural roads, so appropriateness of their use in urban areas is debated (McGinnis 2001). Engineers often take a conservative approach to maximize safety and capacity (Otto 2000).

### Clear Zone

Deterrence and mitigation are primary approaches to improving roadside safety (Mak 1995). Deterrence emphasizes the importance of keeping cars on the roadway, whereas mitigations reduce the severity of consequences when drivers leave the paved area. AASHTO’s approach to roadside safety has historically focused on mitigation, including removing, relocating, altering, and shielding hazards.

The “clear zone” (also referred to as a “recovery zone”) is a primary crash mitigation approach. Clear zones are swaths of land of prescribed width adjacent to road edges that are clear of fixed objects that may damage a vehicle on impact, including trees and utility poles. Adequate clear zone enables an errant driver to safely return to the roadway or bring the vehicle to a safe, controlled stop.

National clear zone policy, based on the concept of the “forgiving roadside,” emerged in a 1967 AASHTO report to address inconsistent practices across the states (Turner et al. 1989). The report standardized clear zone definitions and guidelines at the federal level, thereby providing a model for state and local agencies.

The Green Book and the Roadside Design Guide (AASHTO 2002) are the key references for determining clear zone widths with primary applications being high-speed and rural roads. Engineering tables provide variable clear zone distances based on traffic volumes, speeds, and roadside geometry, particularly shoulder slopes. Additional adjustment or correction factors are provided for particular road section types. Contextual elements such as pedestrian facilities or adjacent land uses are not included in calculations.

A 9.0 m (29.7 ft) clear zone width is generally recommended for high-speed, high-volume roads with nearly level rights of way, whereas a minimum clear zone of 3.0 m (9.9 ft)

is recommended for low-speed roads. Clearance distances may be less if a fixed object is located behind a guardrail or other approved barrier. Also, the AASHTO transportation landscape guide (AASHTO 1991) lists conditions that can be “weighed to decide if a special exception is warranted,” including roads of historic or scenic significance, endangered species impact, adverse impacts of erosion or sedimentation, and significant negative changes in roadside character or aesthetic values.

Less distinct guidelines are provided for urban arterials, collectors, and streets, because the space available for clear zones is typically restricted, and travel speeds are more variable. For instance, a horizontal offset distance of 0.5 m (1.65 ft) beyond the face of the curb to the outside edge of a fixed object (such as the anticipated outside diameter of a mature tree trunk) is the minimum distance allowed for urban low-speed, local roads having a curbed edge. Urban arterials and collectors, usually of higher speeds, are recommended to have increased offset distances (AASHTO 1991). The general inclination is to favor wider clear zones.

### Tree Crashes

Data on tree crashes is presented in a straightforward and consistent way in many transportation planning publications. Based on crash data analysis of the 1990s, single-vehicle collisions with trees account for nearly 25% of all fixed-object accidents each year in the United States, resulting in deaths of approximately 3,000 people and making up approximately 48% of fixed-object fatalities (FHWA 1997; AASHTO 2002). Higher crash rates and fatalities are also associated with roadside utility poles and guardrails.

The crash effects of nearby trees along high-speed, rural roadways are indisputable. County and township roads that generally have restrictive geometric designs and narrow, off-road recovery areas account for a large percentage of the annual tree-related fatal crashes, followed by state and U.S. numbered highways having curved alignments (AASHTO 2002). Existing trees often pose greater risk than trees that have been placed along new or reconstructed roads.

Other than citing the need for large side clearance along high-speed roadways, most guidelines on geometric design are vague regarding design standards pertaining to trees (Sullivan and Jud 2001). An often cited rule of thumb, first posed in the 1960s for interstate highways (AASHTO 1961), is that a tree with trunk size of more than 100 mm (4 in) dbh is considered a fixed object and should be placed 6.0 m (19.8 ft) from the road edge. Later, vegetation management guidelines placed such trees 9.0 m (29.7 ft) from the road edge (USDOT 1992). Alternative findings are rarely considered. For instance, Zeigler (1986) found that fatal accidents on rural roads were usually associated with larger trees, of 500 mm (20 in) or more in diameter, with nonfatal accidents associated with smaller trees.

Specifics of accident rates and crash circumstances in urban areas are not well understood. Designers are urged to remove trees or install protective devices where strategically appropriate to reduce crash risk (such as on curves or to protect sight lines). Generally applied clear zone practices and the absence of empirically based urban design standards makes such fine-grain decisions difficult for urban road designers.

