Introduction to Crash Analysis

Prepared by
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Northwestern University
Center for Public Safety

Introduction to Highway Safety Series

Course Modules provided:

• History, Perspectives and Institutionalization of Traffic Safety in the United States
• The Es of Safety
• Introduction to Traffic Safety Data
• Introduction to Transportation Safety Planning
• Introduction to Human Factors
• Introduction to The Road Environment
• Introduction to Safety Evaluation: Part I
• Introduction to Safety Evaluation: Part II
• Introduction to Crash Analysis
Housekeeping

• Be prepared to respond to polls.

• All participant phone lines are muted to avoid distractions during presentations.

• If you have technical difficulties contact Genesys help desk by press *10* on your phone or dial 1-800-305-5208.

• Questions can be asked via the Chat Room.

Earn Course Credit

Successful completion of this Web seminar includes:
• Verification of attendance
• Completion of course evaluation
• Verification of learning objectives (online quiz)

These requirements must be met to earn 1.5 PDH or .2 IACET CEU per course.

At the conclusion of the course you will receive an email with directions to the online quiz and course evaluation (an additional fee may apply)
Instructor

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Learning Objectives

• Identify the elements of a successful highway safety program.

• Select an appropriate method of identifying hazardous locations.

• Apply processes for analyzing high-hazard locations to deduce underlying causal factors.

• Apply process for identifying potential countermeasures
The E’s of Traffic Safety

- Engineering
- Education
- Enforcement
- Emergency Medical Services
- Environment
- Economics
- Evaluation
- Everyone

ELEMENTS OF A SUCCESSFUL HIGHWAY SAFETY PROGRAM

- Identification of problems
- Objective analysis of problems
- Development of alternative solutions
- Objective selection of solutions for implementation
- Evaluation of outcome of improvements
IDENTIFICATION OF HAZARDOUS LOCATIONS

- Higher Than Expected Frequency, Rate, or Severity of Crashes
  - Spots
  - Intersections
  - Sections
  - Systems
- High-Hazard Locations are Not Necessarily High-Crash Locations
ANALYSIS OF SPOT LOCATIONS AND EXTENDED LENGTHS OF ROADWAY

• Spot locations are short segments of highway such as intersections or bridges, or short segments 0.2 or 0.3 miles long
• Roadway sections are longer, homogeneous length of highways; typically 1 or more miles in length
• “Floating” spots or sections help to capture all crashes at a high-hazard location that may have imprecise location coding

IDENTIFYING HIGH-HAZARD LOCATIONS

• Crash Frequency
• Crash Rate
• Number-Rate
• Rate Quality Control
• Crash Severity
• Bayesian Methods
• Expected Value Analysis
Audience Participation

What are some of the advantages and disadvantages you have found in using these techniques?

Share answer/comments in the chat room

CRASH FREQUENCY

• Rank all locations by the total number of crashes or number of crashes per mile

• Advantages
  – Simple, makes intuitive sense
  – Logical approach if goal is reducing the total number of crashes

• Disadvantages
  – Does not consider exposure
  – Bias toward high-volume locations
### RANKING BY CRASH FREQUENCY

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Number of Crashes</th>
<th>Ranking by Frequency</th>
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<tbody>
<tr>
<td>A</td>
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</table>

### RANKING BY CRASH FREQUENCY

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CRASH RATES

- Risk of crashes is often a more useful method of ranking locations.
- Risk or hazard is expressed as crash rate
- Requires traffic volume data (AADT) for all roadways

CRASH RATES: ROADWAY SEGMENTS

Crashes per 100 million vehicle miles (km)

\[
R_{SEC} = \frac{C \times 10^{8}}{365 \times T \times V \times L}
\]

- \(R_{SEC}\): crash rate for the roadway section
- \(C\): number of reported crashes
- \(T\): time period of the analysis (years)
- \(V\): annual average daily traffic volume (veh/day)
- \(L\): length of the segment (mi or km)
CRASH RATES: INTERSECTIONS

Crashes per million entering vehicles

\[ R_{SPOT} = \frac{C \times 10^6}{365 \times T \times V} \]

- \( R_{SPOT} \) = crash rate for the spot
- \( C \) = number of reported crashes
- \( T \) = time period of the analysis (years)
- \( V \) = annual average daily traffic volume entering the spot (veh/day)

RANKING BY CRASH RATES

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Number of Crashes</th>
<th>Ranking by Frequency</th>
<th>Crash Rate (MEV)</th>
<th>Ranking by Crash Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9</td>
<td>6</td>
<td>11.8</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>5</td>
<td>6.6</td>
<td>2</td>
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<td>3.1</td>
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LIMITATIONS OF CRASH RATES

