Why Urban Street Trees Aren’t the Hazard the Traffic Engineer Thinks They Are.

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Program Coordinator, Graduate Certificate in Transportation Planning
Texas A&M University
Background: Livable Streets

- Livable streets recognize the multiple roles of the public right-of-way:
  - Accomplish travel objectives
  - Provide social/recreational amenities
  - Encourage physical activity and personal health
  - Enhance developmental quality (and profitability)
Roadside Design

Pedestrian-supportive roadside treatments

DeLand, Florida
Considering Roadside Safety

• Roadside Safety
  – Roughly 12,000 fatal crashes, and 190,000 injury crashes associated with fixed-objects each year (FARS; GES)
  – Current practice encourages the provision of clear runout zones

Clear Zone Specifications (AASHTO, 2002)
The Larger Design Problem

“Safe” vs. “Livable”

Palm Beach Gardens, FL vs. Delray Beach, FL
Early AASHO Guidance

“Wider lanes and shoulders may invite higher speeds.”

- AASHO, 1940, p. 2
Roadside Design Guidance

• “For all types of highway projects, clear zones should be determined or identified and forgiving roadsides established.”


• “Through decades of experience and research, the application of the forgiving roadside concept has been refined to the point where roadside design is an integral part of transportation planning.”

- Roadside Design Guide, 2002

• “The wider the crash zone, the safer it will be.”

- Transportation Research Board, 2004
Why We Address Safety the Way We Do...

• 1965: “Unsafe at Any Speed”
  – “Epidemic on the Highways”
  – Apply principles of epidemiology to address the “designed-in” dangers of vehicles and roadways.
    • Specifically: eliminate environmental sources of injuries and fatalities.

• 1966: Senate/AASHO Highway Safety Hearings
  – Interstates reported fewer crashes than other roadway types.
  – Safety performance attributed to the use of high design values.
    • “Forgiving to error”
  – Resulted in the conclusion that the use of high design values for design speeds, offsets and clear zones enhances safety.
Highway Safety Hearings of 1966

Even if people have accidents, even if they make mistakes, even if they are looking out a window, or they are drunk, we should have a second line of defense for these people... the sequence of events that leads to an accident injury can be broken by engineering countermeasures even before there is a complete understanding of the causal chain.

Ralph Nader
Highway Safety Hearings of 1966

What we must do is to operate the 90% or more of our surface streets just as we do our freeways... [converting] the surface highway and street network to freeway road and roadside conditions.”

Kenneth Stonex
Addressing Safety...

“Highways built with high design standards put the traveler in an environment which is fundamentally safer because it is more likely to compensate for the driving errors he will eventually make.”

- AASHTO, 1974
The epidemiological Idea has been carried forward to the AASHTO “Green Book”

“Every effort should be made to use as high a design speed as practical to attain a desired degree of safety.”

- AASHTO, 2001
The Passive Safety Paradigm

Tenets of Passive Safety:

1. Drivers will err, make mistakes, and engage in behaviors that result in crashes and injuries.

2. Driver errors are random and unpreventable.

3. The best strategy for addressing driver errors is to ensure that all roadways are “forgiving” to such errors when they (inevitably) occur.
Passive Safety

Logical Conclusion: Enhance Safety by Widening Lanes, Shoulders, and Clear Zones…
Why do Roadside Crashes Occur?

- Presumption is that run-off-roadway events are *random* and *unpreventable*.
- If so, then rates of run-off-roadway events should be relatively constant.
  - This is what is currently assumed in safety applications such as the ROADSIDE program which uses fixed crash probabilities.
- Studies of two-lane, rural roads support this conclusion...
But what about urban areas?

**The Evidence:**

The majority of urban tree-related crashes occur on roadways with offsets of 30 feet or less.

**Study Conclusion:**

30 ft clear zones in urban areas are desirable for safety.

Source: Turner and Mansfield, 1990
A second opinion...

- Examined entire lengths of arterials traversing urbanized areas three small metro regions.

- Substantial design variation:
  - Pedestrian-oriented “livable” streetscape in downtown core.
  - Conventional suburban.
  - Suburban/rural transition.
Re-Examining Roadside Statistics...

