Flexible, Practical & Performance-Based Design

CEAM Annual Conference
January 25, 2018
• What are we doing?
• Standards-based design and the case for change
• Performance-based design overview
• What does this actually mean, especially for urban and suburban streets?
What’s going on?
What’s this all about?
...toward a design regime that’s more: Flexible
"Strictly interpreted, the meaning would indicate that the standard design was the best design." "Standards are merely recommended designs which are to be adhered to unless conditions indicate that a variation in the design would meet them better."

"The temptation is to neglect the detailed study of local conditions..."
...toward a design regime that’s more:

Flexible

Practical / economical
“Building good projects everywhere rather than a perfect project somewhere”
...toward a design regime that’s more:

**Flexible**

**Practical / economical**

**Performance-based / evidence-based**
“We will root our decision making in evidence-based practices.”

Derek Falvey
Standards-based design & the case for change
Origin of road design standards
Seriously, why do we even have them?

- **Consistency**
- **Convenience**
- **Minimum degree of performance?**
Early days of road building
In 1928, AASHO members proposed to adopt “standards of practice” to achieve some uniformity. On March 1, 1928, AASHO approved its first four standards:

- Wherever practicable shoulders along the edges of pavements shall have a standard width of not less than 8 feet.
- On pavements 10 feet shall be considered as the standard width for each traffic lane.
- The crown of a two-lane concrete pavement shall be 1 inch.
- No part of a concrete pavement shall have a thickness of less than 6 inches, and that all unsupported edges shall be strengthened.
Evolution of AASHO design policies

A Policy on Highway Classification – September 16, 1938
A Policy on Highway Types (Geometric) – February 13, 1940
A Policy on Sight Distance for Highways – February 17, 1940
A Policy on Criteria for Marking and Signing No-Passing Zones for Two- and Three-Lane Roads – February 17, 1940
A Policy on Intersections at Grade – October 7, 1940
A Policy on Rotary Intersections – September 26, 1941
A Policy on Grade Separations for Intersecting Highways – June 19, 1944
NCHRP Report 839:

“The notion of human factors and the human element as an input to design was understood only in rudimentary terms. Indeed, a prevailing philosophy of highway engineers was that any road properly designed should be able to be driven safely by anyone and everyone.”
Pennsylvania Turnpike

Greater Pittsburgh Chamber of Commerce:

“Since there is no reason for speed limits...travel is expedited to the point where it combines the speed of the aeroplane with the safety of the railroad.”

Turnpike publicity release:

...an “all-weather highway.”
Pennsylvania Turnpike

Story in the Washington News:

“I never thought I could drive at 75 miles an hour around mountain curves in heavy rain and live to write about it.”
Wilburn Cartwright, U.S. House Roads Committee chair:

“I think we should have roads leading to and from other eastern cities.”
Unintended Consequences

U.S. Traffic Fatalities
1949 to 2010

Source: Department of Transportation
“It would therefore be appropriate to consider a top assumed speed of 80 mph on fully controlled access highways and a speed of 70 on other rural highways.”

1965 AASHO “Blue Book”
What could possibly go wrong?

Increasingly expensive tastes in road building

+ Declining revenue
Finding:

Some AASHTO criteria are unnecessarily simplistic in their formulation or are based on models that are lacking a proven scientific basis.
## Shoulder Width

<table>
<thead>
<tr>
<th>Metric</th>
<th>US Customary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum width of traveled way (m)</td>
</tr>
<tr>
<td>Design for specified design volume (veh/day)</td>
<td>Design for specified design volume (veh/day)</td>
</tr>
<tr>
<td>speed (km/h)</td>
<td>under 400</td>
</tr>
<tr>
<td>60</td>
<td>6.6</td>
</tr>
<tr>
<td>70</td>
<td>6.6</td>
</tr>
<tr>
<td>80</td>
<td>6.6</td>
</tr>
<tr>
<td>90</td>
<td>6.6</td>
</tr>
<tr>
<td>100</td>
<td>7.2</td>
</tr>
<tr>
<td>110</td>
<td>7.2</td>
</tr>
<tr>
<td>120</td>
<td>7.2</td>
</tr>
<tr>
<td>130</td>
<td>7.2</td>
</tr>
<tr>
<td>All Width of usable shoulder (m)</td>
<td>All Width of usable shoulder (ft)</td>
</tr>
<tr>
<td>speeds</td>
<td>1.2</td>
</tr>
</tbody>
</table>

- On roadways to be reconstructed, an existing 6.6-m [22-ft] traveled way may be retained where alignment and safety records are satisfactory.
- Usable shoulders on arterials should be paved; however, where volumes are low or a narrow section is needed to reduce construction impacts, the paved shoulder may be reduced to 0.6 m [2 ft].
Shoulder Width

Highway Safety Manual Figure 13-5
Findings:

AASHTO design criteria produce uneven outcomes re. performance.

