The Highway Safety Manual:
Will you use your new safety powers for good or evil?

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- Specialize in road user and rail safety
- Transportation system design, operations, and maintenance litigation
- Expert in in-service safety reviews
- ITE Involvement:
  - Current Canadian District Director
  - Member and Past Chair Transportation Safety Council Executive Committee
  - Vice-Chair of Expert Witness Council Executive Committee
  - Past member of TENC Executive Committee
  - Member of the Ethics Standing Committee
Presentation - Overview

• Principal HSM tools and their application in the project development process:
  – Network screening
  – Collision modification factors
  – Safety performance functions
• Benefits and potential pitfalls
• Ethics case study
The Highway Safety Manual

- Published in 2010
- HSM is not “The Bible”
- Assembly of collective safety experience and research from the past 10+ years
- Will have a major impact on “business as usual”:
  - Identifying “black spots”
  - Evaluating projects and designs
  - Identifying causal factors
  - Determining effective countermeasures
  - Establishing liability
The Highway Safety Manual

The HSM is not a legal standard of care as to the information contained herein. Instead, the HSM provides analytical tools and techniques for quantifying the potential effects of decisions made in planning, design, operations, and maintenance. There is no such thing as “absolute safety,” notwithstanding efforts by government to maintain, improve and operate highway facilities to the highest level that government funding allows. There is risk in all highway transportation. That risk is inherent due to the variability of user behaviors, environmental conditions, and other factors over which the government has no control. A universal objective is to reduce the number and severity of crashes within the limits of available resources, science, technology, and legislatively mandated priorities. Because these considerations are constantly changing, it is unlikely, if not impossible, that any highway facility can be “state of the art”. The information in the HSM is provided to assist agencies in their effort to integrate safety into their decision-making processes. The HSM is not intended to be a substitute for the exercise of sound engineering judgment. No standard of conduct or any duty toward the public or any person shall be created or imposed by the publication and use or nonuse of the HSM.
HSM Contents

• Part A: Introduction, Human Factors, and Fundamentals:
  – Chapter 1: Introduction and Overview
    • Advancements in Safety Knowledge
    • HSM and the Project Development Process
  – Chapter 2: Human Factors
    • Driver Characteristics and Limitations
    • Positive Guidance
    • Impacts of Road Design on the Driver
  – Chapter 3: Fundamentals
    • Crashes as the Basis for Safety Analysis
    • Data for Crash Estimation
    • Evolution of Estimation Methods

Figure 3-2. Crashes Are Rare and Random Events
**Figure 2 Applications of the HSM in the Project Development Process**

- **System Planning**
  - Identify needs and program projects.

- **HSM Application – Part B**
  - Identify sites most likely to benefit from safety improvement.
  - Identify targeted crash patterns for the network.
  - Prioritize expenditures for efficiency.

- **Operations and Maintenance**
  - Modify existing conditions to maintain and improve safe and efficient operation.

- **HSM Application – Part B and C**
  - Identify crash patterns at existing locations.
  - Evaluate safety effectiveness of potential countermeasures.
  - Modify policies and design criteria for future planning and design.

- **Project Planning & Preliminary Engineering**
  - Identify alternatives and choose the preferred solution.

- **HSM Application – Part B**
  - Identify targeted crash patterns for the project.
  - Evaluate countermeasures' costs and effectiveness.
  - Compare change in crash frequency to predict safety effect of alternatives.

- **Design and Construction**
  - Develop design plans and build projects.

- **HSM Application – Part C**
  - Evaluate how performance measures are impacted by design changes and construction.
  - Assess potential change in crash frequency during design exception evaluation.
HSM Contents

• Part B: Road Safety Management Processes:
  – Chapter 4: Network Screening
    • Network Screening Process
    • Performance Measure Methods and Sample Applications
  – Chapter 5: Diagnosis
    • Safety Data Review
    • Office Review/Analysis
    • Assess Field Conditions
    • Identify Concerns
HSM Contents

• Part B: Road Safety Management Processes:
  – Chapter 6: Select Countermeasures
    • Identifying Contributory Factors
    • Select Potential Countermeasures
  – Chapter 7: Economic Appraisal
    • Assess Expected Project Benefits
    • Estimate Project Costs
    • Economic Evaluation Methods for Individual Sites
  – Chapter 8: Prioritize Projects
  – Chapter 9: Safety Effectiveness Evaluation
HSM Contents

• Part C: Predictive Method
  – Chapter 10: Rural Two-Lane, Two-Way Roads
  – Chapter 11: Rural Multilane Highways
  – Chapter 12: Urban and Suburban Arterials

Note: Includes road sections and intersections
HSM Contents

- Part D: Crash Modification Factors:
  - Chapter 13: Road Segments
  - Chapter 14: Intersections
  - Chapter 15: Interchanges
  - Chapter 16: Special Facilities and Geometric Situations
  - Chapter 17: Road Networks

Table 14-17. Potential Crash Effects of Increasing Intersection Median Width (18)

