Performance-Based Approaches for Geometric Design of Roads

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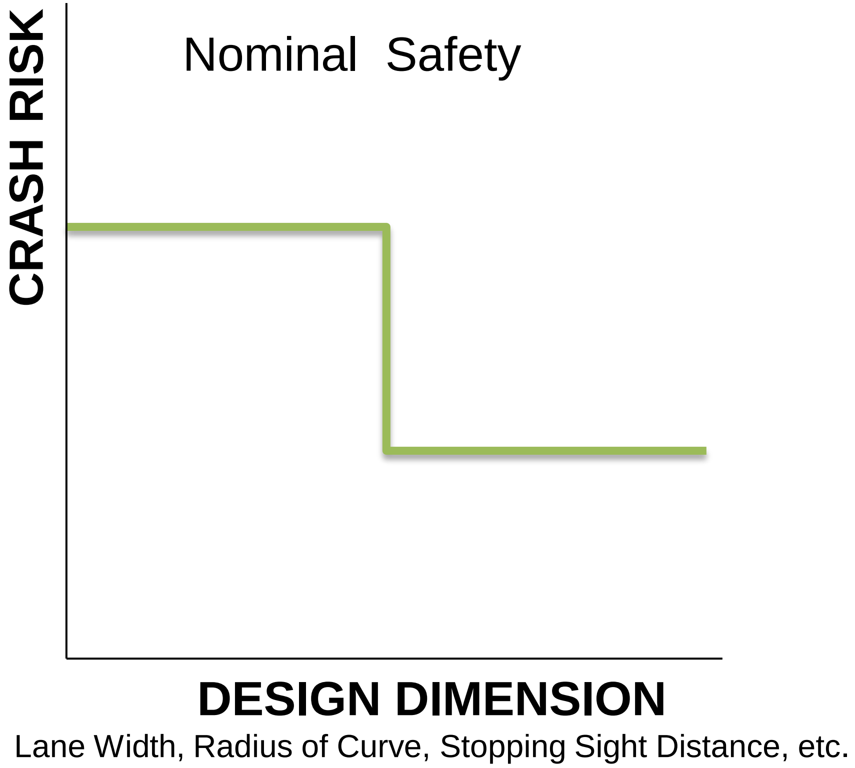
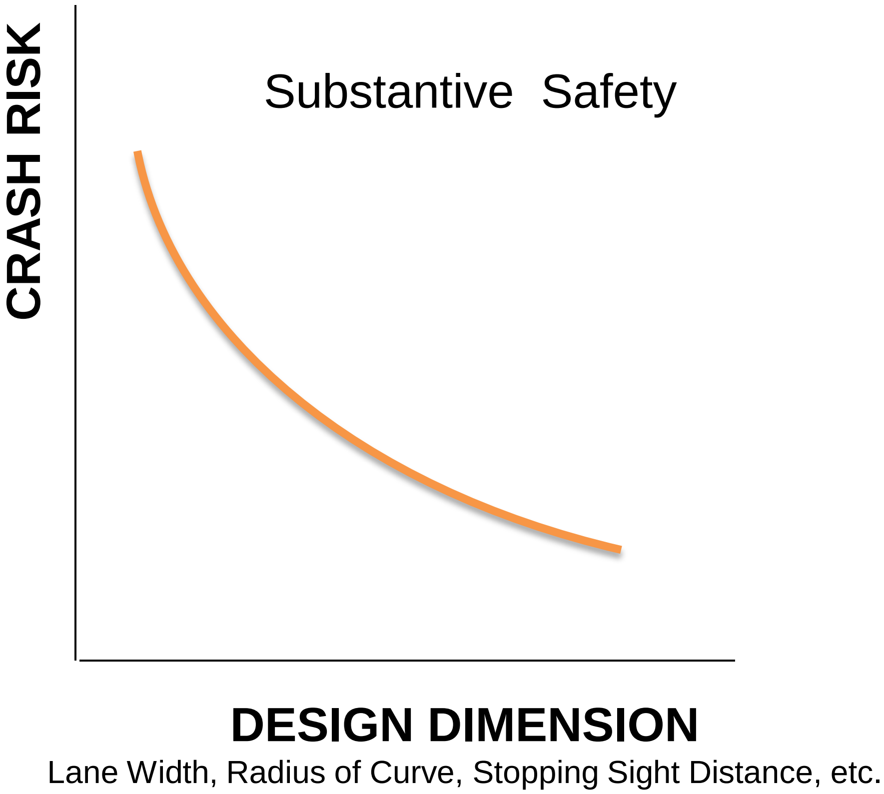
Traditional Approaches to Highway Geometric Design

