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

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 design criteria.”
  - Roadside Design Guide, 2002

• “The wider the clear 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
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.”
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, 2004
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 Uninfluenced by Clear Zone Width

Injurious Tree/Pole Crashes and Lateral Clearance

Cumulative Percentage

Offset from Edge of Travelway (feet)
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></td>
<td></td>
<td></td>
<td>0.181</td>
</tr>
<tr>
<td>Injurious Roadside</td>
<td>0.081</td>
<td>0.92</td>
<td>-0.092</td>
</tr>
<tr>
<td>Crashes</td>
<td></td>
<td></td>
<td>0.253</td>
</tr>
<tr>
<td>Total Midblock Crashes</td>
<td>0.004</td>
<td>0.09</td>
<td>-0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.076</td>
</tr>
<tr>
<td>Injurious Midblock</td>
<td>0.055</td>
<td>1.39</td>
<td>-0.023</td>
</tr>
<tr>
<td>Crashes</td>
<td></td>
<td></td>
<td>0.132</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</td>
</tr>
<tr>
<td>Injurious Roadside Crashes</td>
<td>-0.053</td>
<td>-1.65</td>
<td>-0.118</td>
</tr>
<tr>
<td>Total Midblock Crashes</td>
<td>0.003</td>
<td>0.24</td>
<td>-0.024</td>
</tr>
<tr>
<td>Injurious Midblock Crashes</td>
<td>0.001</td>
<td>-0.05</td>
<td>-0.029</td>
</tr>
</tbody>
</table>
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.
Visual enclosure leads to lower speeds...

- Roadside elements that create visual enclosure – such street trees and street-oriented buildings – are associated with lower vehicle speeds.

- The effect is independent of a roadway’s geometry.

Dumbaugh, 2005; 2006; Ivan, Garrick, & Hanson, 2009; Naderi Kweon & Maghelal, 2008, Smith and Appleyard, 1981.
... and lower speeds equal reductions in crash frequency AND severity.

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>% yielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>100%</td>
</tr>
<tr>
<td>11-15</td>
<td>28%</td>
</tr>
<tr>
<td>16-20</td>
<td>23%</td>
</tr>
<tr>
<td>21+</td>
<td>17%</td>
</tr>
</tbody>
</table>

Garder, 2001
Single Vehicle Fixed-Object Crashes

• Engineering presumption is that run-off-roadway events are random and unpreventable.

• If so, then rates of run-off-roadway events should be relatively constant, and clear zones should enhance safety.

• Studies of two-lane, rural roads support this conclusion…
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.

  - 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.

Representative Urban Fixed-Object Crash
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”
A “Suburban” Arterial: Orange Blossom Trail

The Problem: Mixing Speed and Access

<table>
<thead>
<tr>
<th></th>
<th>Crashes per 100 MVMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Livable Streets (Avg)</td>
</tr>
<tr>
<td>Total Roadside</td>
<td>3.3</td>
</tr>
<tr>
<td>Injurious Roadside</td>
<td>0</td>
</tr>
<tr>
<td>Total Midblock</td>
<td>23.1</td>
</tr>
<tr>
<td>Injurious Midblock</td>
<td>18.1</td>
</tr>
</tbody>
</table>
The Problem: Mixing Speed and Access

A “Suburban” Arterial: Orange Blossom Trail

86% of these crashes are attributable to mixing access and speed

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-End</td>
<td>188</td>
<td>46.4%</td>
</tr>
<tr>
<td>Head-On</td>
<td>6</td>
<td>1.5%</td>
</tr>
<tr>
<td>Angle</td>
<td>52</td>
<td>12.8%</td>
</tr>
<tr>
<td>Left-Turn</td>
<td>5</td>
<td>1.2%</td>
</tr>
<tr>
<td>Right-Turn</td>
<td>1</td>
<td>0.2%</td>
</tr>
<tr>
<td>Sideswipe</td>
<td>63</td>
<td>15.6%</td>
</tr>
<tr>
<td>Pedestrian/Bicyclist</td>
<td>24</td>
<td>5.9%</td>
</tr>
<tr>
<td>Roadside</td>
<td>23</td>
<td>5.7%</td>
</tr>
<tr>
<td>Other/System Missing</td>
<td>43</td>
<td>10.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>405</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>
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
Visual enclosure leads to lower speeds...

- Roadside elements that create visual enclosure – such street trees and street-oriented buildings – are associated with lower vehicle speeds.

- The effect is independent of a roadway’s geometry.

Dumbaugh, 2005; 2006; Ivan, Garrick, & Hanson, 2009; Naderi Kweon & Maghelal, 2008, Smith and Appleyard, 1981.
... and lower speeds equal reductions in crash frequency AND severity.

Table 8  Speed and yield behavior

<table>
<thead>
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<th>Speed (mph)</th>
<th>% yielding</th>
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<tbody>
<tr>
<td>0-10</td>
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</tr>
<tr>
<td>21+</td>
<td>17%</td>
</tr>
</tbody>
</table>

Garder, 2001
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
  - Relevant design function
  - Mobility (connector)
  - Access (collector)
  - Local, ped. use

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

Step 4
- Statewide or Interstate Connection
  - I
  - A I
  - B I
  - C I
- Overregional/Regional Connection
  - II
  - A II
  - B II
  - C II
  - D II
- Connection between Municipalities
  - III
  - A III
  - B III
  - C III
  - D III
  - E III
- Area Accessibility Connection
  - IV
  - A IV
  - B IV
  - C IV
  - D IV
  - E IV
- Subordinate Connection
  - V
  - A V
  - B V
  - C V
  - D V
  - E V
- Agricultural Sideroad
  - VI
  - A VI
  - B VI
  - C VI
  - D VI
  - E VI

Step 5
<table>
<thead>
<tr>
<th>Road Category</th>
<th>Travel Speed Range [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A I</td>
<td>70 - 100</td>
</tr>
<tr>
<td>A II</td>
<td>60 - 90</td>
</tr>
<tr>
<td>A III</td>
<td>50 - 80</td>
</tr>
<tr>
<td>A IV</td>
<td>40 - 60</td>
</tr>
<tr>
<td>A V</td>
<td>NO</td>
</tr>
<tr>
<td>A VI</td>
<td>NO</td>
</tr>
</tbody>
</table>

Primary Arterial
- B II
- 50 - 70

Secondary Arterial
- B III
- 40 - 60

Main Collector
- B IV
- 30 - 50

Primary / Secondary Arterial
- C III
- 30 - 50

Main Collector
- C IV
- 30 - 40

Collector
- D IV
- 20 - 30

Local
- D V
- NO

Local Pedestrian Use
- E V
- NO

- E VI
- NO
UK Manual for Streets
Street Classification in the United States

- **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 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:
Linking Design to Urban Form

The Transect

T1 NATURAL ZONE  T2 RURAL ZONE  T3 SUBURBAN ZONE  T4 GENERAL URBAN ZONE  T5 URBAN CENTER ZONE  T6 URBAN CORE ZONE
Safe Urban Thorougfares

Urban Avenue

Commercial Main Streets
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.