Crash Risk Factors for Low-Volume Roads: an ODOT Case Study

Presented by: Levi Ewan, Western Transportation Institute at MSU Bozeman
Webinar Logistics

• Duration is 11:00 AM - 12:30 PM Mountain

• Webinar – recorded and archived on website. For quality of recording, phone will be muted during presentation

• If listening on the phone, please mute your computer

• To maximize the presentation on your screen click the 4 arrows in the top right of the presentation

• At the end of each section, the phones will be opened up to allow for Q&A

• Please complete follow-up surveys; they are vital to assessing the webinar quality
Today’s Presenter

Levi Ewan, P.E.
Western Transportation Institute
Montana State University

Experience:
• Masters in CE
• 7 years transportation research experience
• Safety & Operations focus
Goals of this Webinar

Once you have completed this webinar, you will be:

- Familiar with a new methodology, tool, and case study used to determine crash risk on low-volume road segments using road geometry and roadside features.
- Familiar with low-cost safety countermeasures used to address potentially risky features on low-volume roads.
To achieve the webinar goal, you will learn to:

- Identify road geometry characteristics and roadside features that may correspond to increased crash risk.
- Select certain road characteristics that influence a resulting crash risk using the Oregon risk index developed in the project.
- Identify low-cost safety countermeasures that may be most applicable to low-volume roads.
- Identify how this approach could be reproduced and/or tailored for participant’s agency.
Identify road geometry characteristics and roadside features that may correspond to increased crash risk.

Select certain road characteristics that influence a resulting crash risk using the Oregon risk index developed in the project.

Identify low-cost safety countermeasures that may be most applicable to low-volume roads.

Identify how this approach could be reproduced and/or tailored for participant’s agency.
Crash Risk Factors and Low-Volume Roads

- Project Background and Need
  - Crashes are rare and random
  - More traffic : more crashes
  - More traffic : more improvement funding
  - Risk identification challenges on low-volume roads
  - High crash location vs. hazardous locations
## Crash Risk Factors and Low-Volume Roads

### National Fatality Rates by Road Class

<table>
<thead>
<tr>
<th>Class</th>
<th>Fatalities</th>
<th>VMT (Billions)</th>
<th>Rate (100MVMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14,987</td>
<td>2,046.41</td>
<td>0.73</td>
</tr>
<tr>
<td>Interstate</td>
<td>2,088</td>
<td>505.31</td>
<td>0.41</td>
</tr>
<tr>
<td>Other Arterial</td>
<td>8,550</td>
<td>1,068.93</td>
<td>0.80</td>
</tr>
<tr>
<td>Collector</td>
<td>1,101</td>
<td>188.55</td>
<td>0.58</td>
</tr>
<tr>
<td>Local</td>
<td>3,231</td>
<td>283.63</td>
<td>1.14</td>
</tr>
<tr>
<td><strong>Rural</strong></td>
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<td></td>
</tr>
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FARS and USDOT Highway Statistics Data 2013
# Crash Risk Factors and Low-Volume Roads

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FARS and USDOT Highway Statistics Data 2013
Crash Risk Factors and Low-Volume Roads

• Road characteristics that may affect crash risk
  – Alignment
    • Horizontal and vertical curves, sight distance
  – Cross Section
    • Lane and shoulder width and type, edge drop, pavement surface condition
  – Roadside
    • Fixed objects, side slopes, ditches, guardrail
  – Other
    • Intersections, driveways, land use, terrain, traffic volume, traffic speed, signing and marking
Crash Risk Factors and Low-Volume Roads

• ODOT Project Goals
  – Quantify crash risk for low-volume road segments in Oregon.
  – Develop crash risk index that can be used to proactively screen for risky locations.
  – Determine most promising low-cost safety countermeasures to address risky locations.
Directing Your Questions via the Chat Pod

1. Chat pod is on left side of screen between attendees pod & closed caption pod

2. Type your question or comment here

3. Answers will appear here unless addressed verbally
Identify road geometry characteristics and roadside features that may correspond to increased crash risk.

Select certain road characteristics that influence a resulting crash risk using the Oregon risk index developed in the project.