AASHTO dimensional criteria should ideally be based on known and proven measurable performance effects.

“Too many designers don’t understand the relative importance of a given criteria, or are not allowed to exercise judgment in ignoring or violating a criterion.”
Performance Continuum

Nominal Performance

Substantive Performance
Finding:

Replace dimensional guidance with direct performance guidance where possible within the AASHTO policy.
Performance-based design overview
NCHRP Report 785:

• Understanding the desired outcomes of a project
• Selecting performance measures that align with those outcomes
• Evaluating the impact of design decisions on those performance measures
• Arriving at solutions that achieve the desired outcomes
OUTCOMES
(Performance)

...rather than...

OUTPUT
(Dimensions)
Two primary facets of performance-based design:

1. **Disciplined focus on needs, problems and objectives**

2. **Use of performance-based tools and methods to address problems and achieve objectives**
Needs, problems and objectives

What goes wrong?

• Misidentification of problems and needs
  • Imaginary problems or perceived problems
    • Existing condition not meeting standards
  • Missing or ignoring problems

• Non-issues hijacking the project

• Non-existent or wacked objectives
  “If you don’t know where you’re going, you’ll end up someplace else.”
  Yogi Berra
Performance-based tools and methods

Relationship between design features and expected performance
### Code-based design

#### Ramp terminal spacing

<table>
<thead>
<tr>
<th>EN-EN OR EX-EX</th>
<th>EX-EN</th>
<th>TURNING ROADWAYS</th>
<th>EN-EX (WEAVING)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="Image" alt="Diagram" /></td>
<td><img src="Image" alt="Diagram" /></td>
<td><img src="Image" alt="Diagram" /></td>
<td><img src="Image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

- NOT APPLICABLE TO CLOVERLEAF LOOP RAMPS

<table>
<thead>
<tr>
<th>FULL FREeway</th>
<th>COR OR FDR</th>
<th>FULL FREeway</th>
<th>COR OR FDR</th>
<th>SYSTEM INTERCHANGE</th>
<th>SERVICE INTERCHANGE</th>
<th>SYSTEM TO SERVICE INTERCHANGE</th>
<th>SERVICE TO SERVICE INTERCHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 m (1000 ft)</td>
</tr>
</tbody>
</table>
Code-based design

It doesn’t account for...

• Respective ramp volumes
• Mainline traffic density
• Speeds
• Geometry
• Signing considerations
• Cost or feasibility of attaining the standard
• Design context
“...balance system efficiency and safety with the need to provide access...

“The selection criteria include geometric design needs, operational performance, signing needs, and safety performance.”
T.H. 27 – Hoffman to Alexandria
Original design speed: 50 mph
# Table 2-4.05A
## DESIGN SPEED
### New Construction and Multi-Lane Highways

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>DESIGN SPEED (MPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DESIRABLE</td>
</tr>
<tr>
<td>FULL CONTROL OF ACCESS:</td>
<td></td>
</tr>
<tr>
<td>URBAN FREEWAYS</td>
<td>70</td>
</tr>
<tr>
<td>RURAL FREEWAYS</td>
<td>70</td>
</tr>
<tr>
<td>PARTIAL CONTROL OF ACCESS:</td>
<td></td>
</tr>
<tr>
<td>URBAN ARTERIALS</td>
<td>60</td>
</tr>
<tr>
<td>RURAL ARTERIALS</td>
<td>70</td>
</tr>
<tr>
<td>UNLIMITED ACCESS:</td>
<td></td>
</tr>
<tr>
<td>RURAL – FLAT TERRAIN</td>
<td>70</td>
</tr>
<tr>
<td>RURAL – ROLLING TERRAIN</td>
<td><strong>70</strong></td>
</tr>
<tr>
<td>RURAL – RUGGED TERRAIN</td>
<td>60</td>
</tr>
<tr>
<td>URBAN</td>
<td>50</td>
</tr>
</tbody>
</table>

1980’s era Road Design Manual
New design speed: 70 mph
Sight distance: diminishing or zero return
13.6.2. Alignment Treatments with CMFs

