Rational road safety management
Practice and Theory

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Overview

- Road infrastructure safety management process
- Evolution of road infrastructure safety management
- Current management initiatives
  - Highway Safety Manual
  - AASHTO strategic highway safety plan
- Current research directions
  - Theoretical challenges
  - Applications
- Future directions
THE ROAD INFRASTRUCTURE SAFETY MANAGEMENT PROCESS

- NETWORK EVALUATION
- SAFETY CONSCIOUS PROCEDURES
- IMPROVEMENTS TO STANDARDS, POLICIES AND PROCEDURES
NETWORK EVALUATION
(Of Roads in Service)

- NETWORK SCREENING
  - identification of sites (road segments, intersections, etc.) with promise of safety improvement

- DIAGNOSIS
  - what is wrong?
    - consider deficiencies – human, engineering factors

- DEVELOPMENT OF REMEDIES
  - selection of countermeasures for specific locations
  - prioritization of projects

- EVALUATION OF REMEDIES
  - What works, what does not
  - For what works,
    - When/where does it work?
    - How to make it work?
    - What works best?
Evolution of road safety management

- **Pre-1950’s:** emphasis on providing mobility
- **> 1950:** increasing importance of congestion management (1st edition of the Highway Capacity Manual)
- **1960’s:** Increasing interest of administrators: Start of revolutionary practical resolutions
  - Guide-rail, barriers and crash-cushions
    - *Reduced severity, but increased hits*
  - Breakaway-poles – eliminate severe accidents
    - *but also reduce non-severe ones!*
Evolution of road safety management, ctd.

**Early 1980’s: Start of the knowledge revolution**
- Recognition of problems with existing knowledge on safety implications of roadway improvements
  - Regression-to-mean in before after studies – safety benefits overestimated
  - Knowledge from cross-section studies -- safety benefits tend to be underestimated
  - Better methods for before-after and cross-section studies
  - *5 papers on safety analysis submitted to TRB in 1985.*

**Mid-1980’s: From congestion management to safety management**
- Managing congestion to improve safety
Is it better to be ………

- DEAD?

- OR ALIVE AND STUCK IN TRAFFIC??
Evolution …. ctd.

- **Mid-1980’s to mid-1990’s:** Dramatic increase in road safety research, researchers and practitioners
  - Mostly ad hoc research
  - Road Safety Auditor as a profession
  - Safety considerations in design, construction and maintenance

- **1997:** Ezra Hauer’s landmark book on observational before-after studies

- **Late 1990’s:** Formal recognition by administrators of need for science based road safety management;
  - Increase in research directed to facilitate the management process
    - Identify locations for detailed safety investigation
    - Detailed safety investigations of sites and development of remedies
    - Prioritization and implementation of remedies
    - Evaluation of remedies
Evolution of road safety management, ctd.

- **TURN OF THE CENTURY**: Formalizing safety considerations in the design, construction and maintenance processes
  - Explicit consideration of safety in design guides and manuals
  - Interactive Highway Safety Design Model
  - Safety audits

- **2000’s**:
  - AASHTO Strategic Highway Safety Plan
  - Highway Safety Manual
  - PIARC Road Safety Manual

- **2008**: 100+ papers on highway safety analysis submitted to Transportation Research Board Annual Meeting
IMPLEMENTATION OF RATIONAL ROAD SAFETY MANAGEMENT

- INITIATIVES
  - Highway Safety Manual
  - AASHTO Strategic Highway Safety Plan

- THEORETICAL CHALLENGES
  - Problems with existing analysis methods, knowledge

- RECENT RESEARCH
  - Evaluation of safety measures

- FUTURE DIRECTIONS
INITIATIVES

THE HIGHWAY SAFETY MANUAL

– a new era in highway safety analysis
HSM Purpose

- To provide the best factual information and tools in a useful form to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of their safety consequences.
The ‘vision’ of the HSM -- a document akin to the HCM

- Definitive; represents quantitative ‘state-of-the-art’ information
- Widely accepted in professional practice
- Science-based; updated regularly to reflect new research
EXAMPLE – Part C Methodology

- For 4-legged signalized intersections on two-lane roads

\[ N_{bi} = \exp(-5.73 + 0.60\ln ADT_1 + 0.20\ln ADT_2) \]

- Base conditions:
  - NO LEFT turn lanes on major (or minor)
  - NO RIGHT turn lanes on major (or minor)

- AMF for 1 left turn lane on major = 0.67
- AMF for 1 right turn lane on major = 0.975
- AMF for 2 right turn lanes on major = 0.95
A comprehensive plan to substantially reduce vehicle-related fatalities and injuries on U.S. highways

- Achieve less than 0.6 fatalities per 100 million vehicle-km

Produce guidebooks for emphasis areas

- Identify proven, tried and experimental countermeasures

Not just a plan!