Injurious Tree/Pole Crashes and Lateral Clearance

Cumulative Percentage

Offset from Edge of Travelway (feet)
Crash Probability Roughly Constant
Which enhances safety most in urban areas – Forgiving Design or Urban Design?

• Negative Binomial Models

• Test the safety effects of:
  – Paved Shoulder Width
  – Unpaved Fixed Object Offset
  – “Livable Street” Dummy Variable

• While controlling for:
  – ADT
  – Posted Speed Limit
  – Number of Lanes
  – Lane Width
  – Median Width
Defining Safety

• To be a “safe” roadside treatment...
  – **Must** be associated with fewer roadside crashes, and;
  – **Must not** be associated with an increase on other crash types that would offset these reductions (e.g., multiple-vehicle crashes or vehicle pedestrian crashes).
  – Consider both total and injurious crashes, since their incidence may be different.
    • From a safety perspective, it is injurious crashes that we care about.
Model Results: Paved Shoulders

Wider shoulders are consistently associated with *increases* (though not at statistically-significant levels) in roadside and midblock crashes.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Coefficient</th>
<th>Z</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Roadside Crashes</td>
<td>0.055</td>
<td>0.85</td>
<td>-0.072</td>
</tr>
<tr>
<td>Injurious Roadside Crashes</td>
<td>0.081</td>
<td>0.92</td>
<td>-0.092</td>
</tr>
<tr>
<td>Total Midblock Crashes</td>
<td>0.004</td>
<td>0.09</td>
<td>-0.07</td>
</tr>
<tr>
<td>Injurious Midblock Crashes</td>
<td>0.055</td>
<td>1.39</td>
<td>-0.023</td>
</tr>
</tbody>
</table>
Model Results: Fixed Object Offsets

Wider fixed object offsets are associated with decreases in fixed-object crashes, but have no effect on midblock crashes.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Coefficient</th>
<th>Z</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Roadside Crashes</td>
<td>-0.038</td>
<td>-1.51</td>
<td>-0.088, 0.011</td>
</tr>
<tr>
<td>Injurious Roadside Crashes</td>
<td>-0.053</td>
<td>-1.65</td>
<td>-0.118, 0.011</td>
</tr>
<tr>
<td>Total Midblock Crashes</td>
<td>0.003</td>
<td>0.24</td>
<td>-0.024, 0.031</td>
</tr>
<tr>
<td>Injurious Midblock Crashes</td>
<td>0.001</td>
<td>-0.05</td>
<td>-0.029, 0.028</td>
</tr>
</tbody>
</table>
Model Results: Livable Streets

Livable street treatments are consistently associated with decreases in both fixed-object and midblock crashes.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Coefficient</th>
<th>Z</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Roadside Crashes</td>
<td>-1.533</td>
<td>-2.33</td>
<td>-2.824</td>
</tr>
<tr>
<td>Injurious Roadside Crashes</td>
<td>-2.020</td>
<td>-1.75</td>
<td>-4.285</td>
</tr>
<tr>
<td>Total Midblock Crashes</td>
<td>-0.650</td>
<td>-1.66</td>
<td>-1.416</td>
</tr>
<tr>
<td>Injurious Midblock Crashes</td>
<td>-0.526</td>
<td>-1.28</td>
<td>-1.329</td>
</tr>
</tbody>
</table>
How much safer are livable streets?

- Per vehicle mile traveled, the livable streets reported:
  - 40% fewer midblock crashes than roadway averages.
  - 67% fewer roadside crashes than roadway averages.
How much safer are livable streets?

• **Further:**
  
  – Not a single injurious fixed object-related crash occurred on the livable sections during the 5-year analysis period
  
  – Nor was there a single traffic fatality involving either a pedestrian or a motorist.
Corroborating Research...

• Ivan, Pasupathy and Ossenbruggen (1999)
  – Widening shoulders decreases roadside crashes, but increases multiple vehicle crashes.

• Lee and Mannering (1999; 2001)
  – Trees and other fixed objects adjacent to the ROW decreases fixed object crash frequency.