13.6.2.1. Modify Horizontal Curve Radius and Length, and Provide Spiral Transitions

**Rural two-lane roads**

The probability of a crash generally decreases with longer curve radii, longer horizontal curve length, and the presence of spiral transitions (16). The crash effect for horizontal curvature, radius, and length of a horizontal curve and presence of spiral transition curve is presented as a CMF, as shown in Equation 13-5. The standard error of this CMF is unknown. This equation applies to all types of roadway segment crashes (16,35). Figure 13-9 illustrates a graphical representation of Equation 13-5. The base condition of the CMFs (i.e., the condition in which the CMF = 1.00) is the absence of curvature.

\[
CMF_v = \frac{(1.5L_c + \frac{900}{R} - 0.012S)}{(1.55L_c)}
\]

Where:

- \(L_c\) = Length of horizontal curve including length of spiral transitions, if present (mi);
- \(R\) = Radius of curvature (ft); and
- \(S\) = 1 if spiral transition curve is present; 0 if spiral transition curve is not present.
Urban and suburban street design
...was to describe the controlling roadway design criteria on safety and operations for various urban and rural roadway types. The research team considered how the current criteria or possible modified criteria influence the flexibility of the design process.
13 Controlling Criteria:

- Which ones are safety- and performance-critical enough to keep, and which ones should be tossed?

- How do they rank in terms of safety sensitivity?
Conclusion regarding urban and suburban arterials:

NOTHING MATTERS!
“It is recommended that the concept of controlling criteria for roadway geometrics not be applied to urban and suburban arterials…”

“…or that only a minimum set of controlling criteria be applied, including lane width (for lane widths less than 10 ft), stopping sight distance (for locations where a hidden curve, intersection or driveway is present), and cross slope.”
Federal revision of the controlling criteria

Controlling criteria retained for low-speed facilities:

1. Structural Capacity
2. Design Speed
What ails us?
(on urban/suburban arterials and collectors)
“...the traffic operational and safety performance of urban and suburban arterials appears to depend on factors such as intersection design and access management...”

“...flexibility to adapt roadway cross sections to the specific needs of each corridor...would appear to be of greater importance to design of urban and suburban arterials than the administrative controls provided by the 13 controlling criteria.”
Minnesota Traffic Fatalities

Total Traffic Fatalities
Pedestrian Fatalities
Bicyclist Fatalities

Note. 2017 fatality information is preliminary
### Table 14-3. Potential Crash Effects of Converting a Signalized Intersection into a Modern Roundabout (29)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert signalized intersection to modern roundabout</td>
<td>Urban (One or two lanes)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.99*</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Suburban (Two lanes)</td>
<td>Unspecified</td>
<td>All types (Injury)</td>
<td>0.40</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All settings (One or two lanes)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (All severities)</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.22</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Base Condition: Signalized intersection.
Intersections
Intersections

Level of Service ‘C’
New York City 1980's: Williamsburg Bridge project
“Desirably the through lanes on arterial streets should also be 12 feet wide. However, the stringent controls of right-of-way and existing development may make use of 11-foot lanes necessary.”

“Any width less than 11 feet is considered unsatisfactory for arterial highways.”
"...no general indication that the use of lanes narrower than 12 ft on urban and suburban arterials increases crash frequencies."

"The lane width effects...were generally either not statistically significant or indicated that narrower lanes were associated with lower rather than higher crash frequencies."
MnDOT – 2013

“...changes including lane width reduction...did not have any adverse safety impacts.”

“Overall, the complete street improvements at the study sites did not indicate any occurrences of significant safety issues after reconstruction and in general, safety was improved.”
The apparent formula:

**Design for safety!**

Devote as little space to the motor vehicular way as you can while still having a functional facility.

- Element widths right sized for the context, need and operating speed
- LOS is a performance measure, not a design standard
- Balance
Minnesota Traffic Fatalities

Note: 2017 fatality information is preliminary
Pedestrian fatalities

![Fatality Rate by Vehicle Speed](image)

- 32 km/h (20 mph)
- 48 km/h (30 mph)
- 64 km/h (40 mph)
Takeaways: urban/suburban street design

- Design speed: right size for a contextually-appropriate speed outcome
  - DS equal to or less than the target speed
- Cross section: the narrowest vehicular way that gets the job done
- Design around the pedestrian
  - Not good enough to just design for the pedestrian
Questions...

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