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Geometric Design, Speed, and Safety

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From the TREC “instructions for Friday seminar speakers…”

Students in the seminar appreciate knowing how you advanced to your current position, so a brief background statement is usually of interest…
• Pittsburgh coal seam
• Monongahela River
• Coal patches (1880-1920)
  -- Highly stratified
  -- 75% + eastern and southern European
  -- Company stores
  -- Rented company housing
  -- Iron and Coal Police
  -- Union formation

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www.coalcampusa.com
Vesta #6
Denbo, PA (pop. 713*)

- avg house value: $14,300*
- avg income: 

* data from 2000 census
Pictures from www.coalcampusa.com
Education and Academic Experience

Teaching and Research:

- highway and street design
- road safety
- project development
- traffic operations
- statistics/econometrics
- risk and reliability analysis

- Penn State, ‘95-’97...
- Penn State, ‘97-’99
- Penn State, ’00
- Virginia Tech (research)
- Penn State, ’07
- Texas A&M
- The U (July 2009 - )
Geometric Design, Speed, and Safety

- Why do we get what we get?
- Can we get what we want? How?

Pictures from FHWA-HRT-05-098 (2006)
Background

Self-enforcing, self-explaining design

Complete streets

Speed management

Traffic calming

Speed prediction

Design consistency

Speed harmony

Speed discord

Inferred design speed
Design Speed

“...a selected speed used to determine the various geometric design features of the roadway...” (2001-current)

“...should be a logical one with respect to topography, anticipated operating speed, the adjacent land use, and the functional classification...”
Structural Design

"Design Load"

Legal Load Limit

Anticipated vehicle loads
Design Speed (a look back)

“...the maximum approximately uniform speed which probably will be adopted by the faster group of drivers but not, necessarily, by a small percentage of reckless ones” (pre-1954)

“... the maximum safe speed that can be maintained over a section of highway when conditions are so favorable that the design features of the highway govern.” (1954-2001)
Approximate Relation Between Design and Running Speeds for Urban Conditions

Design speed ranges from 30 to 40 mph (corresponding to *target speeds* of 25 to 35 mph).

Adapted from AASHTO (1957)
Design Speed Selection
Insights from NCHRP Report 504

• In urban areas, designers generally select design speeds that are within the range of anticipated operating speeds, regardless of terrain or functional class. The selected design speed was often equal to or 5 mph higher than the anticipated posted speed limit across terrain types and functional classifications.

• In rural areas, designers generally select design speeds that are within the range of anticipated operating speeds, regardless of terrain or functional class. The selected design speed was nearly always 5 mph higher than the anticipated posted speed limit across terrain types and functional classifications.
Speed Relationships in Design Process
As Intended/Desired...

from Donnell et al. (2009)
Criteria Related to Design Speed

\[ \frac{V^2}{15(e+f)} = R \]

\[ SSD = 1.47Vt + \frac{V^2}{30 \left( \frac{a}{32.2} \pm G \right)} \]

\[ M_s = R_v \left( 1 - \cos \frac{28.65S}{R_v} \right) \]

\[ L = \frac{AS^2}{200 \left( \sqrt{H_1} + \sqrt{H_2} \right)^2} \]
Example of Limiting Values

\[ R_{\text{min}} = \frac{V^2}{15(e_{\text{max}} + f_{\text{max}})} \]

\( e_{\text{max}} \): Influenced by climate conditions, constructability, adjacent land use and the frequency of slow moving vehicles

\( f_{\text{max}} \): The point “at which discomfort due to the lateral acceleration is evident to drivers has been accepted as a design control for the maximum side friction factor on high-speed streets and highways.”

Exhibit 3-12. Side Friction Factors Assumed for Design

from AASHTO (2004)
“Limiting” Values?

Available ‘f’, passenger cars, wet pavement

“Margin of Safety”

Maximum ‘f’ used for design

Design Speed, mph

side friction factor, f

Design Speed, mph

Available ‘f’, passenger cars, wet pavement

“Margin of Safety”

Maximum ‘f’ used for design

Design Speed, mph

side friction factor, f
"Limiting" Values?

Minimum curve radius used for design

"Margin of Safety"

Minimum curve radius based on actual f, passenger cars, wet pavement

Design Speed, mph

Minimum Curve Radius, feet
Roadway Design Guidance

“Above-minimum design values should be used, where practical...”
Inferred Design Speed

Maximum speed for which all critical design-speed-related criteria are met at a particular location.