### Roadside Tree Benefits

Arborists and urban foresters are well aware of the many benefits and functions that trees provide in cities. Extensive research has documented environmental, social, and economic benefits for communities, municipalities, and regions (Nowak and Dwyer 2000; Wolf 2004). Unfortunately, this empiric evidence is not yet widely acknowledged within the transportation industry. The consequence is that tree crash statistics are often weighed against anecdotal reports of tree benefits in transportation decision-making. Discussions of roadside trees are largely framed as aesthetic values that, when compared against nominal safety standards, may not be viewed as adequate justification for tree retention or planting.

Earlier transportation publications promoted trees. Neale (1949) proposed that “trees have undoubtedly saved many lives and prevented many accidents in intangible ways.” He observed that well-spaced trees might improve driver comfort by providing relief from the sun and wind. Trees can help prevent snow drifting, keep drivers alert, and add beauty to harsh roadways. Trees can reduce storm water runoff and soil erosion as well as keeping dust levels low on roadways. Trees in medians can cut cross-glare. Zeigler (1986) also observed benefits: shade, windbreaks, visual buffer, physical protection for pedestrians from run-off-the-road vehicles, and contributions to historic character.

Investigators have begun to systematically examine the many benefits of the roadside urban forest. Trees are associated with improved visual quality of roadsides (Wolf 2003) and positive judgments of community character (Wolf 2006). Drivers encountering natural roadside views display reduced physiological stress response compared with those viewing built settings (Parsons et al. 1998). Reports of speed reductions or traffic calming are of great interest and have some empiric support (Godley et al. 1999; Rosenblatt Naderi et al. 2006). A study in Toronto, Canada, found that street landscape improvements reduced accidents by 5% to 20% (generating significant public costs savings) and boosted pedestrian use of urban arterials (Rosenblatt Naderi 2003).

### Context Sensitive Solutions

An emerging design policy can provide opportunities to better integrate trees in roadsides. In recent years, citizens and communities have voiced concerns that narrowly defined transportation design generates external decisions that have high local impact (Passonneau 1996). Local protests and legal

challenges have caused costly project delays. In response, national and state transportation agencies have begun to implement practices of flexible highway design and Context Sensitive Solutions (CSS) (also referred to as Context Sensitive Design [CSD]) in an effort to balance issues of concrete and community.

Two guides supplement the Green Book: *Flexibility in Highway Design* (FHWA 1997) and *A Guide for Achieving Flexibility in Highway Design* (AASHTO 2004b). They provide ideas, options, and examples of ways to design more environmentally friendly highways without compromising safety and mobility. The guides stress the importance of early public participation, identifying community interests, and creative thinking to achieve community friendly highway design (Moler 2002). Urban applications of CSS are becoming more common (AASHTO 2006).

### METHODS

The benefits of urban trees are offset by concerns about traffic safety in national roadside policy, and the “clear zone” concept has strongly influenced design guidelines and standards at the municipal level. Roadside trees are fixed objects, contributing to the U.S. annual crash rate, but accident statistics are reported as if the transportation landscape is homogenous. Additional research is needed to better understand the particular incidence and conditions of tree-related accidents on urban streets so that design standards better reflect actual conditions.

An exploratory analysis was conducted to serve as a starting point for new approaches and to discern future research needs. Using archival transportation collision data, a progression of statistical analyses was carried out to evaluate two research questions:

- What are the patterns of association involving trees and roadside crash outcomes?
- Do such patterns differ between urban and rural areas?

Year 2002 data from the General Estimates System (GES) database of the National Automotive Sampling System were used for this study. The data are collected by the U.S. National Center for Statistics and Analysis, a division of the National Highway Traffic Safety Administration (NHTSA), to identify traffic safety problems and conduct analysis of traffic-related programs.

A subset of the 91 GES variables was used for analysis. Selection was based on which factors prior studies had found to be associated with roadside crashes as well as original hypotheses on such relationships. Selected variables included driver gender and age, alcohol consumption, posted speed, restraint use, and road characteristics such as curve geometry and number of travel lanes.

Some variables needed for analysis were not present in the data set in a useful form. When possible, these were con-

structured (using collapsed categories or creating indexes) and included an urban/rural breakout, accident types, and injury severity. The data set contained no explicit measurement to distinguish urban from rural settings. A dummy variable was constructed using five indicators, including population of accident area (>50,000 for urban), number of travel lanes (four or fewer), and posted speeds (less than 72 kph [45 mph]). An accident category variable was collapsed into three dummy variables: collision with a nonfixed object (primarily other vehicles), collision with a fixed object (including trees), and noncollision accident (such as coming to a stop in a ditch).