Identify low-cost safety countermeasures that may be most applicable to low-volume roads.

Identify how this approach could be reproduced and/or tailored for participant’s agency.
Oregon Risk Index Development

Process:

• Data Collection
  – Sample selection, data sources

• Data Analysis
  – Road characteristics, overall crash statistics, road char. – crash rate relationships

• Risk Index Development
  – Geometric and roadside features, crash history, traffic exposure

• Real-World Example
Oregon Risk Index Development

See final report if needed:

http://ruralsafetycenter.org/resources/list/risk-factors-associated-with-high-potential-for-serious-crashes/
Sample Selection

- Target of 600 – 800 miles for large sample
- Various geographies
- State owned roads with AADT < 1000 vpd

- Final sample 680.85 miles
  - Segments only (intersections removed)
  - 48% “western”; 52% “eastern”
- All 2-lane, 2-way road
- All speed limits 55 MPH

[Map Source: Google Maps]
Data Sources

• ODOT Databases
  – Lane type & width, shoulder type & width, grade, horiz. degree of curve and length, vert. curve type and length

• ODOT Video Log Review
  – Driveway density, side slope rating, fixed objects near the roadway

• ODOT Crash Data
  – Lat./long., date, time, collision type, severity, etc.

• ODOT Traffic Volume
  – AADT
Data Sources

- Data collected at 0.05 mi (264 ft) resolution
- 10 years of crash data
- 10 years of traffic volume

- $680.85 \text{ mi} \times 0.05 \text{ mi res.} = 13,620 \text{ rows}$
- $62 \text{ column of road & crash data} = 844,440 \text{ cells}$
Data Analysis

General Road Characteristics

Lane Width
- 9 ft, 4%
- 10 ft, 10%
- 11 ft, 22%
- ≥ 12 ft, 64%

Shoulder Width
- 0 ft, 20%
- 1 ft, 10%
- 2 ft, 18%
- 3 ft, 18%
- 4 ft, 19%
- 5 ft, 7%
- 6 ft, 3%
- ≥ 7 ft, 5%
Data Analysis

General Road Characteristics

AADT Range

- 800-899, 8%
- 700-799, 4%
- 600-699, 13%
- 500-599, 13%
- 400-499, 25%
- 300-399, 20%
- 200-299, 12%
- 900-1000, 3%
- < 200, 8%

Driveway Density (driveways per mile)

- 0, 18%
- 1, 22%
- 2, 18%
- 3, 12%
- 4, 8%
- 5, 6%
- 6, 4%
- \( \geq 7, 12\% \)
Data Analysis

General Road Characteristics

**Fixed Object Rating**
- Few, 67%
- Few/Some, 14%
- Some, 13%
- Some/Many, 5%
- Many, 2%

**Side Slope Rating**
- Flat, 19%
- Flat/Mod., 28%
- Moderate, 39%
- Mod./Steep, 10%
- Steep, 3%
Data Analysis

General Road Characteristics

![Pie chart and bar chart showing degree of curvature and number of curves for Western and Eastern regions.](image-url)
Data Analysis

General Road Characteristics

Length of H. Curve (ft)
- 501-600, 4%
- > 600, 12%
- 0-100, 10%
- 401-500, 8%
- 301-400, 13%
- 201-300, 25%
- 101-200, 28%

Length of V. Curve (ft)
- 501-600, 9%
- 401-500, 3%
- > 600, 23%
- 301-400, 22%
- 201-300, 13%
- 101-200, 35%
Data Analysis

General Road Characteristics

[Pie chart showing grade distribution with percentages: 0-0.99 = 34%, 1-1.99 = 19%, 2-2.99 = 15%, 3-3.99 = 9%, 4-4.99 = 7%, ≥5 = 16%]

[Bar chart showing miles of road by grade: Western and Eastern regions, with grade percentages on the x-axis and miles on the y-axis]
Data Analysis