Inferred design speed of a feature differs from the designated design speed when the actual dimension differs from the criterion-limiting (minimum or maximum) value.
Speed Relationships in Design Process
As Intended... (with inferred design speed)

from Donnell et al. (2009)
Expected & Observed Relation Between Design and Running Speeds (Low-Volume)

Adapted from AASHTO (1957)

Running Speed = Design Speed

1 Estimated using data from Donnell et al., 2009
Case Study: Blue Course Drive
Ferguson Township, PA

- New alignment ≈ 2002
- ADT ≈ 3,500
- Design speed: 40 mph
- Urban collector
- Segment length: 1.5 miles
- Horizontal curves: 3
- Maximum grade: +3.5%, -6.6%
Case Study: Blue Course Drive
Ferguson Township, PA

$R_{\text{min}} = 444 \text{ ft for } V = 40 \text{ mph, } e_{\text{max}} = 8\%; K_{\text{crest,min}} = 44 \text{ ft}/\% \text{ for } V = 40 \text{ mph}$

$K_{\text{crest}} = 90 \text{ ft}/\%$

$R = 1968'$

$R = 1312'$

$R = 2625'$
Case Study: Blue Course Drive
Ferguson Township, PA

Longitudinal Distance (feet)

Speed (mph)

Inferred Design Speed
Designated Design Speed
Posted Speed Limit
85th Percentile Speed
Mean Speed
15th Percentile Speed
Observed Speed Relationships?
Low to Moderate Design Speeds

from Donnell et al. (2009)
Speed Management Through Road Geometrics
“Self-Enforcing, Self-Explaining Roadway Design”
from Porter et al. (2012)

1. What is known about relationships between road geometry and operating speeds?

2. To what degree does road geometry influence operating speeds?

3. How are safety and security influenced by road geometry?

4. What are potential impacts to large vehicles?

5. What is the nature of the speed-safety trade-off?
What is known about relationships between road geometry and operating speeds?

A synthesis of existing operating speed models developed in different regions of the world.

10 authors from 5 different countries

Much of what we know in North America is for rural, two-lane highways.
What is known about relationships between road geometry and operating speeds?

“It is now widely believed that collision rate is more directly affected by speed variations than by speed per se, given that intuitively, the probability of conflicts would be lower if all vehicles were travelling at the same speed.” - TAC
To what degree does road geometry influence operating speeds?

- Design Speed (emax = 8%)
- Operating Speed, rural two-lane
- Operating Speed, urban collector
- Rural, two-lane operating speed line based on Fitzpatrick et al. (2000)
- Urban collector operating speed line based on Tarris et al. (1996)
To what degree does road geometry influence operating speeds?

Operating Speed, rural two-lane

Operating Speed, urban collector

Rural, two-lane operating speed line based on Lamm & Choueiri (1987)

Urban collector operating speed line based on Poe et al. (2000)
What is the nature of the speed-safety trade-off?

![Graph showing the relationship between speed, horizontal curve radius, and crash modification factor.]

- Design Speed (emax = 8%)
- Operating Speed, rural two-lane
- Operating Speed, urban collector
- CMF

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What is the nature of the speed-safety trade-off?
Summary and Conclusions

• Design speed as “safe speed” still reflected in design speed descriptions
• Operating speeds > design speeds when design speeds < 55mph
• No safety support for ‘desirable’ versus ‘undesirable’ speed relationships
• Five questions offered related to speed management through roadway geometrics
Geometric Design, Speed, and Safety

Some possible research recommendations...
From 2009 “Need for Speed” Workshop

We need a process where speed-related transportation outcomes of highway and street design alternatives/decisions are quantified...
From 2009 “Need for Speed” Workshop

...and the *speed-related decision rationale* are consistent and explainable to a variety of user groups and stakeholders
Back to the Big Picture

Transportation investments → Program/Project Development → Social goals

Direct Transportation Support
- Accessibility
- Mobility
- Quality of service
- Reliability
- Safety

Community life
- Cultural enrichment
- Ecological health
- Economic prosperity
- Equity & Justice
- Personal health
- Social interaction

Geometric Design and Speed Sensitivity?

slide adapted from Mahoney (2006)
Recommendations

Combine Speed and Safety Studies
Recommendations
Consider Criteria Combinations

![Graph showing the relationship between Crash Modification Factor and Lane Width (ft) for different values of SW (Lane Width): SW = 3ft (solid line), SW = 4ft (dotted line), SW = 5ft (dashed line), SW = 6ft (dashed-dotted line).](image-url)
Recommendations
Consider Criteria Combinations

Rural, Two-Lane Highways from Bonneson & Pratt (2009)
Recommendations
Consider Criteria Combinations

Urban Roads, Porter & Le (2013)
Recommendations

Consider more than “Site Specific Effects”

Segment Length
(center of intersection to center of intersection)

Plus any changes in roadway segment factors for which there is a CMF (i.e., define homogenous segments)

A All crashes that occur within this region are classified as intersection crashes.

B Crashes in this region may be segment or intersection related, depending on the characteristics of the crash.

Questions

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