## ANALYSIS AND RESULTS

Analysis started with a reconnaissance of the entire 2002 data set and then descriptive evaluations of selected variables to better understand their scope. Subsequent analyses involved greater complexity and predictive capacity and revealed certain limitations of the data set with respect to the research questions. Three sets of findings are presented: descriptive, comparative, and predictive.

### Descriptive Analyses

The GES data set defines three general accident categories. These include collisions with nonfixed objects (85.2% of all accidents), noncollision accidents (4.7%), and collisions with fixed objects, including trees (10.1%). Considering only accidents involving collisions with fixed objects, the top two objects struck are poles and signs (21%) and trees (19%) followed by guardrails (11%), ditches (11%), and traffic barriers (10%).

The GES data set enumerates a total of 36 accident types. The four most common of these overall are car versus car collisions (78.6%), rollovers (4%), collisions with poles or signs (2.1%), and collisions with trees (1.9%).

Fatality and injury (F&I) outcomes are of great interest. For all crashes, the majority (61%) resulted in no injury. Of those having F&I outcomes, 14% resulted in possible injury, 12% resulted in a nonincapacitating injury, 12% resulted in an incapacitating injury, and approximately 1% resulted in fatality.

Crash locations are a key issue of this project's inquiry. Many more accidents occurred in rural areas (63%) than urban areas (37%).

It is important to note that the GES data contain no detailed data regarding vegetation collisions such as trunk size, distance from the road edge, or vegetation densities, making detailed characterization of accident conditions impossible.

### Comparative Analyses

Comparative analysis examined whether a difference exists between two groups across some measure. Tests were structured for two-tailed tests using  $\chi^2$  analysis or independent samples *t*-tests.

Based on the research questions, the rate and outcomes of automobile collisions with trees were examined. One notable difference between tree collisions and all crashes is that of speed. The average speed at which all accidents occurred was 55 kph (34 mph). The average speed at which drivers struck trees was 77 kph (48 mph), a statistically significant difference ( $t = 23.94$ ,  $P < 0.01$ ) that perhaps reflects the higher rural incidence of crashes.

The proportion of tree collisions by urban and rural areas was nearly the same as the rate for all accidents. Thirty-nine percent of tree collisions occurred in urban areas, whereas 61% occurred in rural areas. Most tree crashes occurred on undivided roadways (48.8%), most commonly having two lanes (40.3%), where the average posted speed limit was 84 kph (52 mph). Road traits are consistent with the finding that there is a higher probability of crashes with trees in rural areas.

Tests of injury severity were also done. Certain crash categories result in more serious injuries than others ( $\chi^2 = 7,384$ ,  $P < 0.01$ ). Noncollision accidents (such as rollovers or driving into a ditch) are the most injurious followed closely by collisions with fixed objects. Collisions with nonfixed objects (i.e., vehicle-to-vehicle impacts) are by far the most common accidents, but are also the least injurious. Collisions with fixed objects such as trees are often harmful because impact forces are greater when an object is stationary.

When examining injury severity in more detail, it was found that car versus car was both the most common and least injurious crash situation (Figure 1). Over 63% of all accidents of this type result in no injury, whereas 11% result in serious injury or fatality. By contrast, rollovers are less frequent but result in F&I at a much higher rate. In terms of the two fixed-object crash types, striking a pole or post is generally less injurious than striking a tree.

Although collisions with trees happen at the lowest frequency of these four major accident types, injury rates are