- Bias in favor of identifying low-volume locations
- May not identify locations with the greatest potential for crash reduction relative to available resources
- Need traffic volume data
  - Without volume data, may be able to group locations by functional classification

NUMBER-RATE METHOD

- Combines Crash Frequency and Crash Rate methods
- First step is to rank all locations by number of crashes
- Establish cut-off number of crashes and eliminate locations with fewer crashes
- Re-rank remaining locations by crash rate
- Establish cut-off rate and eliminate locations with lower rate
### PRELIMINARY RANKING BASED ON CRASH FREQUENCY

(CUTOFF CRASH FREQUENCY = 10 CRASHES)

<table>
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<th>Crash Rate (/MEV)</th>
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### FINAL RANKING BASED ON CRASH RATE

(CUTOFF CRASH RATE = 3.5 CRASHES/MEV)

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INCLUDING SEVERITY IN CRASH RATES

- Equivalent Property Damage Only (EPDO) Rate
- Gives greater weight to more severe crashes
- Convert injury and fatal crashes to equivalent property damage only crashes

\[
R_{EPDO} = \frac{(F \times W_F + I \times W_I + PDO) \times 10^6}{N \times 365 \times V}
\]

- \(F\) = number of fatal crashes
- \(I\) = number of injury crashes
- \(PDO\) = number of property damage only crashes
- \(W_F\) = weighting factor for fatal crashes
- \(W_I\) = weighting factor for injury crashes
• Some locations may be identified as high-hazard due to normal, random fluctuations in crashes from year to year
• The random changes in crashes from one year to the next is sometimes called “regression to the mean”
• Rate Quality Control method applies a statistical test to maximize the probability that only “truly” hazardous locations are identified.

For each intersection or section, compute the critical crash rate, $R_c$; also compute the actual crash rate for that location $R_{ACT}$
• If $R_{ACT} > R_c$ then the location is deemed hazardous at the selected level of confidence
RATE QUALITY CONTROL

\[ R_C = R_A + k \sqrt{\frac{R_A}{M}} + \frac{1}{2M} \]

- \( R_C \): Critical Crash Rate (/MEV OR /100MVM)
- \( R_A \): Average Crash Rate for Similar Locations
- \( k \): Level of Confidence Factor
- \( M \): Volume of Traffic (same units as \( R_C \) and \( R_A \))

<table>
<thead>
<tr>
<th>Level of Confidence</th>
<th>( k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td>1.282</td>
</tr>
<tr>
<td>95%</td>
<td>1.645</td>
</tr>
<tr>
<td>99%</td>
<td>2.327</td>
</tr>
</tbody>
</table>

Hazardous locations can be ranked using a “Safety Index” (SI)

\[ SI = \frac{R_{ACT}}{R_C} \]

- Locations with a Safety Index > 1.0 are ranked with the highest SI given highest priority
BAYESIAN METHODS

• Bayesian procedures combine the crash frequency predicted by a crash prediction model ($N_p$) with crash frequency from site specific crash history data ($N_A$)

• Expected crash frequency considers both the predicted and observed crash frequency:

$$E_p = w(N_p) + (1-w)N_A$$

Where $E_p = \text{expected crash frequency}$

$N_p = \text{number of crashes predicted}$

$N_A = \text{number of crashes observed}$

$w = \text{weighting factor}$

---

BAYESIAN METHODS

• U.S. DOT Crash Prediction Model for highway railroad grade crossings

• Crash prediction is expressed as:

$$A = C\left[\frac{T_o}{T_o + T}(a) + \frac{T}{T_o + T} \left(\frac{N}{T}\right)\right]$$

$A = \text{Final crash prediction (crashes per year at crossing)}$

$C = \text{Normalizing constant}$

$a = \text{initial crash prediction from basic formula}$

$N/T = \text{historical crashes per year at crossing where N is number of observed crashes in T years.}$

$T_o = \text{Weighting factor, where } T_o = 1.0/(0.05 + a)$
POTENTIAL FOR SAFETY IMPROVEMENT

• “Potential for Safety Improvement” (PSI) is the difference between a location’s actual crash frequency and the expected frequency for all locations with similar classification ($N_p$)
• The location with the largest potential safety improvement (crash reduction) would be ranked highest.

EXPECTED VALUE ANALYSIS

• Used to identify abnormal crash patterns.
• Statistical test used to determine whether a crash pattern at a location is significantly higher than the same crash pattern at all similar locations within the jurisdiction
• The mean and standard deviation of each crash characteristic are calculated and used to estimate the upper limit for normal occurrences (such as the 90th or 95th percentile)
Audience Poll

What methods/techniques have you used most frequently?