General Crash Characteristics

**Crash Type**
- Fixed Obj.: 55%
- Rollover: 14%
- Animal-Veh.: 13%
- Opp. Dir.: 8%
- Same Dir.: 5%
- Other: 5%

**Vehicle Involvement**
- Pass. Car: 78%
- Truck: 10%
- Motorcycle: 11%
- Other: 1%
Data Analysis

General Crash Characteristics

Crash Severity

- PDO: 45%
- INJ C: 15%
- INJ B: 28%
- INJ A: 9%
- FATAL: 3%

Driver Age

- 20 - 64: 72%
- ≥ 65: 15%
- < 20: 13%
Data Analysis

Road Characteristic – Crash Rate Relationships

Shaded = less than 5% of the sample
Data Analysis

Road Characteristic – Crash Rate Relationships

Shaded = less than 5% of the sample
Data Analysis

Road Characteristic – Crash Rate Relationships

- On Road
- Off Road

- Other
- Same Dir.
- Opposite Dir.
- Animal-Vehicle
- Rollover
- Fixed Object
Data Analysis

Road Characteristic – Crash Rate Relationships

![Bar chart showing crash rate relationships with shoulder width. The chart indicates that as shoulder width increases, the crash rate per MVMT decreases. At 0 ft shoulder width, the crash rate is 1.43, and it decreases to 0.78 at 5 ft. At 6 ft, the crash rate is 1.32, and at ≥7 ft, it is 1.06.](image)
Data Analysis

Road Characteristic – Crash Rate Relationships

![Bar chart showing crash rate per million vehicle miles traveled (MVMT) for different grades. The chart indicates that as the grade percentage increases, the crash rate per MVMT also increases. The highest crash rate is observed for grades between 4-4.99%.](chart.png)
Data Analysis

Road Characteristic – Crash Rate Relationships
Data Analysis

Road Characteristic – Crash Rate Relationships
Data Analysis

Road Characteristic – Crash Rate Relationships

![Bar Chart showing crash rate per driveway density. The y-axis represents crash rate per million vehicle miles traveled (MVMT), and the x-axis represents driveway density (driveways per mile). The chart shows crash rates ranging from 0.86 to 1.34 across different driveway densities.]
Data Analysis

Road Characteristic – Crash Rate Relationships

![Graph showing crash rate relationships based on degree of curvatures. The y-axis represents crash rate per million vehicle miles traveled (MVMT) and the x-axis represents different degree of curvatures ranging from 0.1-4.99 to ≥30.]
Data Analysis

Road Characteristic – Crash Rate Relationships

![Graph showing crash rate vs. length of V. Curve]
Risk Index

General Form

\[ CRI = W_G(x_G) + W_C(x_C) + W_T(x_T) \]

Geometric Features

Crash History

Traffic Exposure
Risk Index

General Form

- \( CRI = W_G(x_G) + W_C(x_C) + W_T(x_T) \)

- \( CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T) \)

- 45% geometric features
- 25% crash history
- 30% traffic exposure
Risk Index

\[ X_G = W_{dc}(y_{dc}) + W_{lvc}(y_{lvc}) + W_{lw}(y_{lw}) + W_g(y_g) \\
+ W_{sw}(y_{sw}) + W_{dd}(y_{dd}) + W_{ss}(y_{ss}) + W_{fo}(y_{fo}) \]

- Geometric Feature value a function of
  - \( dc \) = degree of curvature
  - \( lvc \) = length of vert. curve
  - \( lw \) = lane width
  - \( g \) = grade...
Risk Index

\[ X_G = \frac{1}{8} (y_{dc}) + \frac{1}{8} (y_{lvc}) + \frac{1}{8} (y_{lw}) + \frac{1}{8} (y_{g}) + \frac{1}{8} (y_{sw}) \]
\[ + \frac{1}{8} (y_{dd}) + \frac{1}{8} (y_{ss}) + \frac{1}{8} (y_{fo}) \]

- If all characteristics influenced crash rate equally then all 8 weights would be equal.
Risk Index

\[ X_G = 0.36(y_{dc}) + 0.30(y_{lvc}) + 0.06(y_{lw}) + 0.06(y_g) + 0.07(y_{sw}) + 0.06(y_{dd}) + 0.05(y_{ss}) + 0.04(y_{fo}) \]
Risk Index

$Y_{dc}$

![Graph showing the relationship between $Y_{dc}$ and Degree of Curvature (linear)](image)