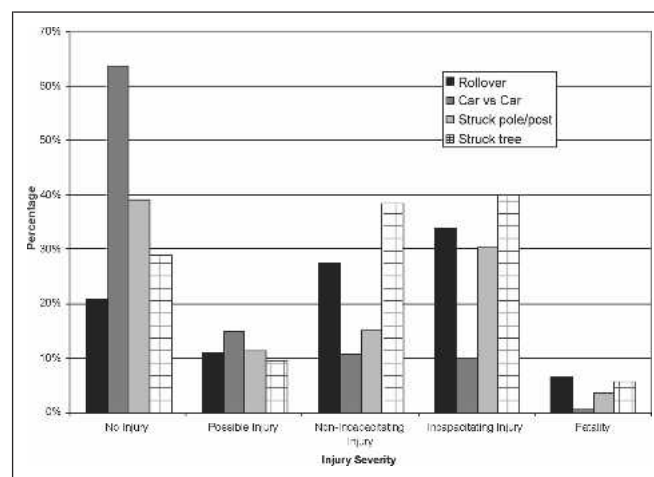


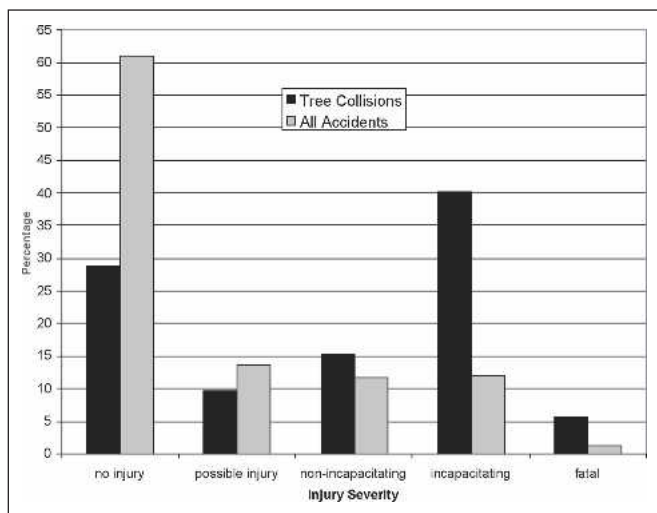
Figure 1. Frequencies of injury severity by accident type (%).

higher. Sixty-one percent of collisions with trees resulted in definite injury, whereas in 29%, vehicle occupants were unharmed. Figure 2 depicts injury rates of tree collisions and other accidents.

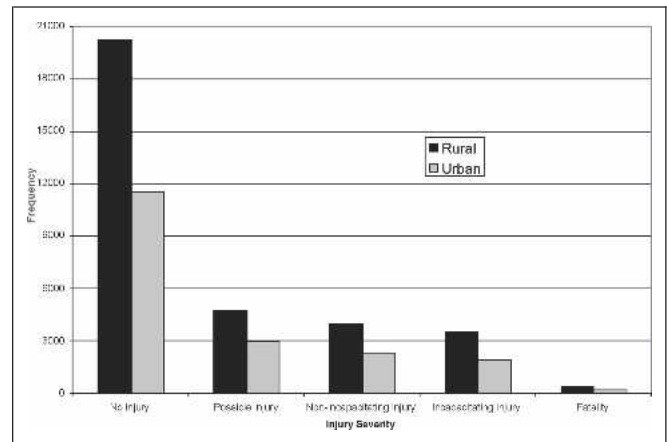
The difference in incidence of accidents in rural versus urban areas (Figure 3) has F&I implications. Accidents in rural areas are likely to be more injurious relative to accidents in urban areas ( $\chi^2 = 15, P < 0.01$ ), and all injury outcomes are more frequent in rural areas. There is a significant difference between urban and rural areas in terms of collisions with fixed objects ( $\chi^2 = 4.57, P = 0.032$ ). Of all accidents in rural areas, 6.1% are collisions with fixed objects, whereas this type constitutes 3.8% of urban accidents. There was no detectable difference between urban and rural areas in relative incidence of cars striking trees (1.1% versus 0.7%), due possibly to a small sample size.

**Predictive Models**

Predictive analysis was used for an additional research question, “What factors influence the injury outcome of accidents, by how much, and which ones really matter?” Regression analysis was performed using binomial logit and ordinal probit models. The binomial logit regression was applied to a dependent variable having two values (injury outcome versus no injury). The dependent variable for the ordinal probit regression was structured as several discrete values having an inherent order; thus, the outcome variable was coded as a five-point scale of continuous injury severity. Regressing a combination of explanatory factors against the dependent measures determined likely influences crash injury outcome and relative magnitudes for both the binomial logit and ordinal probit models. The goodness-of-fit  $\chi^2$  statistic for both models was significant at the 0.01 level.



**Figure 2. Frequencies of injury severity for tree collisions and all accidents (%).**



**Figure 3. Distribution of crash injury severity by urban and rural areas.**

Model results were largely consistent with prior research about crash situations associated with severe injury or death. Statistical details of the predictive models outcomes have been reported elsewhere (Bratton and Wolf 2005); general outcomes are presented here. The explanatory variables speed, vehicle weight, driver gender, road geometry, and accident category were significant at the 95% level or higher for both models. For the binomial logit model, a nonlinear speed variable was also significant, whereas for the ordinal probit model, the urban/rural spatial variable was significant.

