Interactive Highway Safety Design Model (IHSDM) 2013 Release

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Agenda

- Welcome and Introductions
- Integration of Safety Analysis in Design
- IHSDM 2013 – Overview of New Features
- IHSDM 2013 – Demonstration
- Questions / Discussion
What is IHSDM?

• A suite of software tools that support project-level geometric design decisions by providing quantitative information on the expected safety and operational performance
What Benefits does IHSDM Provide?

- IHSDM results help project developers make design decisions that improve the expected safety performance of designs.

- IHSDM helps project planners, designers, and reviewers justify and defend geometric design decisions.
What is the intent of the safety analysis for a transportation improvement project?

To help make more informed project design decisions
The safety analysis should help guide design decisions in effort to:

• Mitigate existing risk features that potentially contribute to increased number and severity of crashes

• Reduce future safety risks by making effective and efficient design choices
Design choices can reduce:
- Chance of human error resulting in crash
- Severity of the consequences of crashes
Project design is an exercise in “risk management”
- There is risk in using only “minimum” design criteria
- Using below “minimum” criteria (i.e. design exception) may not significantly impact safety depending upon other risk factors

Good design is more than just looking up values “in the book”

It’s applying engineering knowledge of the relationship between design factors and the “safety performance” of the facility
Potential IHSDM Applications

- As a tool to identify facilities where the “safety performance” is worse than expected
  
  - Assists in making decisions where to invest limited resources in ways that will clearly improve safety performance

“… evolution in safety analysis from descriptive methods to quantitative, predictive analysis”

AASHTO Highway Safety Manual – Chapter 1 Introduction and Overview
Variation in Short-Term Observed Crash Frequency

Source: AASHTO Highway Safety Manual Figure 3-4
Potential IHSDM Applications

- As a tool to assess the safety “benefit” when conducting a B/C analysis
  - Predict crashes before and after reconstructing or improving a facility
- Convert change in operations into road-user benefit
- Convert change in safety into road-user benefit
- Annualize construction costs using service life
- Compute benefit–cost ratio or net benefit

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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Operational benefit ($1000/yr)</td>
<td>0</td>
<td>17</td>
<td>22</td>
<td>25</td>
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<tr>
<td>Safety benefit ($1000/yr)</td>
<td>0</td>
<td>39</td>
<td>45</td>
<td>84</td>
</tr>
<tr>
<td>Project cost ($1000/yr)</td>
<td>0</td>
<td>41</td>
<td>52</td>
<td>130</td>
</tr>
<tr>
<td>Benefit-cost ratio</td>
<td>--</td>
<td>1.37</td>
<td>1.29</td>
<td>0.84</td>
</tr>
</tbody>
</table>
Potential IHSDM Applications

- As a tool to assess design options:
  - Evaluate alternatives
  - Evaluate proposed design exceptions
  - Evaluate and refine preliminary geometry
Crash Prediction Models

- **General Model Format**
  - Crash frequency, \( N_p = N_{spf} \times CMF_{lw} \times CMF_{sw} \ldots \times C \)
- **Model Components**
  - Safety performance function (SPF), \( N_{spf} \)
  - Crash modification factors (CMF), \( CMF_i \)
  - Calibration factor, \( C \)
  - Empirical Bayes adjustment
Safety Performance Function (SPF)

Crash Frequency

AADT
Model for predicting crash frequency for segment with base conditions

\[ N_{spf} = a \times (AADT)^b \times L \]

- **AADT** = annual average daily traffic volume
- **L** = segment length
- **a** and **b** = Regression coefficients

- May be sensitive to...
  - Crash severity: fatal-and-inj. (FI), prop.-damage-only (PDO)
  - Crash type: multiple-vehicle (MV), single-vehicle (SV)
  - Area type (urban, rural)
  - Number of lanes
Crash Modification Factor (CMF)

Change in crash frequency for a specific change in geometry (or the application of a treatment)
- Adapts SPF to non-base conditions
- One CMF per design element (e.g., lane width)

Example
- 4 lane freeway
- Base condition: 12 ft lanes
- Roadway has 11 ft lanes
- CMF = 1.04
Calibration Factor (C)

- **Purpose**
  - Models developed using data from several states
  - Factor adjusts model estimate to better match local conditions
  - $C = 1.0$ if predicted and observed values match
  - $C > 1.0$ if predicted value underestimates observed
  - $C < 1.0$ if predicted value overestimates observed
IHSDM: A Quantitative Approach to Evaluating Highway Safety
## IHSDM Evaluation Module

### Relationship to HSM Part C

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<td>Intersection Review</td>
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</table>
What Highway Types can the 2013 Release Evaluate?