CHOOSING A METHOD

• No single method of identifying high-hazard locations is universally superior
• Select a method based on availability of data and degree of sophistication needed
• Where possible, use more than one method and compare results
HIGHWAY SAFETY ENGINEERING STUDIES

- Analyze Data to Determine Crash Patterns
- Analyze Contributing Circumstances
  - Roadway Geometrics
  - Traffic Control Devices
  - Traffic Operating Characteristics
  - Environmental Conditions

ANALYSIS OF HIGH HAZARD

- 3 years of crash data are desirable
- Summarize by crash type
- Summarize by environmental conditions
  - rain, snow, day versus night, etc.
- Prepare “collision diagram”
ANALYSIS OF HIGH-HAZARD

Patterns:

• Left-Turn/Head On
• Right Angle
• Rear-End
• Sideswipe
• Pedestrian
• Bicycle

• Run-Off-The Road
• Fixed Object
• Head-On
• Parked Vehicle
• Animal
• Others

COLLISION DIAGRAM

• Direction of Travel and Intended Maneuvers
• Non-Contact Vehicles Involved
• Date, Day of Week and Time of Day
• Unusual Conditions
Can you identify the dominant crash patterns in the previous Collision Diagram?

(See Student Supplement for diagram)

Share answer/comments in the chat room
POTENTIAL FIELD STUDIES

- Speeds
- Volumes
- Sight distance
- Skid resistance
- Traffic conflicts analysis
- Traffic control device visibility
- Traffic control device compliance
- Curve design speed
IDENTIFYING COUNTERMEASURES

Potential countermeasures may be identified through:

- Detailed investigations of crashes to identify causal factors
- Reviews of site plans and condition diagrams
- Site inspections
- The practices and previous experiences of the agency

POTENTIAL COUNTERMEASURES

Right-angle Collisions at 2-Way Stop-Controlled Intersections

<table>
<thead>
<tr>
<th>Potential Causal Factor</th>
<th>Possible Countermeasure</th>
</tr>
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<tbody>
<tr>
<td>Restricted sight distance</td>
<td>Remove sight obstruction</td>
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<tr>
<td></td>
<td>Restrict parking near intersection</td>
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<tr>
<td></td>
<td>Provide all-way stop or signal</td>
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<td></td>
<td>Install/improve warning sign</td>
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<td></td>
<td>Install stop line closer to cross road</td>
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<tr>
<td>Excessive speed</td>
<td>Install/improve warning sign</td>
</tr>
<tr>
<td></td>
<td>Reduce speed limit with enforcement</td>
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<tr>
<td></td>
<td>Install rumble strips</td>
</tr>
<tr>
<td>Inadequate roadway lighting</td>
<td>Improve lighting</td>
</tr>
<tr>
<td>Inadequate advance warning signs</td>
<td>Install or improve warning sign</td>
</tr>
<tr>
<td>Large traffic volume</td>
<td>Provide traffic signal</td>
</tr>
<tr>
<td></td>
<td>Reroute traffic</td>
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<tr>
<td>Inadequate traffic control devices</td>
<td>Upgrade traffic control devices</td>
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<td></td>
<td>Increase enforcement</td>
</tr>
</tbody>
</table>

Source: Manual of Transportation Engineering Studies, ITE 2000
IDENTIFYING POTENTIAL COUNTERMEASURES

• Countermeasure(s) Must Address Problems, not Symptoms
• Countermeasure Should Provide Greatest Benefits Relative to Costs
• Full Range of Alternatives Should Be Considered
  – Engineering
  – Enforcement
  – Education

NEXT STEP

• Estimate crash reduction potential for each candidate countermeasure
• Estimate other benefits and costs
• Evaluate cost-effectiveness of alternative countermeasures to identify desirable projects for implementation
Audience Participation

What is the source of information needed to determine the crash reduction potential of candidate countermeasures?

Share answer/comments in the chat room

REFERENCES

• Traffic Operations Practitioner Specialist Certification Program Refresher Course, ITE, January 2007
• Manual of Transportation Engineering Studies, ITE, 2000
• Fundamentals of Traffic Engineering, Institute of Transportation Studies University of California Berkeley, 2001
Questions

• Enter questions/comments in the chat room. Your question will be answered in the order it was received.

Or

• Press the star button * on your phone to ask the instructor a question. Your phone line will be un-muted.

Thank You

Please provide your feedback. A link to an online Web seminar evaluation and quiz will follow in an e-mail to Web seminar registrants. Please distribute this email to participants at your site. The quiz and survey will close in ONE week.

Questions/Comments
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