Prior research illustrates how the model factors are associated with off-the-road accidents. Drivers are often under 35 years of age, male, and under the influence. Gender patterns are fairly constant; in all countries with high use of automobiles, male traffic fatalities outnumber female fatalities by approximately a factor of two (Evans 2002). Many crashes occur on weekends and during late evening hours, and often involve excessive speeds. A Michigan study (Zeigler 1986) found that the most common environment for an accident is a winding and rural road with the vehicle leaving the road on the outside of curves.

Results illustrate that F&I outcomes of crashes are based on a complex cohort of conditions. Attention to a single roadside element such as trees may not eliminate risk. For instance, driver behavior is of major importance in traffic safety. Driver error is a factor that contributes to more than 95% of traffic accidents (Evans 2002).

**TREES, SAFETY, AND RISK**

If communities choose to act on public values and integrate trees into streetscapes, then up-to-date transportation safety data should be the starting point for planning discussions. Additional research will improve understanding of crash conditions and how to increase safety.

## Crashes and Safety

In absolute terms, trees do pose a risk to drivers, yet the overall incidence of tree-related crashes and injury are rarely communicated within the broader context of U.S. driving behavior. What are the general traffic safety patterns?

Accidents totaled 6,316,000 in the United States in 2002; more than 43,000 people died, and 13,000 were killed in single-vehicle crashes (NHTSA-FARS 2003; NHTSA 2004). If translated to multiyear trends (Evans 2002), the average driver has a crash about once per decade, usually causing minor property damage. The corresponding rate for fatal crashes is approximately one per 4,000 years.

Factors determining traffic safety can be classified broadly into two groups: those related to driver behavior and those related to engineering, whether of roads or motor vehicles. Roadway and vehicle engineering have generated many effective countermeasures such as vehicle body design and roadside barrier design.

Behavioral factors that determine an individual's risk in traffic are (1) an individual's behavior and (2) the behavior of other road users. Personal choices about travel speed, use of intoxicants, and not using seatbelts have great influence over first, the vehicle leaving the road, and second, the outcome of any crash that may occur in the roadside. Drunk driving is a major safety problem, accounting for as much as half of all traffic fatalities (Evans 2002).

The National Highway Traffic Safety Administration (2004) provides additional details. Speed-related fatalities (meaning travel speeds that exceed posted speed limits) accounted for approximately 30% of all traffic fatalities each year for the past 10 years. Seatbelt use reduces a driver's risk of death in a crash by 42%. Although drivers routinely violate safe driving laws (such as speed limits and drunk driving), changes in driver behavior brought about by legislation have led to large reductions in casualties.

## Trees and Safety

To summarize the findings of this study, tree collisions numbered approximately 1.9% of all traffic accidents in 2002. Forty-six percent of these were severely injurious or fatal. Of 229 billion household vehicle trips taken in the United States in 2001 (as estimated from U.S. Census and FHWA data), approximately 141,000 included crashes with trees. Somewhat more than one third of such accidents occur in urban areas.

Trees, guardrails, and utility poles are all fixed objects associated with a high incidence of injury, whereas vehicle rollovers also pose high injury risk. Among the three object types, trees have the highest severity index for collisions both with and without airbags (Council and Stewart 1996). Vehicle impacts with trees are concentrated, which may highly deform vehicles and lead to higher incidence of injury.

Injury severity has been consistent across studies. A Connecticut study (Zuckier et al. 1999) found that trees are one of

the leading causes of death by people striking fixed objects. More crashes occurred with guardrails, curbing, and utility poles (compared separately), but injury rates are higher in crashes with trees.

## Urban versus Rural Conditions

Few studies have distinguished urban from rural conditions when assessing tree crash rates and outcomes. Patterns of statistical association in this study lead to these general conclusions: (1) roadside crashes are more frequent in rural areas than in urban areas, (2) collisions with fixed objects are more frequent in rural areas, and (3) crashes occurring in rural areas are generally more harmful than those in urban areas.

The few sources of urban/rural breakout data are generally consistent. In 1997, the U.S. fatal accident rate was less for urban areas (0.05 accidents per million vehicle miles [mvm]) than rural areas (0.07/mvm). Seventy-seven percent of fatal incidents involving trees occurred on rural roads in 1999 (Neuman et al. 2003). Studies in Michigan (Zeigler 1986) and Alabama (Turner 1990) found that urban tree crashes were lower injury risk situations than rural accidents.