- Facility types:
  - Two-lane rural highways (All Modules)
  - Multilane rural highways (Crash Prediction)
  - Urban & suburban arterials (Crash Prediction)
  - Freeway segments (Crash Prediction)
  - Freeway ramps/interchanges (Crash Prediction)

- Existing and proposed alternative highway geometric designs
Data Needs

- Vary by IHSDM evaluation module (and by highway type in CPM)
- Highway Segment Data (all modules)
- Intersection Data (CPM, IRM)
- Interchange Data (CPM)
- Crash Data (CPM – optional)
New / Updated for 2013

- Crash Prediction Method for Freeway Ramps/Interchanges
- Tutorial
  - Added exercises for Ramps/Interchanges
- Help/Documentation
  - Updated to reflect new features
Crash Prediction Module (CPM) 

Typical Uses

- Predicts crash frequency for highway segments, intersections and interchanges
- Evaluates the safety impact of highway improvements/treatments
- Compares relative safety performance of design alternatives
- Assesses safety cost effectiveness of design decisions
A. Introduction and Fundamentals

B. Roadway Safety Management Process

C. Predictive Method (IHSDM CPM)
   Chapter 10: Rural, Two–Lane Roads
   Chapter 11: Rural, Multilane Highways
   Chapter 12: Urban & Suburban Arterials
   Chapter 18 (draft): Freeways (Beta version)
   Chapter 19 (draft): Ramps (Beta version)

D. Crash Modification Factors
CPM for Freeway Ramps/Interchanges

- Based on draft HSM Chapter 19 (Predictive Method for Ramps)
  - Developed under NCHRP Project 17–45 (Enhanced Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges)
• Evaluation of freeway ramps/interchanges, including:
  – Ramps
  – Collector–Distributor (C–D) Roads
  – Ramp Terminals
CPM automatically segments highways for evaluation (including ramps and C–D roads), following draft HSM Chapter 19

Application of the Empirical–Bayes (EB) process to factor in historical crash data – for ramps and C–D roads
Crash Prediction Models

<table>
<thead>
<tr>
<th>Ramp Segments</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>1−Lane Entrance Ramps</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1−Lane Exit Ramps</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2−Lane Entrance Ramps</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>2−Lane Exit Ramps</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
### Crash Prediction Models

<table>
<thead>
<tr>
<th>Collector–Distributor (C–D) Road</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–Lane C–D Road</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2–Lane C–D Road</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Safety Performance Functions (SPFs)
Ramp Segments & C–D Roads

- Multiple–vehicle crashes
  - Fatal and Injury (FI)
  - Property Damage Only (PDO)
- Single–vehicle crashes
  - FI
  - PDO
Crash Prediction Models

Ramp Terminals (Fig. 19-1; HSM)

a. Three-Leg Ramp Terminal With Diagonal Exit or Entrance Ramp ($D_{3ex}$ and $D_{3en}$)

b. Four-Leg Ramp Terminal With Diagonal Ramps ($D_{4}$)

c. Four-Leg Ramp Terminal at Four-Quadrant Parclo A ($A_{4}$)

d. Four-Leg Ramp Terminal at Four-Quadrant Parclo B ($B_{4}$)

e. Three-Leg Ramp Terminal at Two-Quadrant Parclo A ($A_{2}$)

f. Three-Leg Ramp Terminal at Two-Quadrant Parclo B ($B_{2}$)
## Crash Prediction Models

<table>
<thead>
<tr>
<th>Ramp Terminals: Cross-Section and Control Type</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-way Stop-control; 2, 3 or 4-lane crossroad</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Signalized; 2-lane crossroad</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Signalized; 3-lane crossroad</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Signalized; 4-lane crossroad</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Signalized; 5-lane crossroad</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Signalized; 6-lane crossroad</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
• All crash types
  - FI
  - PDO
Crash Modification Factors (CMFs) Ramp Segments & C–D Roads

- Horizontal Curve
- Lane Width
- Right Shoulder Width
- Left Shoulder Width
- Right side Barrier
- Left side Barrier
- Lane add or drop
- Ramp speed–change lane
- Weaving section (C–D Road only)
# CMFs

## Ramp Terminals

<table>
<thead>
<tr>
<th>CMF Description</th>
<th>Signalized</th>
<th>Stop–controlled</th>
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</thead>
<tbody>
<tr>
<td>Exit Ramp Capacity</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Crossroad Left–Turn Lane</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Crossroad Right–Turn Lane</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Access Point Frequency</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Segment Length</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Median Width</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Protected Left–Turn Operation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Channelized Right Turn on Crossroad</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Channelized Right Turn on Exit Ramp</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Non–Ramp Public Street Leg</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Skew Angle</td>
<td></td>
<td>X</td>
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CPM for Freeway Ramps/Interchanges

Calibration Utility

• Assists agencies in implementing the calibration procedures described in the Appendix to HSM Part C
  – Organizes Required and Desired Data
  – Calculates Calibration Factors

• Allows agencies to enter their own SPFs and to modify default crash distributions
CPM for Freeway Ramps/Interchanges Calibration Utility

- **Calibration** – input calibration factors for groupings of the various freeway ramp/interchange Safety Performance Functions (SPFs)