- Based on established geometric design criteria (standards, policies, guidelines)
  - example: AASHTO Green Book
- Merely meeting standards cannot ensure safety
- A performance-based approach requires understanding how geometric design features affect safety

Nominal vs. Substantive Safety





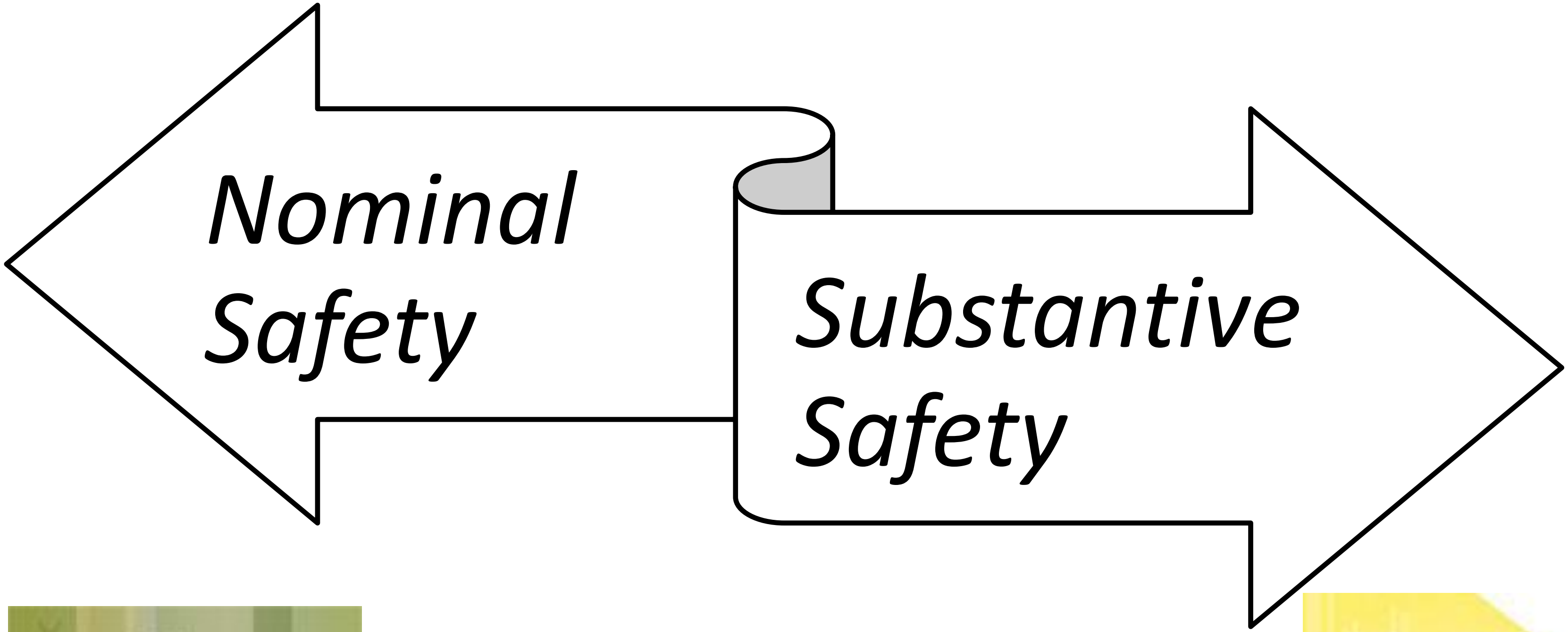
Substantive Safety

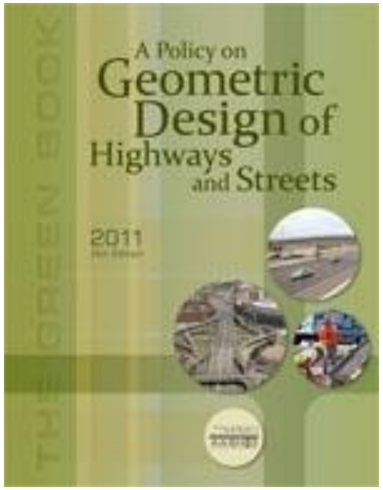
- In design of highway improvement projects, every other effect is quantified – traffic operations, air quality, noise, right-of-way, wetlands impacts, community impacts, project cost – WHY NOT QUANTIFY SAFETY EFFECTS?
- To quantify safety effects, crash prediction models are needed
- Designers need to be able to predict the effects of their design decisions on safety