The NHTSA (2004) reported that the majority of traffic crashes (67%) occur in rural areas, and the distribution for tree crashes is nearly the same. When compared with the distribution of U.S. annual household vehicle travel miles, an inverse relationship is observed (Figure 4). Urban travel miles were approximately 62% of the total in 2002, or 1.6 trillion miles; rural vehicle travel miles totaled 975 billion or 38% (NHTSA 2004).

More information is needed about urban situations, because both driving distances and conditions differ in cities as compared with rural roads. As an example, the NCHRP (2002) comprehensive guide to Context Sensitive Solutions

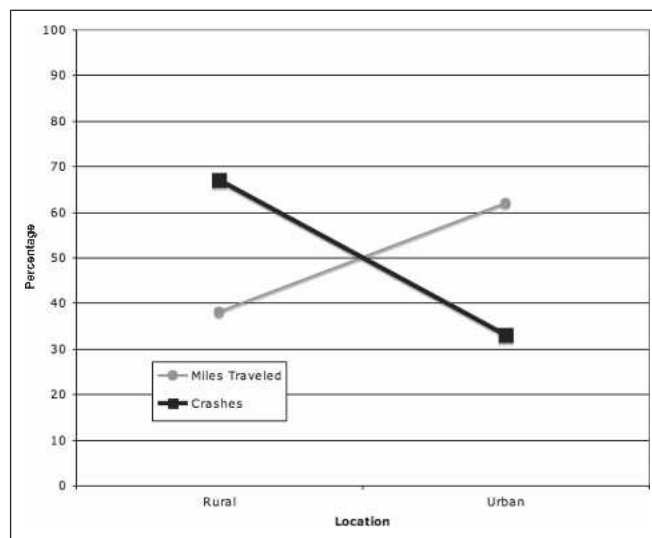


Figure 4. Urban/rural distributions of U.S. travel and accidents (%).

ends with a list of “key resources and references.” Of the 30 publications, five address rural conditions in their titles; no documents specifically address urban road conditions. One of the few studies of urban tree crash data were conducted in Alabama (Turner 1990) and empirically confirmed some concerns about trees (such as placement on curves) but failed to corroborate the risk of other roadside design standards (such as the 4 inch in dbh trunk size restriction).

West (2000) observes that design practices for freeways such as tree obstacle removal are now being applied to urban streets. Approximately 80% of the U.S. population resides in cities. Increased use of urban roads, and greater expectation for mixed use of that space, presents the need for better informed road design and crash deterrence approaches.

### TREES AND TRANSPORTATION RESEARCH

In recognition of the loss of life and injury, the Transportation Research Board (2004) has identified roadside landscape and safety as a research focus. Specific needs are more investigation into the relationships between roadway features and the propensity for crashes into trees and poles and in varied road conditions (McGinnis 2001) and to provide more detailed standards (Michie 1996). This study indicates that an expanded scientific program must not assume that trees are the cause of crashes, but that a complex set of circumstances—some driver-related and some road environment-related—contribute to crash situations. Two research approaches are proposed.

#### Trees as Technology

The transportation engineering community adheres to a rigorous process of technology development and refinement. First, empiric assessment of current crash conditions is done, often using archived crash data (as in this study). New technologies are proposed using simulation and supplemented by full-scale crash testing. Finally, field test implementations of the technology are conducted to determine driver and crash responses. These research and development procedures should be applied to the concerns of urban trees and traffic safety (Sullivan and Jud 2001) and should incorporate the input of arboricultural and urban forestry scientists.

Deterrence and mitigation are two engineering approaches to improving roadside safety. Deterrence features reduce the likelihood that drivers will leave the road and include rumble strips, warning signs, and guardrails. Mitigation focuses on mechanical attributes of roadside elements and assumptions about driver fallibility. The basic premise is that people will continue to drive off the road, so the fewer and friendlier objects they might hit, the better (Karr 2001).

Most roadside mitigation improvements have dealt with either landscape transformations (such as ditch design) or roadside hardware technologies (such as guardrails or impact

attenuators) that reduce hazards to drivers. Trees are often regarded as fixed objects that cannot be physically redesigned, and because they are often judged to offer no inherent technologic benefit, it is often thought best to simply remove them. Although outright removal may lead to a reduction in injurious roadside accidents, the broader benefits that trees provide or their value to communities is not attained. Research about trees as roadside technology should address both deterrence and mitigation approaches. Knowledge about the physical properties of various trees and configurations of tree placement would enable roadside design that integrates plant life as a safety feature (Zeigler 1986).

