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

- avg house value: $14,200*
- 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

Context sensitive design/solutions

Complete streets

Design consistency

Speed management

Traffic calming

Speed prediction

Feedback loop

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

Vehicle Loads

“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

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

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

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

\[ L = \frac{AS^2}{200\left(\sqrt{H_1} + \sqrt{H_2}\right)^2} \]
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.”

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
“Limiting” Values?

Minimum curve radius used for design

“Margin of Safety”

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

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

$R_{min} = 444 \text{ ft for } V = 40 \text{ mph, } e_{max} = 8\%; K_{crest,min} = 44 \text{ ft/}% \text{ for } V = 40 \text{ mph}$
Case Study: Blue Course Drive
Ferguson Township, PA

Longitudinal Distance (feet)

- Inferred Design Speed
- Designated Design Speed
- Posted Speed Limit
- 85th Percentile Speed
- Mean Speed
- 15th Percentile Speed

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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. The graph includes curves for Design Speed (emax = 8%), Operating Speed in rural two-lane, and Operating Speed in urban collector. The Crash Modification Factor (CMF) is also shown.]
What is the nature of the speed-safety trade-off?

![Graph showing speed-safety trade-off](image)

- Operating Speed, rural two-lane
- Operating Speed, urban collector
- CMF, ADT > 2000 vpd
- CMF, 400 < ADT < 2000 vpd

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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

Speed Prediction for Two-Lane Rural Highways

Development of a Highway Safety Manual

Prepared for:
National Cooperative Highway Research Program

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Submitted by:
Warren Hughes and Kim Eccles
Bellemo-McGee, Inc.
Vienna, Virginia

Douglas Harwood and Ingrid Potts
Midwest Research Institute
Kansas City, Missouri

Ezra Hauer
University of Toronto
Toronto, Ontario, Canada

March 2004
Recommendations
Consider Criteria Combinations

Crash Modification Factor vs Lane Width (ft)

- SW = 3ft
- SW = 4ft
- SW = 5ft
- SW = 6ft

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Recommendations
Consider Criteria Combinations

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

Recommendations

Urban Roads, Porter & Le (2013)

- 10ft lane
- 11ft lane
- 12ft lane
- 13ft lane

Crash Modification Factor vs. Shoulder Width (ft)

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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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