• Ossenbruggen, Pendharkar, and Ivan (2001)
  – “Urban village” streetscape treatments report fewer crashes than suburban treatments.

• Naderi (2003)
  – Aesthetic streetscape improvements reduce midblock crashes.

• Noland and Oh (2004)
  – Widening shoulders decreases total crashes, but increases fatal ones.
Why this does not receive more attention...

• An illustrative recent study:
  – “The results show that run-off-roadway frequencies and severities can be reduced by widening lanes, bridges and shoulders [and] relocating roadside fixed objects.”
The actual results show that...

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad lane indicator (1 if lane is greater than 12 feet, 0 otherwise)</td>
<td>1.684</td>
<td>3.984</td>
</tr>
<tr>
<td>Number of isolated trees in a section</td>
<td>-0.093</td>
<td>-1.857</td>
</tr>
<tr>
<td>Number of miscellaneous fixed objects in a section</td>
<td>-0.094</td>
<td>-2.140</td>
</tr>
</tbody>
</table>
Explaining “Anomalous” Findings

- **Novel Idea:** Examine urban crash locations.
- **83%** of tree and pole crashes occurred behind an intersection or driveway on higher-speed roadway sections.

Representative Urban Fixed-Object Crash
Explaining “Anomalous” Findings

Systematic Pattern:

- Higher operating speeds along primary arterial
- Attempt to turn onto a driveway or side street at higher speeds.
- Higher-speed turn results in vehicle leaving the travelway behind the side street.
Random vs. Systematic Error

- **Random Error** is error that naturally occurs as a result of human fallibility.
  - Humans will err, and a roadway should be “forgiving” when they do.
  - Assumes driver error is constant and fixed.
  - Strives for a single, “fail-safe” design solution.

- **Systematic Error** is a design problem that results from mismatches in the interaction between people and their environment.
  - Recognizes that designs may *produce* error.
  - Systematic error occurs when a roadway encourages inappropriate expectations regarding safe operating behavior.
  - Focuses on understanding and addressing unsafe driver behavior, rather than attempting to engineer “fail-safe” designs.
Rethinking Urban Road Safety

• A safe design is one that eliminates systematic error while simultaneously reducing the consequences of random error.

• Two strategies for addressing urban roadside safety:
  1. The Interstate Approach
  2. The Livable Street Approach
1. The Interstate Approach

- Random error addressed through “forgiving” design.

- Systematic error minimized by design:
  - Limited access, with few opportunities for turning maneuvers.
  - Where turns permitted, they are accompanied by ramps that allow for gradual deceleration.
Access-Managed Arterials are Effective From a Safety Perspective...

- Similar design solution appropriate on urban arterials where access-management principles are fully applied.

- Similar characteristics:
  - Higher speeds
  - Few driveways and side streets.
  - Deceleration lanes.

“Access Management”
The Problem: Mixing Speed and Access

A “Suburban” Arterial: Orange Blossom Trail
The Problem: Mixing Speed and Access

A “Suburban” Arterial: Orange Blossom Trail

65% of these crashes are attributable to mixing access and speed
Where are the high crash locations in B-CS?
2. The Livable Street Approach

- “Unforgiving” by design:
  - But roadside hazards are obvious and expected, resulting in behavioral compensations from drivers.

- Systematic error substantially reduced:
  - Turning movements safely accommodated because of lower operating speeds.

- Minimizes the consequences of random error:
  - Lower speeds result in less severe crashes when they occur.
  - Lower speeds equate to reduced stopping sight distance, and thus reduced crash frequency.
The Livable Street Approach

Case Illustration: Woodland Blvd

5-Year Totals:
0 Roadside Crashes
4 Injurious Midblock Crashes
0 Fatalities
Advancing Professional Practice
In 1965, only Britain surpassed the US in terms of safety. Currently, U.S. ranks behind all other developed countries.