Crash Prediction Models

- Crash frequencies can be predicted with regression models
- Ordinary least squares regression modeling is not appropriate because crashes do not follow a normal distribution
- Negative binomial regression models are more suited for application to crash data

Nominal vs. Substantive Safety





Based on compliance with general standards, policies, guidelines and established design procedures

Based on estimation of the expected crash frequency and severity for a specific design at a specific site

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Vision for the AASHTO *Highway Safety Manual* – the Safety Equivalent to the TRB *Highway Capacity Manual*

1. Definitive; represents quantitative 'state-of-the-art' information
2. Widely accepted within professional practice of transportation engineering
3. Science-based; updated regularly to reflect research

Outline of the *Highway Safety Manual*

Part A
Introduction, Human Factors, and Fundamentals

Part B
Roadway Safety Management Process

Part C
Predictive Method

Part D
Accident Modification Factors

Highway Facility Types with HSM Part C Predictive Models

HSM First Edition, 2010

- Rural two-lane highways
  - roadway segments
  - intersections
- Rural multilane highways (non-freeways)
  - roadway segments
  - intersections
- Urban and suburban arterials
  - roadway segments
  - intersections

Highway Facility Types with HSM Part C Predictive Models

New Models Developed for Addition to the HSM

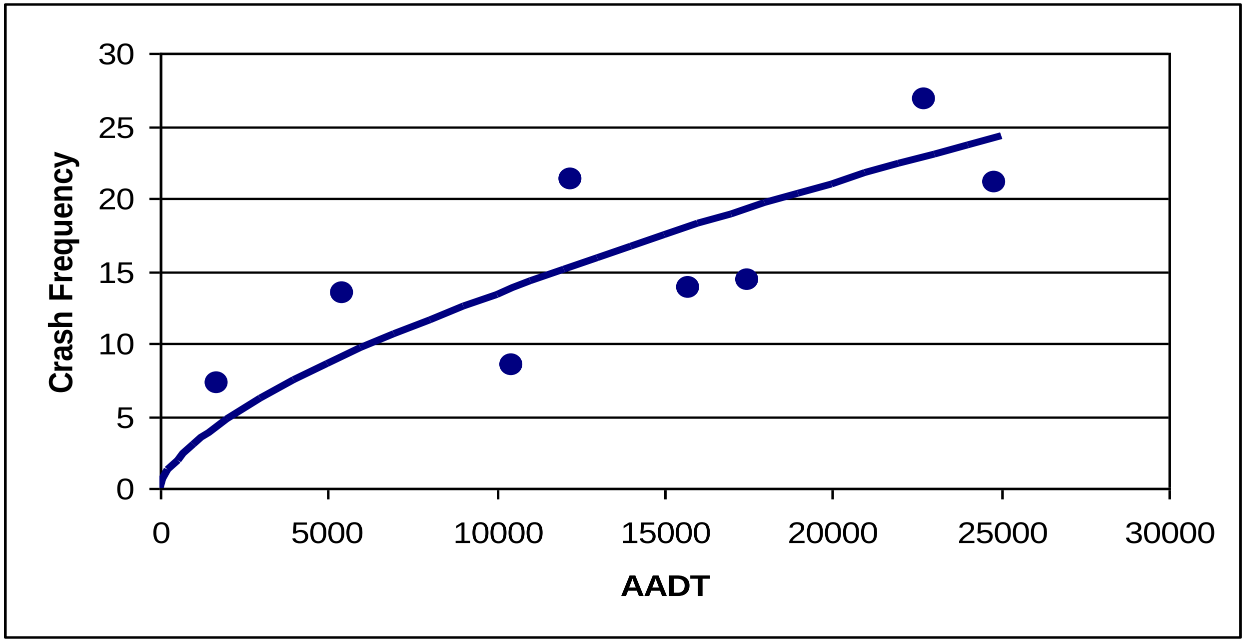
- Mainline freeway segments
- Speed-change lanes
- Interchange ramp segments
- Crossroad ramp terminals

Structure of Part C Crash Prediction Models

- Apply Safety Performance Function (SPF) for actual traffic volume to base conditions
- Apply Crash Modification Factors (CMFs) to adjust SPF prediction for actual site conditions
- Apply Local Calibration Factor (C) to adjust crash prediction to local area