Other nations provide precedent. Western European countries have lower crash injury rates (Lamm et al. 1999) despite less support of tree removal due to aesthetic and environmental reasons. The Traffic Authority of New South Wales, Australia, addressed an increasing number of accidents along busy roads and in areas with accident-prone geometry by developing a tree planting policy (Rigby 1988). Minimum distances from the roadway were specified for certain tree species, with the Authority differentiating the physical characteristics and associated accident outcomes of species. Emphasis was placed on improving driver visibility and selecting frangible (i.e., breakable) trees for stretches of road that were more prone to run-off-road accidents.

#### Risk and Community Values

Risk assessment and risk acceptance have been used as part of decision-making processes that include multiple stakeholders and address complex situations (Brehmer and Sahlin 1994). Context Sensitive Solutions encourages collaborative design processes that bring together diverse stakeholders to identify community and environmental values that are to be integrated with traffic safety. Risk assessments of roadside elements and impacts can be used to consider and record project opportunities, restrictions, and tradeoffs.

Risk assessment processes can lead to broader public acceptance of road projects, precluding costly public or legal challenges to projects. In particular, documentation of the decision process for a roadway has proven to ease liability concerns of transportation agencies. If an inclusive stakeholder process is recorded, courts have been more likely to not hold transportation agencies liable for the consequences of the inevitable accidents that will occur in any roadway (NCHRP 2002; Milton and St. Martin 2005).

Risk scenarios should acknowledge specific contexts. This study provides a snapshot of U.S. national data regarding tree accident risk (Table 1), revealing risk variability associated with urban versus rural settings. If urban community values include high regard for trees and landscape, then consequences should be realistically assessed and presented to the public rather than reporting normative standards that may be premised on a historic emphasis on rural situations.

**Table 1. U.S. accident percentages involving trees and urban settings in 2002.**

|                                    | U.S. total              | Tree accidents            | Urban accidents | Urban tree accidents |
|------------------------------------|-------------------------|---------------------------|-----------------|----------------------|
| All accidents                      | (6,316,000; 100%)*      | 1.9%;<br>(141,000; 2.2%)* | 37%             | 0.7%                 |
| Incapacitating injury and fatality | 13%                     | 0.9%                      | 4.1%            | 0.04%                |
| Fatality                           | 1.2%<br>(43,005; 0.6%)* | 0.1%<br>(3,258; <0.001%)* | 0.4%            | <0.001%              |

\*NHTSA 2004. Percentages may differ from current study due to sampling and analysis procedures.

Context Sensitive Solutions represent a “paradigm shift” in how road and street corridors are planned and designed (Otto 2000; Lockwood 2001). Transportation planning can become urban planning. Proponents of growth management and new urbanism view integrative transportation practices as opportunities to create more walkable and livable urban streets. Such multidimensional perspectives could expand the recognition of urban forest functions and benefits within the transportation industry. Increased community input encourages a transportation planning and research agenda that goes beyond crash hazard mitigation to improved science about how trees can contribute to safer streets and vital cities.

**Acknowledgments.** This project was supported by: the USDA Forest Service (2003-CA-11062764-638) on recommendation of the National Urban and Community Forestry Advisory Council; and the College of Forest Resources, University of Washington. We thank roadside design professionals of the Washington and Minnesota Departments of Transportation for their review of a manuscript draft. Additional information about the project and related research can be found at: [www.cfr.washington.edu/research.envmind/](http://www.cfr.washington.edu/research.envmind/)