<table>
<thead>
<tr>
<th>Country or Area</th>
<th>Per 100,000 Inhabitants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>9.5</td>
</tr>
<tr>
<td>European Union*</td>
<td>11</td>
</tr>
<tr>
<td>Great Britain</td>
<td>5.9</td>
</tr>
<tr>
<td>Japan</td>
<td>8.2</td>
</tr>
<tr>
<td>Netherlands</td>
<td>6.8</td>
</tr>
<tr>
<td>Sweden</td>
<td>6.7</td>
</tr>
<tr>
<td>United States</td>
<td>15.2</td>
</tr>
</tbody>
</table>

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom

Source: World Health Organization, 2005
We’re Not Safer When Adjusting for VMT, Either.

TABLE 1: Comparative Fatality Rates per Billion Vehicle-Kilometers Traveled

<table>
<thead>
<tr>
<th>Country</th>
<th>Rate</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>8.0</td>
<td>2003</td>
</tr>
<tr>
<td>Canada</td>
<td>8.9</td>
<td>2003</td>
</tr>
<tr>
<td>Finland</td>
<td>7.6</td>
<td>2003</td>
</tr>
<tr>
<td>Netherlands</td>
<td>7.7</td>
<td>2003</td>
</tr>
<tr>
<td>Norway</td>
<td>8.3</td>
<td>2002</td>
</tr>
<tr>
<td>Sweden</td>
<td>7.5</td>
<td>2002</td>
</tr>
<tr>
<td>Switzerland</td>
<td>8.8</td>
<td>2003</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>7.2</td>
<td>2001</td>
</tr>
<tr>
<td>United States</td>
<td>9.1</td>
<td>2003</td>
</tr>
</tbody>
</table>

Source: Transportation Research Board, 2006
Peer Comparisons

• Reduction in annual traffic fatalities if US safety performance had paralleled safety trends in peer countries:

  Canada: 13,718 fewer deaths – **32% reduction**

  Britain: 16,695 fewer deaths – **39% reduction**

  Australia: 20,426 fewer deaths – **48% reduction**

Adapted from Evans, 2004
European Design Guidelines: Address safety by linking road design and context

Step 3:
- Road surroundings
  - Without buildings: concentration low or zero
  - With buildings: concentration high
- Relevant design function
- Mobility (connector)
- Access (collector)
- Local, ped. use

Category Group:
- A
- B
- C
- D
- E

Step 4:
- Statewide or Interstate Connection
  - I
- Overregional/Regional Connection
  - II
- Connection between Municipalities
  - III
- Area Accessibility Connection
  - IV
- Subordinate Connection
  - V
- Agricultural Sideroad
  - VI

Road Categories:
- A1
- B1
- C1
- D1
- E1
- Acceptable
- Problematic
- Very Problematic
- Not Justifiable

Step 5:
- Road Category
- Travel Speed Range [km/h]
  - A1: 70 - 100
  - AII: 60 - 90
  - AIII: 50 - 80
  - AIV: 40 - 60
  - AV: NO
  - AVI: NO
  - BII: 50 - 70
  - BIII: 40 - 60
  - BIV: 30 - 50
  - CIII: 30 - 50
  - CIV: 30 - 40
  - DIV: 20 - 30
  - DV: NO
  - EV: NO
  - EVI: NO

Primary Arterial
Secondary Arterial
Main Collector
Primary / Secondary Arterial
Main Collector
Collector
Local
Local
Pedestrian Use
Street Classification in the United States

This design model does not relate to urban environments.

- **Arterials**
  - higher mobility
  - low degree of access

- **Collectors**
  - balance between mobility and access

- **Locals**
  - lower mobility
  - high degree of access
Problem: Street Designations

Which streets are urban arterials?
Problem: Street Designations

Which streets are urban arterials?