- Stimulate/support research to fill in gaps in countermeasure knowledge
- Market research to ensure implementation of results
Emphasis areas

- **Drivers**
  - Young
  - Unlicensed/Suspended/Revoked
  - Older
  - Aggressive
  - Impaired
  - Distracted/Fatigued
  - Seat Belt Use
  - Speed

- **Special Users**
  - Pedestrians
  - Bicyclists

- **Vehicles**
  - Motorcycles
  - Heavy Trucks

- **Highways**
  - Trees
  - Run Off the Road
  - Horizontal Curves
  - Utility Poles
  - Unsignalized Intersections
  - Head-On Collisions
  - Work Zones

- **Emergency Medical Services**
  - Rural EMS

- **Management**
  - Data
  - Integrated Safety Management Process
Guide for addressing run-off-road collisions — *Strategies to keep vehicles from encroaching on the roadside*

- shoulder rumble strips
- edgeline “profile marking,” edgeline rumble strips
- midlane rumble strips
- enhanced shoulder or in-lane delineation and marking for sharp curves
- improved highway geometry for horizontal curves
- enhanced pavement markings
- skid-resistant pavement surfaces
- shoulder treatments
- shoulder drop-offs
- wider and/or paved shoulders
Theoretical challenges

- Rational management requires use of accident data
- Accident counts can be randomly high or low, therefore:
  - Sites can be wrongly identified as safe or unsafe in network screening
  - Sites with high counts will experience a reduction in accidents in future if nothing is done (regression-to-the mean).
    - This reduction can be wrongly attributed to an implemented remedy
Example of random fluctuation over time

Long term average = 4.23 accidents per year
# Real evidence of regression to the mean

742 California rural stop controlled untreated intersections

<table>
<thead>
<tr>
<th>Intersections with given number of accidents in 1994-96</th>
<th>Accidents/intersection in 1994-96</th>
<th>Accidents/intersection in 1997-99</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>0</td>
<td>0.96</td>
<td>Large increase</td>
</tr>
<tr>
<td>136</td>
<td>1</td>
<td>1.65</td>
<td>65.4%</td>
</tr>
<tr>
<td>101</td>
<td>2</td>
<td>2.64</td>
<td>32.2%</td>
</tr>
<tr>
<td>101</td>
<td>3</td>
<td>2.97</td>
<td>-1.3%</td>
</tr>
<tr>
<td>37</td>
<td>6</td>
<td>4.89</td>
<td>-18.5%</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>8.55</td>
<td>-14.4%</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>8.79</td>
<td>-20.0%</td>
</tr>
</tbody>
</table>
REGRESSION TO THE MEAN IN INSTALLING GATES AT RAIL CROSSINGS WITH FLASHERS

Accidents before = 286
Accidents after = 114

Apparent savings = 172
(60% reduction)

The Reality:
Accidents expected = 208

Actual savings
(208 – 114) = 94
(45% reduction)
Implication of temporal fluctuation -- regression-to-the-mean

- A high accident count will on average be followed by a reduced count even if site is unchanged.

- Therefore, if a site is selected for treatment because of a high count it will experience an apparent improvement in safety even if the treatment is useless.

- Therefore, this regression-to-the-mean effect must be accounted for in:
  - Selecting sites for treatment
  - Evaluating the safety effect of treatment
Accounting for regression to the mean

- **Crashes**
- **Long-term average (m)**
- **3-year average ‘before’ (Xa)**
- **Observed safety effect**
- **True safety effect**
- **3-year average ‘after’**
Use safety performance functions to estimate expected (long term) accident frequency, $m$.

- $m$ is a weighted average of the safety performance function estimate (SPF) and the observed accident frequency ($X$) of a site.
Recent EB safety evaluations with latest methods (for AASHTO SHSP)

- Flashing beacons
- Raised pavement markers
- Centre line rumble strips
- Improve skid resistance
- Offset left turn lanes
- Two way left turn lanes
- Road Diets
## Flashing Beacons

**Accident reductions at 106 sites**

<table>
<thead>
<tr>
<th>Angle</th>
<th>Injury &amp; Fatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.3%</td>
<td>10.2%</td>
</tr>
</tbody>
</table>
SAFETY EVALUATION OF CENTRE LINE RUMBLE STRIP
340 km at 98 U.S. sites

<table>
<thead>
<tr>
<th>Impact types</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Impact</td>
<td>14-15%</td>
</tr>
<tr>
<td>Opposite direction and sideswipe</td>
<td>21-25%</td>
</tr>
</tbody>
</table>
SAFETY EVALUATION OF Pavement markers