$y = 0.020x + 0.100$

$R^2 = 0.934$
Risk Index

$y_g$

Grade (exponential)

$y = 0.510e^{0.096x}$

$R^2 = 0.628$
Risk Index

\[ CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T) \]

Geometric Features

\[ 0.36(y_{ac}) + 0.30(y_{ivc}) + 0.06(y_{lw}) + 0.06(y_g) + 0.07(y_{sw}) + 0.06(y_{ad}) + 0.05(y_{ss}) + 0.04(y_{fo}) \]

Crash History

Traffic Exposure

- Sharper H. Curves: Higher \( X_G \)
- Shorter V. Curves: Higher \( X_G \)
- Narrower Lanes: Higher \( X_G \)
- Steeper Grades: Higher \( X_G \)
- Narrower Shoulders: Higher \( X_G \)
- More Driveways: Higher \( X_G \)
- Steeper Side Slopes: Higher \( X_G \)
- More Fixed Objects: Higher \( X_G \)
Risk Index

\[ CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T) \]

Geometric Features

Traffic Exposure

Crash History

Defined by:
- Average Rate for sample
  - 1.06 / MVMT
- Critical Rate for sample
  - 2.52 / MVMT
Risk Index

\[ CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T) \]

Geometric Features
Crash History
Traffic Exposure

Defined by:
- Total volumes on the sample
- Truck traffic (ave. = 29%  std. dev. = 10%)
Risk Index

\[
CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T)
\]
Risk Index – Case Study

Risk Index Values for Highway #171

- Sliding 1 mile value
- 95% Confidence Interval
- Average
- Sliding 1 mile crash rate
Risk Index – Case Study (cont.)

- CRI risky locations not always the same as high crash locations

- Systemic Safety
  - Low-volume roads: fewer crashes
    - Hazardous locations not always same as high crash locations
Next Steps/Implementation for ODOT

ODOT (Doug Bish, Traffic Services Engineer) using project to:

• Identify critical data elements that we need to add to the collection of Fundamental Data Elements.

• Under the current setting of ODOT’s All Roads Transportation Safety (ARTS) Program ODOT does not have a separate program area for low-volume roads.
  – This research will have ODOT re-examine the need and will be helpful for network screening purposes.

• Local agencies will find it useful in assessing the risks on low-volume roads.
Summary

• Crash Risk Index
  – Proactive, network-wide, quantitative, objective, automated - no/limited site visits

• Easy to match risky locations to applicable low-cost safety countermeasures
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I found my risky locations… now what

- Low-volume roads: low-volume funding
- Low-cost treatments **NOT** low-impact treatments
Low-cost Safety Countermeasures

CMF clearinghouse:

• [http://ruralsafetycenter.org/resources/list/crash-modification-factors-clearinghouse/](http://ruralsafetycenter.org/resources/list/crash-modification-factors-clearinghouse/)

Manual for Selecting Safety Improvements on High Risk Rural Roads (for FHWA by SAIC, TTI)

Economic Analysis of Countermeasures

- **Alignment**
  - Horizontal Alignment Signs
  - Flashing Beacons
  - Chevrons
  - Post Mounted Delineators
  - Raised Pavement Markers
Economic Analysis of Countermeasures

• **Cross Section**
  - Widen Lanes
  - Widen Shoulders
  - Adding Shoulders
  - Stabilizing Shoulders
  - High Friction Surface Treatments

Countermeasure Example Images from FHWA HRRR Manual (Atkinson, et. al., 2014)
Economic Analysis of Countermeasures

- **Roadside Features**
  - Flatten Side Slopes
  - Install Safety Edge
  - Object Markers
  - Relocate Objects
  - Remove Objects

Countermeasure Example Images from FHWA HRRR Manual (Atkinson, et. al., 2014)
Economic Analysis of Countermeasures

- **Other Countermeasures**
  - Shoulder Rumble Strips / Stripes
  - Centerline Rumble Stripes
  - Edge-line Markings
  - Centerline Markings
  - Widen Edge-line Markings
  - Widen Centerline Markings