(a)  
(b)  
(c)
The Functional Network

The functional classification system has levels of connectivity and access embedded in its definitions. Winston Park, a South Florida subdivision centered on an arterial roadway, perfectly illustrates how the functional hierarchy translates into the design of street networks:

![Diagram showing different types of roads: Local, Collector, Minor Arterial, Highway]
Linking Design to Urban Form

The Transect
Developing Intermediate Thoroughfares

Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities

An ITE Proposed Recommended Practice

Avenue/Boulevard

Commercial Street
# Concrete Design Specifications

<table>
<thead>
<tr>
<th>Context</th>
<th>Suburban (C-3)</th>
<th>General Urban (C-4)</th>
<th>Urban Center/Core (C-5/6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boulevard</td>
<td>Avenue</td>
<td>Boulevard</td>
</tr>
<tr>
<td>Building Orientation (entrance orientation)</td>
<td>front, side</td>
<td>front, side</td>
<td>front</td>
</tr>
<tr>
<td>Maximum Setback [1]</td>
<td>20 ft.</td>
<td>20 ft.</td>
<td>20 ft.</td>
</tr>
<tr>
<td>Off-Street Parking Access/Location</td>
<td>rear, side</td>
<td>rear, side</td>
<td>rear, side</td>
</tr>
<tr>
<td>Roadside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended Roadside Width [2]</td>
<td>14.5 ft.</td>
<td>12.5 ft.</td>
<td>16 ft.</td>
</tr>
<tr>
<td>Pedestrian Buffers (planting strip exclusive of travel way width) [2]</td>
<td>8 ft planting strip</td>
<td>6-8 ft planting strip</td>
<td>7 ft tree well</td>
</tr>
<tr>
<td>Street Lighting</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| For all arterial thoroughfares in all context zones, intersection safety lighting, basic street lighting and pedestrian-scaled lighting is recommended. See Chapter 8 (Roadside Design Guidelines) and Chapter 10 (Intersection Design Guidelines).

## Traveled Way

| Design Speed                               | Design speed should be a maximum of 5 mph over the operating speed. Design speed is used as a control for certain geometric design elements including sight distance and horizontal and vertical curvature. |
| Number of Through Lanes [4]                | 4-6             | 4-6                 | 4-6             | 4-6             | 4-6        | 4-6             | 4-6        | 4-6             | 4-6        |
| Parallel On-Street Parking Width [6]        | 7 ft.           | 7 ft.               | 8 ft.           | 8 ft.           | 7 ft.      | 8 ft.           | 7 ft.      | 8 ft.           | 8 ft.      |
| Horizontal Radius (per AASHTO) [7]          | 762 ft.         | 510 ft.             | 762 ft.         | 762 ft.         | 510 ft.    | 762 ft.         | 510 ft.    | 510 ft.         | 510 ft.    |
| Vertical Alignment                          | Use AASHTO minimums as a target, but consider combinations of horizontal and vertical per AASHTO Green Book. |
| Bike Lanes (min./preferred width)            | 5 ft./6 ft.     | 5 ft./6 ft.         | 5 ft./6 ft.     | 5 ft./6 ft.     | 5 ft./6 ft. | 5 ft./6 ft.     | 5 ft./6 ft. | 5 ft./6 ft.     | 5 ft./6 ft. |
| Access Management [9]                       | Moderate        | Low                 | Moderate        | Low              | High       | Low              | Moderate   | Low              | Low        |
| Typical Traffic Volume Range (rdp)           | 20,000-35,000   | 15,000-25,000       | 20,000-50,000   | 10,000-35,000   | 10,000-20,000 | 15,000-40,000   | 5,000-30,000 | 15,000-20,000   | 15,000-40,000 |

## Intersections

| Roundabout                                  | Consider urban single-lane roundabouts at intersections on arterial avenues with less than 20,000 entering vehicles per day, and urban double-lane roundabouts at intersections on Boulevards and Avenues with less than 40,000 entering vehicles per day. |
| Curb Return Radii                          | Refer to Chapter 10 (Intersection Design Guidelines) for details |
Rethinking Form and Function

Conventional

Arterial

Commercial Street

Arterial

Boulevard

Arterial

Rural Highway

Transect

Use ONLY in conjunction with land use controls
Conclusion

• Trees – at least in urban areas – are not the hazard they are commonly believed to be, and may even be **BENEFICIAL TO URBAN SAFETY**

• The battle – whether relating to urban trees or to urban safety generally – is over **URBAN ARTERIALS**

• The problem is **SPEED**, especially when combined with roadway access.

• The profession is beginning to revisit existing safety assumptions (or at least is being forced to), which is promising for the increased integration of trees on urban streets.