Previous comparison group studies had found an increase in crashes

% Reduction in crashes (EB Study)

<table>
<thead>
<tr>
<th></th>
<th>Night</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Jersey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Selective</td>
<td>0.9</td>
<td>3.2</td>
</tr>
<tr>
<td>174 miles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selective</td>
<td>12.7</td>
<td>20.2</td>
</tr>
<tr>
<td>82 miles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Improve skid resistance at targeted locations (New York) (*High skid numbers and wet weather accident frequency*)

<table>
<thead>
<tr>
<th>Location Type</th>
<th>All Crashes</th>
<th>Wet-road</th>
<th>Rear-end Wet-road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segments</td>
<td>23%</td>
<td>56%</td>
<td>43%</td>
</tr>
<tr>
<td>Intersection approaches</td>
<td>20%</td>
<td>57%</td>
<td>68%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>Injury</td>
<td>Left-Turn</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>EB estimate of crashes expected in the after period without strategy</td>
<td>233.77</td>
<td>95.88</td>
<td>94.85</td>
</tr>
<tr>
<td>Count of crashes observed in the after period</td>
<td>155</td>
<td>62.0</td>
<td>59</td>
</tr>
<tr>
<td>Estimate of percent reduction (standard error)</td>
<td>33.8</td>
<td>35.6</td>
<td>38.0</td>
</tr>
<tr>
<td></td>
<td>(6.0)</td>
<td>(9.0)</td>
<td>(8.9)</td>
</tr>
</tbody>
</table>
Addition of TWLTL to 2-Lane Road

Rural and urban locations in NC, IL, CA and AK

<table>
<thead>
<tr>
<th>Percent reduction in crashes</th>
<th>Rear-end</th>
<th>Injury</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(significant at the 5% level)</td>
<td>38.7</td>
<td>26.1</td>
<td>20.3</td>
</tr>
</tbody>
</table>
Where do we go from here?

… Future directions … From EB to FB
From EB to FB….

Using Markov Chain Monte Carlo simulation techniques (WINBUGS software)

- Model development and posterior distributions of estimates are integrated. \( \lambda \) estimated in single step
- Smaller sample sizes possible
- Flexibility to choose crash distribution (EB assumes negative binomial)
- Provides the posterior distributions of outcomes (\( \lambda \)) …usually not normal as for EB
- Can easily consider spatial correlation between sites in the model formulation
- Can easily accommodate very complex model forms (EB uses generalized linear models typically)
Application to conversion from 4-lane cross-section to 3 lanes plus two-way left turn lane.
Data for TWLT lane evaluation

- 16 treatment sites
- 16 yoked comparison sites (used for FB)
- 256 similar but untreated “reference” sites
  - Used to develop safety performance function required for EB
  - Used for FB to see if results differ from using 16 yoked sites
## RESULTS -- ROAD DIET EVALUATION

% reduction in crashes (and standard error)

<table>
<thead>
<tr>
<th>Number of reference sites</th>
<th>EB</th>
<th>FB</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 (yoked)</td>
<td>Not done</td>
<td>53% (1%)</td>
</tr>
<tr>
<td>296</td>
<td>47% (2%)</td>
<td>49% (1%)</td>
</tr>
</tbody>
</table>
## RESULTS
Evaluation of 28 rural traffic signal installations

% reduction in crashes (and standard error)

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>FB Approach</th>
<th>EB Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>22% (6%)</td>
<td>16% (6%)</td>
</tr>
<tr>
<td>Rear-end</td>
<td>-27% (23%)</td>
<td>-26% (27%)</td>
</tr>
<tr>
<td>Right-angle</td>
<td>79% (3%)</td>
<td>72% (5%)</td>
</tr>
<tr>
<td>Left-turn</td>
<td>52% (6%)</td>
<td>49% (7%)</td>
</tr>
</tbody>
</table>
CONCLUSIONS – EB/FB COMPARISON

- FB is quite complicated and only worth the effort if:
  - Reference sample is too small to develop reliable safety performance functions
  - Reference data are spatially correlated
  - Informative priors available
  - Good Ph.D. students are available
My vision for the future of road safety management

- Road safety as public health issue
  - Research funding/interest from Health Institutes
  - Publications in public health journals

- Interdisciplinary/multidisciplinary approaches
  - Accommodation in all road engineering disciplines
  - Canadian multidisciplinary examples
    - Network Centre of excellence: AUTO21
    - Fatigue related accidents.. Canadian Institutes for Health Research

- International cooperation
  - Research transferability – Is it possible?
    - E.g., transferability of accident prediction models

- High level research using microscopic and related data
  - SHRPII
  - Surrogate measures