<table>
<thead>
<tr>
<th>Treatment Description</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>Urban and suburban Three-leg unsignalized</td>
<td>Rural (Four-leg unsignalized)</td>
<td>0.66</td>
<td>Multiple-vehicle (All severities)</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Urban and suburban Three-leg unsignalized</td>
<td>Urban and suburban (Four-leg unsignalized)</td>
<td>0.66</td>
<td>Multiple-vehicle (All severities)</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Urban and suburban Three-leg unsignalized</td>
<td>Urban and suburban (Four-leg unsignalized)</td>
<td>Unspecified</td>
<td>Multiple-vehicle (Injury)</td>
<td>1.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Urban and suburban Three-leg unsignalized</td>
<td>Urban and suburban (Four-leg unsignalized)</td>
<td>Unspecified</td>
<td>Multiple-vehicle (All severities)</td>
<td>1.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Urban and suburban Three-leg unsignalized</td>
<td>Urban and suburban (Four-leg unsignalized)</td>
<td>Unspecified</td>
<td>Multiple-vehicle (Injury)</td>
<td>1.03</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Base Condition: A 14-ft-wide to 80-ft-wide median.
Network Screening

“a process for reviewing a transportation network to identify and rank sites from most likely to least likely to realize a reduction in crash frequency with implementation of a countermeasure” … HSM, 2010
Network Screening

- HSM provides thirteen potential performance measures covering “Average Crash Frequency” to “Excess Expected Average Crash Frequency with Empirical Bayes Adjustment”
- HSM does not recommend a specific method
- Provides the criteria, pros and cons of each process
- Regardless of method … how you apply the results is paramount
“Sites that repeatedly appear at the higher end of the list could become the focus of more detailed site investigations, while those that appear at the low end of the list could be ruled out for needing further investigation” … HSM, 2010
Network Screening - Cautions

• Network screening results is one of the “tools” in our decision making process
• Practitioners indiscriminately relying on results, i.e., no collision history … no problem … just another one of “those roads”
• Potential for “black box” mentality similar to other transportation analyses:
  – Traffic control device “warrants”
  – Intersection capacity analysis and delay / V/C thresholds
Network Screening – Cautions

• Critical look at collision frequency and dominant collision types at higher ranking locations and segments

• Common issues to check before initiating detailed review:
  – One or two “unexpected” collisions on low volume road or short segment could flag dominant collision type, i.e., angle or rear end on road segment
  – One fatal collision could create high POI
  – Variable collision types at same location could trigger POI but no definitive trend to investigate
CMFs

- CMFs quantify the expected change in collision frequency as a result of operational or geometric modifications to a road section or intersection compared to a base condition.
- Aggregated before and after results for various remedial actions.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Road Type)</th>
<th>Traffic Volume</th>
<th>Accident Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a median</td>
<td>Urban (Arterial Multilane)</td>
<td>Unspecified</td>
<td>All types (Injury)</td>
<td>0.78</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Rural (Multilane)</td>
<td></td>
<td>All types (Non-injury)</td>
<td>1.09</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.88</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Non-injury)</td>
<td>0.82</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Base Condition: Absence of raised median
CMF - Cautions

- Technical rigor
- Contributory causes
- Applying multiple countermeasures
- Applicability
## CMF Quality Rating

<table>
<thead>
<tr>
<th>Relative Rating</th>
<th>Excellent</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Design</td>
<td>Statistically rigorous study design with reference group or randomized experiment and control</td>
<td>Cross sectional study or other coefficient based analysis</td>
<td>Simple before / after study</td>
</tr>
<tr>
<td>Sample Size</td>
<td>Large sample, multiple years, diversity of sites</td>
<td>Moderate sample size, limited years, and limited diversity of sites</td>
<td>Limited homogeneous sample</td>
</tr>
<tr>
<td>Standard Error</td>
<td>Small compared to CRF</td>
<td>Relatively large SE, but confidence interval does not include zero</td>
<td>Large SE and confidence interval includes zero</td>
</tr>
<tr>
<td>Potential Bias</td>
<td>Controls for all sources of known potential bias</td>
<td>Controls for some sources of potential bias</td>
<td>No consideration of potential bias</td>
</tr>
<tr>
<td>Data Source</td>
<td>Diversity in States representing different geographies</td>
<td>Limited to one State, but diversity in geography within State (e.g., CA)</td>
<td>Limited to one jurisdiction in one State</td>
</tr>
</tbody>
</table>
## CMF Example – Raised Median vs TWLTL