Countermeasure Example Images from FHWA HRRR Manual (Atkinson, et. al., 2014)
## Economic Analysis of Countermeasures

### – Crash Modification Factors, Crash Reduction

<table>
<thead>
<tr>
<th>Treatment (Source)</th>
<th>Setting</th>
<th>Analysis</th>
<th>Effectiveness</th>
</tr>
</thead>
</table>
| Advanced curve warning sign (38) | Statewide (curves) – KY, MO | State of practice survey | CRF for all crashes 30% (MO)  
CRF for fatal crashes 55% (MO)  
CRF for injury crashes 20% (MO)  
CRF for head-on crashes 29% (MO)  
CRF for run-off-road crashes 30% (KY, MO) |
| Chevrons, Arrow Signs, Advanced Warning Signs and Fluorescent Sheeting (b) | 89 rural two lane curves in CT and 139 rural two lane curves in WA | Empirical Bayes before and after with an average of 5.6 years before data and 5.4 years of after data | Reduced injury and fatal crashes by 18%;  
Reduced night-time crashes by 27.5%;  
Reduced lane departure night-time crashes by 25%;  
Conservative benefit to cost ratio 8.6 : 1 |
| Raised Pavement Markers (c) | 10 rural roadways (tangents and curves) in Mobile County, AL with documented high run-off-road crashes | Simple before and after with 4 years data before and 4 years data after | Total crashes reduced from 224 to 33;  
Fatalities from 7 to 0;  
Injuries from 152 to 10 |

a: (Gan, et. al, 2005)  
b: (Srinivasan, et. al., 2009)  
c: (FHWA, 2013)
# Economic Analysis of Countermeasures

- Sample crash reduction amounts

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<th>CRF</th>
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<tr>
<td>Install Safety Edge</td>
<td>6%</td>
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<tr>
<td>Improve Roadside Hazard Rating</td>
<td>6% to 33%</td>
</tr>
<tr>
<td>Install Object Markers for Objects Near the Roadway</td>
<td>16% 14% 17% 41%</td>
</tr>
<tr>
<td>Relocate Objects Near the Roadway</td>
<td>25% to 55% 25% 40%</td>
</tr>
<tr>
<td>Remove Objects Near the Roadway</td>
<td>18% to 61% 30% 50%</td>
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## Economic Analysis of Countermeasures

- Sample treatment costs

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<tr>
<th>Treatment</th>
<th>Initial Cost</th>
<th>Maintenance / Life Cycle Cost</th>
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</thead>
<tbody>
<tr>
<td>Horizontal Alignment Sign</td>
<td>$300 to $3,500 per installation</td>
<td>$1,300 / 5 years</td>
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<td>$2,400 per installation</td>
<td>$1,000 / 2 years</td>
</tr>
<tr>
<td>Chevrons</td>
<td>$600 to $7,200 per installation</td>
<td>$3,600 / 5 years</td>
</tr>
<tr>
<td>Post Mounted Delineators for Curves</td>
<td>$5,600 per installation</td>
<td>Life ≥ 10 years</td>
</tr>
<tr>
<td>Raised Pavement Markers for Curves</td>
<td>$600 per installation</td>
<td>$600 / 2 years</td>
</tr>
<tr>
<td>Dynamic Speed Feedback Display on Approach to Curves</td>
<td>$2,300 to $12,600 per installation</td>
<td>$1,000 / 2 years</td>
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## Economic Analysis of Countermeasures

### – Sample Benefit/Cost Ratios

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<th>B/C (HSM $)</th>
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<td>Horizontal Alignment Sign</td>
<td>1.64</td>
<td>1.10</td>
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<td>1.46</td>
<td>1.14</td>
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<td>Chevrons</td>
<td>1.08</td>
<td>0.84</td>
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<tr>
<td>Post Mounted Delineators for Curves</td>
<td>1.42</td>
<td>1.10</td>
</tr>
<tr>
<td>Raised Pavement Markers for Curves</td>
<td>0.85</td>
<td>0.66</td>
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<tr>
<td>Dynamic Speed Feedback Display on Curves</td>
<td>0.10</td>
<td>0.08</td>
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Economic Analysis of Countermeasures

Overall B/C ranges

< 0.5
- speed feedback sign
- high-friction surface
- widen lane/shoulder

~1 to ~2
- relocate objects
- horiz. align. sign
- beacon for curv.
- post-mount. delineator
- chevrons
- raised pavement mark.