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**Résumé.** Au milieu jusqu'à la fin du 20<sup>e</sup> siècle, les agences américaines de transport ont mis l'emphase sur la planification de la circulation et des pratiques de design dans le but d'atteindre des capacités de circulation et des niveaux sécuritaires sur la route, et ce à des coûts les plus bas possibles. Les valeurs intangibles des abords routiers, telles que le caractère de la communauté et les systèmes environnementaux, ont souvent été oubliées, et ce au même titre que la forêt urbaine. Les *solutions aux contextes sensibles* constituent une politique nationale américaine créée dans le but de mieux incorporer les valeurs des communautés locales au sein des processus de planification et de production. Le point de départ du design des abords routiers en fonction de la communauté est une recherche adéquate. Cette étude analyse les données nationales de collisions, incluant les incidences d'accident et leur sévérité, afin d'étudier les préoccupations par rapport aux arbres urbains et la sécurité de la circulation. Les distinctions entre conditions rurales et urbaines ont été explorées, et ce au moyen de méthodes d'analyse descriptive, comparative et prédictive. Les résultats confirment les conséquences sérieuses des accidents contre des arbres tout en faisant la distinction entre milieux rural et urbain. Les circonstances des accidents impliquant des arbres ne sont pas bien comprises. Des conclusions sont faites en fonction d'applications plus flexibles de design de transport. La philosophie de la zone dégagée a été largement appliquée en milieu rural, mais a besoin d'être modifiée afin de mieux incorporer les valeurs de la communauté dans le design urbain. Les besoins futurs en recherche incluent les tests d'arbres comme technologie de mitigation dans le design de routes sécuritaires ainsi que l'évaluation du risque en tant que valeur d'expression de la communauté.

**Zusammenfassung.** Mitte bis Ende des 20. Jahrhundert haben amerikanische Transportunternehmen auf Verkehrsplanung und Design mit der Absicht fokussiert, einen hohen Grad von Verkehrskapazität und Straßensicherheit bei niedrigen Kosten zu erreichen. Nicht bezifferbare Werte der Straßen, wie z.B. kommunaler Charakter und Umweltsysteme, werden oft übersehen, einschließlich der Stadtwälder. "Context Sensitive Solutions" (Lösungen, die einen sensiblen Zusammenhang berücksichtigen) ist eine amerikanische nationale Verordnung, die lokale kommunale Werte besser in die Prozesse und Produkte der Verkehrsplanung einbinden soll. Der Startpunkt für ein kommunal basierendes Straßendesign ist eine adäquate Forschung. Diese Studie analysiert nationale Verkehrsunfalldaten, um sich mit den Bedenken über Stadtbäume und Verke-

hrssicherheit einschließlich Unfallnachweis und Schwere zu befassen. Es wurden unter Verwendung von beschreibender, vergleichender und voraussagender Analyse die Unterschiede zwischen urbanen und ländlichen Bedingungen untersucht. Die Ergebnisse berücksichtigen die ersten Konsequenzen von Baumunfällen, aber unterscheiden urbane und rurale Situationen. Die Umstände für Baumunfälle sind noch nicht völlig verstanden. Die Schlussfolgerungen ergeben zukünftige Anwendungen eines flexiblen Verkehrsdesigns. In ländlichen Gegenden wird weitgehend eine Philosophie der freien Zone angewendet, aber es braucht Modifizierungen, um die o. g. Werte in das urbane Umfeld zu integrieren. Eine zukünftige Forschung erfordert ein Testen der Bäume als Verbesserungsmittel von Straßendesign und Risikobewertung als einen kommunalen Wertausdruck.

**Resumen.** En la segunda mitad del siglo 20 las agencias de transportación de los Estados Unidos se enfocaron en la planeación del tráfico y el diseño de prácticas con el fin de alcanzar altos niveles de capacidad y seguridad del tráfico para carreteras a bajo costo. Los valores intangibles en las zonas aledañas, tales como sistemas ambientales y carácter de la comunidad, fueron con frecuencia pasados por alto, incluyendo el bosque urbano. *Context Sensitive Solutions* es una política nacional dirigida a incorporar mejor los valores de la comunidad local en los productos y procesos de planeación del transporte. El punto de comienzo para el diseño de estas áreas aledañas es una adecuada investigación. Este estudio analizó los datos nacionales de colisión del tráfico para dirigir las preocupaciones acerca de los árboles urbanos y la seguridad del tráfico, incluyendo incidencia y severidad del accidente. Se exploraron las distinciones de condiciones urbanas y rurales, usando métodos de análisis descriptivo, comparativo y predictivo. Los resultados reconocen las serias consecuencias de los árboles involucrados, pero distinguen situaciones urbanas/rurales. Las circunstancias de los árboles afectados en ambientes urbanos no son bien entendidas. Las conclusiones se dirigen a futuras aplicaciones en el diseño flexible del transporte. La filosofía de la zona libre ha sido ampliamente aplicada en ambientes rurales, pero puede necesitar modificación para incorporar mejor los valores de la comunidad en ambientes urbanos. Se requiere en el futuro investigación incluyendo pruebas de árboles como una tecnología de mitigación en el diseño de carreteras seguras y valoración del riesgo, como una expresión de valores comunitarios.