- **Crash Distributions** – default crash distributions for freeway ramps/interchanges (from draft HSM Chapter 19) are available, and can be adjusted by the user (e.g., an agency can enter their own crash distributions if they differ from those in the HSM)
• Model Data (SPFs, CMFs, etc.) – model data from draft HSM Chapter 19 are available, and can be adjusted by the user (e.g., an agency can enter their own SPF if they desire)
• CPM (Lesson 4)
  – Freeways
    • Exercises 4.6.1 to 4.6.6 (Implementing HSM Chapter 19 Sample Problems 1–6)
    • Exercise 4.6.7 ("Example Freeway" project; evaluate components of two interchanges)
• “CPM Engineer’s Manual for Freeway Ramps, C–D Roads and Ramp Terminals” added

• Help/Documentation updated to reflect current release
IHSDM Freeway/Ramps Data Structure

- Freeway 1 with Interchanges 1 & 2
  - Crossroad A (Imported v1)
  - Crossroad B (Imported v1)
  - Freeway 1 (Imported v1)
  - Interchange 1
    - C-D Road A (v1)
    - Ramp Exit 1 (v1)
      - [v1] Evaluation 1 (Crash Prediction)
      - Ramp Entrance 1 (v1)
      - Ramp Exit 2 (v1)
      - Ramp Entrance 2 (v1)
    - Crossroad A Terminal D4 (v1)
      - [v1] Evaluation 1 (Crash Prediction)
  - Interchange 2
IHSDM Freeway/Ramps Data Structure

- Freeway 1 with Interchanges 1 & 2
  - Crossroad A (Imported v1)
  - Crossroad B (Imported v1)
  - Freeway 1 (Imported v1)
  - Interchange 1
    - C-D Road A (v1)
    - Ramp Exit 1 (v1)
      - [v1] Evaluation 1 (Crash Prediction)
      - Ramp Entrance 1 (v1)
      - Ramp Exit 2 (v1)
      - Ramp Entrance 2 (v1)
    - Crossroad A Terminal D4 (v1)
      - [v1] Evaluation 1 (Crash Prediction)
  - Interchange 2
IHSDM Freeway/Ramps Data Structure

Crossroad (Highway)
Freeway (Highway)

C-D Road (Highway)
Ramp (Highway)
IHSDM Freeway/Ramps Data Structure

Interchange

Ramp Terminal
IHSDM Freeway/Ramps
Data Structure

- Freeway 1 with Interchanges 1 & 2
  - Crossroad A (Imported v1)
  - Crossroad B (Imported v1)
  - Freeway 1 (Imported v1)
- Interchange 1
  - C-D Road A (v1)
  - Ramp Exit 1 (v1)
    - [v1] Evaluation 1 (Crash Prediction)
    - Ramp Entrance 1 (v1)
    - Ramp Exit 2 (v1)
    - Ramp Entrance 2 (v1)
- Crossroad A Terminal D4 (v1)
  - [v1] Evaluation 1 (Crash Prediction)
- Interchange 2

Evaluation (Ramp)
Evaluation (Ramp Terminal)
IHSDM Demonstration

- IHSDM 2013 Release (version 9.0.0; September 30, 2013)
Summary of CPM Capabilities

- Fully implements HSM Part C Predictive Methods
- Can evaluate many highway segments, intersections and interchanges over a number of years
- “Station-Based” Data Input automatically segments the highway into homogeneous segments as per HSM Part C
- “Site-Based” Data Input – especially useful for projects where detailed, station-based geometry not available (to be added for freeways/ramps in future)
• Can handle complex (and simple) alignments
• Seamlessly evaluates a highway that changes facility type (e.g., rural 2–lane to rural multilane)
• Full implementation of Empirical–Bayes procedure
• Incorporates Calibration Factors from IHSDM Calibration Utility
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Typical IHSDM Applications

- Evaluate relative safety impacts of alternative designs for EIS (CPM+)
- Evaluate expected safety impacts of recently completed improvements (CPM+)
- Safety analysis of preliminary construction plans (CPM+)
- Evaluate operational impacts of passing/climbing lanes (TAM)
- In conjunction with Road Safety Audits (CPM, DCM, IRM, PRM)
Typical IHSDM Applications

• Quantify relative safety/operational performance of alternatives and compare against other (e.g., environmental, cost) impacts (CPM, TAM+)

• Refine alternatives to optimize safety and operational performance (All)

• Evaluate / prioritize 3R safety improvements (All)

• Verify design exception areas (PRM, CPM)
2013 Release

- Download: http://www.ihsdm.org

- Technical support:
  - IHSDM.Support@dot.gov
  - (202)-493-3407

- Training:
  - On-Site: FHWA-NHI-380071
  - Web-based: FHWA-NHI-380100
  - See NHI catalog at http:// nhi.fhwa.dot.gov
Questions / Discussion

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