~2 to ~4
- stabilize shoulder
- widen un-pav. shoulder
- flatten side slope
- edgeline marking/widening

~5 to ~15
- centerline marking/widening
- safety edge
- object markers

~25 to ~40
- shoulder rumble strips
- centerline rumble strips
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Developing a Crash Risk Index

• Data Available?
• Road type(s)?
  – Geography, Usage
• Crash rates by characteristic?
• Weights?
  – Geometry, Crashes, Traffic
  – Individual Characteristics
• Crash history component?
• Traffic volume component?
Risk Index

General Form

\[ CRI = W_G(x_G) + W_C(x_C) + W_T(x_T) \]

- Geometric Features
- Crash History
- Traffic Exposure
Risk Index

\[ X_G = 0.36(y_{dc}) + 0.30(y_{lvc}) + 0.06(y_{lw}) + 0.06(y_g) + 0.07(y_{sw}) + 0.06(y_{dd}) + 0.05(y_{ss}) + 0.04(y_{fo}) \]
Risk Index

\[ CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T) \]

Geometric Features

Collision History

Traffic Exposure

\[ 0.36(y_{dc}) + 0.30(y_{lvc}) + 0.06(y_{lw}) + 0.06(y_g) + 0.07(y_{sw}) + 0.06(y_{ad}) + 0.05(y_{ss}) + 0.04(y_{fo}) \]
Risk Index

\[ CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T) \]

Geometric Features

Crash History

Traffic Exposure

Defined by:
- **Average Rate for sample**
  - 1.06 / MVMT
- **Critical Rate for sample**
  - 2.52 / MVMT
### Risk Index

\[
CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T)
\]

#### Geometric Features

- Crash History

#### Traffic Exposure

<table>
<thead>
<tr>
<th>AADT (vpd)</th>
<th>Percent Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 29%</td>
</tr>
<tr>
<td>&lt; 300</td>
<td>0.20</td>
</tr>
<tr>
<td>300 – 499</td>
<td>0.40</td>
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<tr>
<td>500 – 699</td>
<td>0.60</td>
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<tr>
<td>700 – 900</td>
<td>0.80</td>
</tr>
<tr>
<td>&gt; 900</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Defined by:**
- Total volumes on the sample
- Truck traffic (ave. = 29%  std. dev. = 10%)
Risk Index

\[ CRI = W_G(x_G) + W_C(x_C) + W_T(x_T) \]
Risk Index – Case Study (cont.)

- Risk Index because hazardous locations **not always the same as** high crash locations, especially with low traffic

- Low-volume roads: low-volume funding

- Low-cost treatments **NOT** low-impact treatments
Thank you!!

- ODOT and FHWA for research funding
- ODOT Technical Panel for Guidance
  - Doug Bish, Timothy Burks, Kevin Haas, Nick Fortey, Amanda Salyer, Zahidul Siddique, Mark Joerger
- WTI Research Team
  - Dr. Ahmed Al-Kaisy, Dr. David Veneziano and student Fahmid Hossain
Directing Your Questions via the Chat Pod

1. Chat pod is on left side of screen between attendees pod & closed caption pod

2. Type your question or comment here

3. Answers will appear here unless addressed verbally
Learning Outcomes

In this webinar, you have learned to:

- Identify road geometry characteristics and roadside features that may correspond to increased crash risk.
- Select certain road characteristics that influence a resulting crash risk using the Oregon risk index developed in the project.
- Identify low-cost safety countermeasures that may be most applicable to low-volume roads.
- Identify how this approach could be reproduced and/or tailored for participant’s agency.
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National Working Summit on Transportation in Rural America

Save the Date:
September 7-9, 2016
Denver, CO

Registration now open!

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Contact Information

If you have any questions related to this webinar, please contact the instructors at:

levi.ewan@montana.edu

Or contact the Safety Center help desk at:

(844) 330-2200 or info@ruralsafetycenter.org

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