Safety Performance Function

SPF = Mathematical relationship between crash frequency per unit of time (and road length) and annual average daily traffic volume (AADT)



Typical Safety Performance Function

$$N_{spf} = \exp\left[a + b \ln(AADT)\right]$$

N_{spf} = predicted crash frequency for base conditions

AADT = annual average daily traffic volume (vehicles per day)

a, b = regression coefficients

Crash Modification Factors

- CMFs represent the safety effect of a specific geometric or traffic control feature (for example, lane width)
- CMF = 1.0 for base condition (for example, shoulder width of 0.9 m)
- CMF > 1.0 represents a situation with more predicted crashes than the base condition (for example, narrower shoulders)
- CMF < 1.0 represents a situation with fewer predicted crashes than the base condition (for example, wider shoulders)

Predictive Method for Individual Roadway Segments or Intersections

$$N_{rs} = N_{spf} \times (CMF_1 \times CMF_2 \times \ldots.) \times C$$
$$N_{int} = N_{spf} \times (CMF_1 \times CMF_2 \times \ldots.) \times C$$

'Safety Performance Function'

'Crash Modification Factors'

'Local Calibration Factor'

Predicting Safety for Entire Projects

- Divide project into roadway segments and intersections
- Apply appropriate predictive method for each roadway segment and intersection
- Combine results

$$N_{total} = \sum_{\substack{all \\ roadway \\ segments}} N_{rs} + \sum_{\substack{all \\ intersections}} N_{int}$$

CMFs for Roadway Segments – Rural Two-Lane Highways

- Lane width
- Shoulder type and width
- Horizontal curve geometrics
- Grades
- Driveway density
- Centerline rumble strips
- Passing lanes
- Center turn lanes
- Roadside design features
- Lighting

CMFs for Intersections – Rural Two-Lane Highways

- Intersection skew angle
- Intersection right-turn lanes
- Intersection left-turn lanes
- Lighting

Compensation for Regression to the Mean

- If sites are selected based on high crash experience, those sites are likely to experience lower crashes in future years, even if no improvements are made
  - this potential bias in evaluating crash reduction effectiveness of improvements is called **regression to the mean**
- HSM crash prediction methods include procedures to compensate for the potential bias caused by regression to the mean
  - this compensation is accomplished with the Empirical Bayes method
  - combined crash model predictions with site-specific crash history data

Uses of the HSM Predictive Method

Evaluate and compare expected crash frequency:

- Existing facilities
- Alternative design modifications
- New facility designs
- Estimated countermeasure effectiveness

Implementing HSM Crash Prediction Models

- Manual worksheets for individual roadway segments or intersections are included in the HSM
- Interactive Highway Safety Design Model (IHSDM) provides software to efficiently evaluate entire projects

Interactive Highway Safety Design Model -- IHSDM

- Developed by the U.S. Federal Highway Administration (FHWA) beginning in 1991
- Software includes HSM Part C predictive methods for all available roadway and intersection types
- Software also include other design and safety analysis tools for rural two-lane highways

IHSDM Crash Prediction Module

- Provides estimates of:
  - expected crash frequency
  - expected crash frequency by severity level
  - expected crash frequency by crash type
- applies HSM procedures to predict crash frequencies for:
  - existing roadway for current traffic volumes if no improvements are made
  - existing roadway for future traffic volumes if no improvements are made
  - improved roadway for potential design alternatives

Other IHSDM Modules (for Rural Two-Lane Highways only)

- Policy Review Module
  - compares geometric design elements for existing or proposed designs to established design policies and flags differences
- Design Consistency Module
  - identifies and flags successive geometric features (such as horizontal curves) that will produce large vehicle speed changes

Other IHSDM Modules (for Rural Two-Lane Highways only)

- Traffic Analysis Module
  - performs traffic operational simulation of two-lane highways using the TWOPAS model (including effects of passing lanes)
- Intersection/Review Module
  - reviews existing or proposed intersection designs and flags design inconsistencies
- Driver/Vehicle Module
  - Identifies vehicle guidance or loss-of-control issues on horizontal curves

IHSDM Software

- Software functions for designs in either metric/SI or U.S. customary units
- Roadway design data can be entered manually or transferred automatically from Computer-Aided Design and Drafting (CADD) software
- Software is available for free download from www.ihsdm.org

Questions?