**Countermeasure: Replace TWLTL with raised median**

<table>
<thead>
<tr>
<th>CMF</th>
<th>CRF(%)</th>
<th>Quality</th>
<th>Crash Type</th>
<th>Crash Severity</th>
<th>Roadway Type</th>
<th>Area Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.77</td>
<td>23</td>
<td>★★★★★</td>
<td>Angle, Fixed object, Head on, Rear end, Run off road, Sideswipe, Single vehicle</td>
<td>All</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
<tr>
<td>0.65</td>
<td>36</td>
<td>★★★★★</td>
<td>Angle</td>
<td>All</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
<tr>
<td>0.81</td>
<td>19</td>
<td>★★★★★</td>
<td>Rear end</td>
<td>All</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
<tr>
<td>0.79</td>
<td>21</td>
<td>★★★★★</td>
<td>Sideswipe</td>
<td>All</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
<tr>
<td>0.53</td>
<td>47</td>
<td>★★★★★</td>
<td>Head on</td>
<td>All</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
<tr>
<td>0.79</td>
<td>21</td>
<td>★★★★★</td>
<td>Angle, Fixed object, Head on, Rear end, Run off road, Sideswipe, Single vehicle</td>
<td>Serious injury, Minor injury</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
<tr>
<td>0.67</td>
<td>33</td>
<td>★★★★★</td>
<td>Angle, Fixed object, Head on, Rear end, Run off road, Sideswipe, Single vehicle</td>
<td>Property damage only (PDO)</td>
<td>All</td>
<td>Urban</td>
<td>Mauga and Kaseko, 2010</td>
</tr>
</tbody>
</table>
Trip Generation Data Parallel
Safety Performance Functions

• Safety Performance Functions (SPFs) are equations used to estimate the expected annual crash frequency at a location as a function of traffic volume and basic characteristics of the road section or intersection.

• Characteristics are generally limited to:
  – Number of lanes;
  – Number of approaches;
  – Traffic control; and/or,
  – Median type.
Figure 10-4. Graphical Representation of the SPF for Three-leg Stop-controlled (3ST) Intersections (Equation 10-8)
SPF - Cautions

• Calibrated SPFs account for traffic volumes and primary geometric features, they do not explicitly account for site specific characteristics

• Traffic volume variations, i.e., hourly, daily, seasonal, recreational, special events

• Road user populations

• Environment
Ethics Case Study
Background

• Four lane highway facility in medium sized community
• Varying degrees of access management on this and other peer highways through community
• Residential neighborhood with some frontage highway commercial with access via a RIRO access
Representative Location
Background (continued)

- Improved access requested for a number of years
- Unsignalized RIRO with left inbound access would be permitted if highway operations and safety were not compromised
- Signalization was not palatable option, i.e., no more “stop lights” on the highway
- Road jurisdiction hired an independent consultant to review future operations and safety
Background (continued)

- Consultant concluded that the proposed intersection would operationally fail in 15 year horizon
- Intersection would require traffic signal control
- Collisions risk would be 2 to 3 times that of the road authorities average rate
- Access was turned down by Council
- Proponents hired Giffin Koerth to peer review the consultant report
- Preliminary review suggested technical analysis was solid including methodologies consistent with the “soon to be released” HSM
HCM Analysis – Traffic Operations

- Present RIRO access working at LOS “A” with little or no delay. No surprises.
- Existing trips reassigned to proposed new left access
- A reasonable amount of “new” trips generated for pass-by commercial trips
- RIRO-Left In access to operate LOS “C” on opening day
- Access would fail in the 15 year horizon
- Highway traffic would queue to the upstream intersection under traffic signal control
- Background growth rates appeared aggressive and questionable
HSM Analysis – Collision Risk

- Existing collision risk assessed for the road section between the two existing full-turns accesses
- Future collision risk estimated with calibrated SPF for 3-leg stop controlled intersection
- Scenarios assessed differed only by AADT with and without left turn volume
HSM Analysis – Collision Risk

- Left turn inbound movement would increase collisions by over 100% and result in 20+ more collisions in the 15 year analysis period.
- Expect about 1.25 more collisions per year.
- Converted future annual frequency to a collision rate and compared it to jurisdiction’s “average collision rate”.
- Collision rate at the proposed intersection was determined to be over 2 to 3 times that of the jurisdiction average.
Issues Identified

• Proponents were not proposing full moves T-intersection
  – Not your typical t-intersection … outbound left turn not being requested
  – “Expected” conflict potential over-estimated
  – No mention or adjustment for this fact

FIGURE 1-6 Percentage of driveway crashes by movement (1).
Issues Identified

- Analysis assumed “new” trip generation at the proposed intersection
- Trip reassignment impacts not assessed on remainder of the road network
- Potential for a reduction in collision potential at numerous signalized and unsignalized intersections
Issues Identified
Issues Identified

- SPF generates an “expected” collision risk for the proposed intersection
- How is it that this “theoretical” future intersection would operate with a collision rate 2 to 3 times than the “average”?
- “Apples to oranges” comparison used to convey unsafe operations of the proposal
Ethics … you be the judge

- Were the analysis shortcomings just minor oversights?
- Did the consultant knowingly skew the analysis results to obtain a foregone conclusion?
- Did the client understand the analysis methodologies and accept the favorable results regardless?
- Do you consider these ethical issues?
The Highway Safety Manual:  
Will you use your new safety powers for good or evil?

April 4, 2011