National Center for Rural Road Safety

Est. Dec. 2014

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.

Learning Outcomes

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.**

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WTI

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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

	Class	Fatalities	VMT (Billions)	Rate (100MVMT)
Urban	**Total**	**14,987**	**2,046.41**	**0.73**
	Interstate	*2,088*	*505.31*	*0.41*
	Other Arterial	*8,550*	*1,068.93*	*0.80*
	Collector	*1,101*	*188.55*	*0.58*
	Local	*3,231*	*283.63*	*1.14*
Rural	**Total**	**17,696**	**941.91**	**1.88**
	Interstate	*1,992*	*234.30*	*0.85*
	Other Arterial	*7,388*	*358.76*	*2.06*
	Collector	*4,744*	*221.22*	*2.14*
	Local	*3,469*	*127.62*	*2.72*

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

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3. Answers will appear here unless addressed verbally

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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

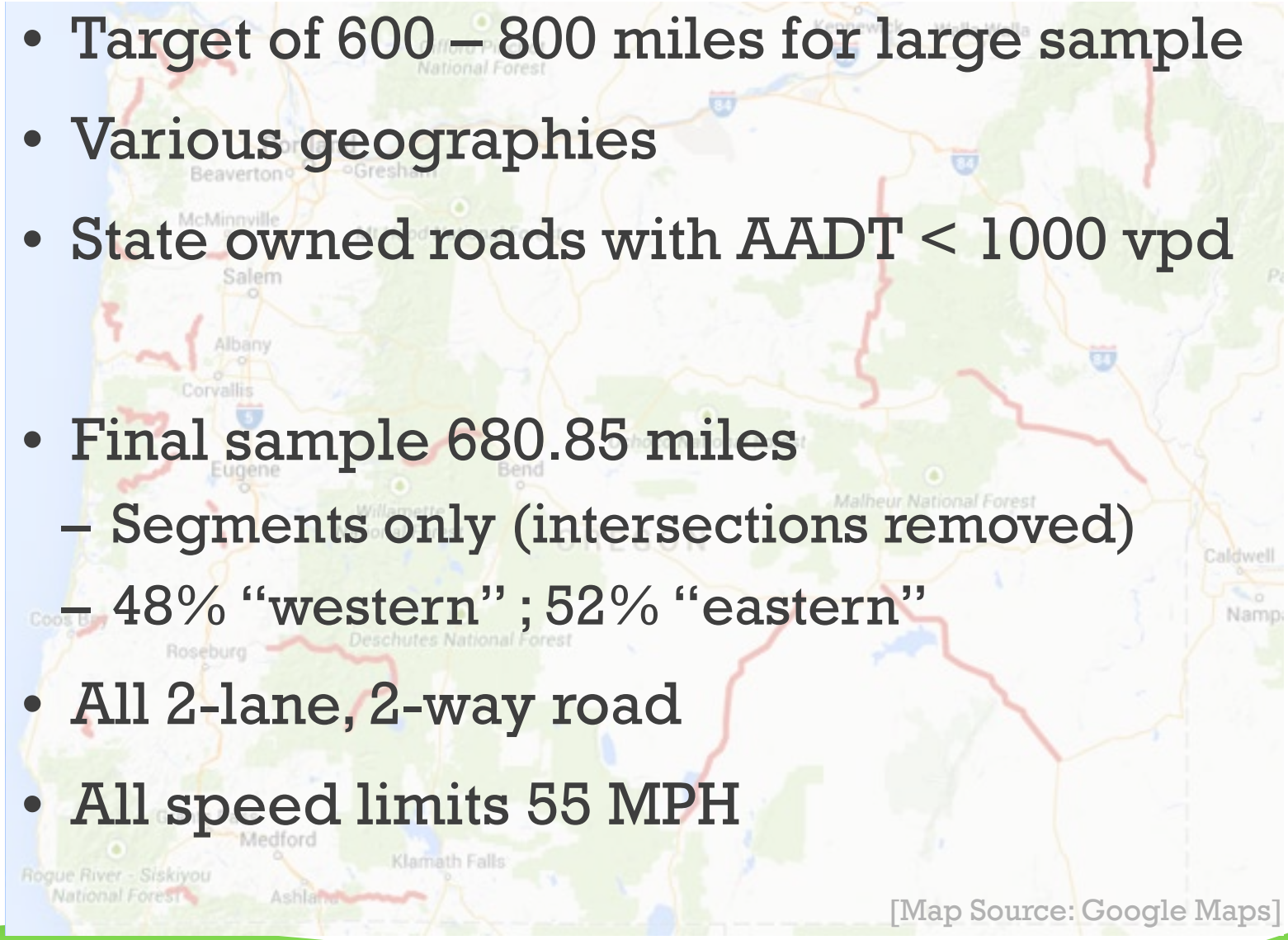
Oregon Risk Index Development

See final report if needed:

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

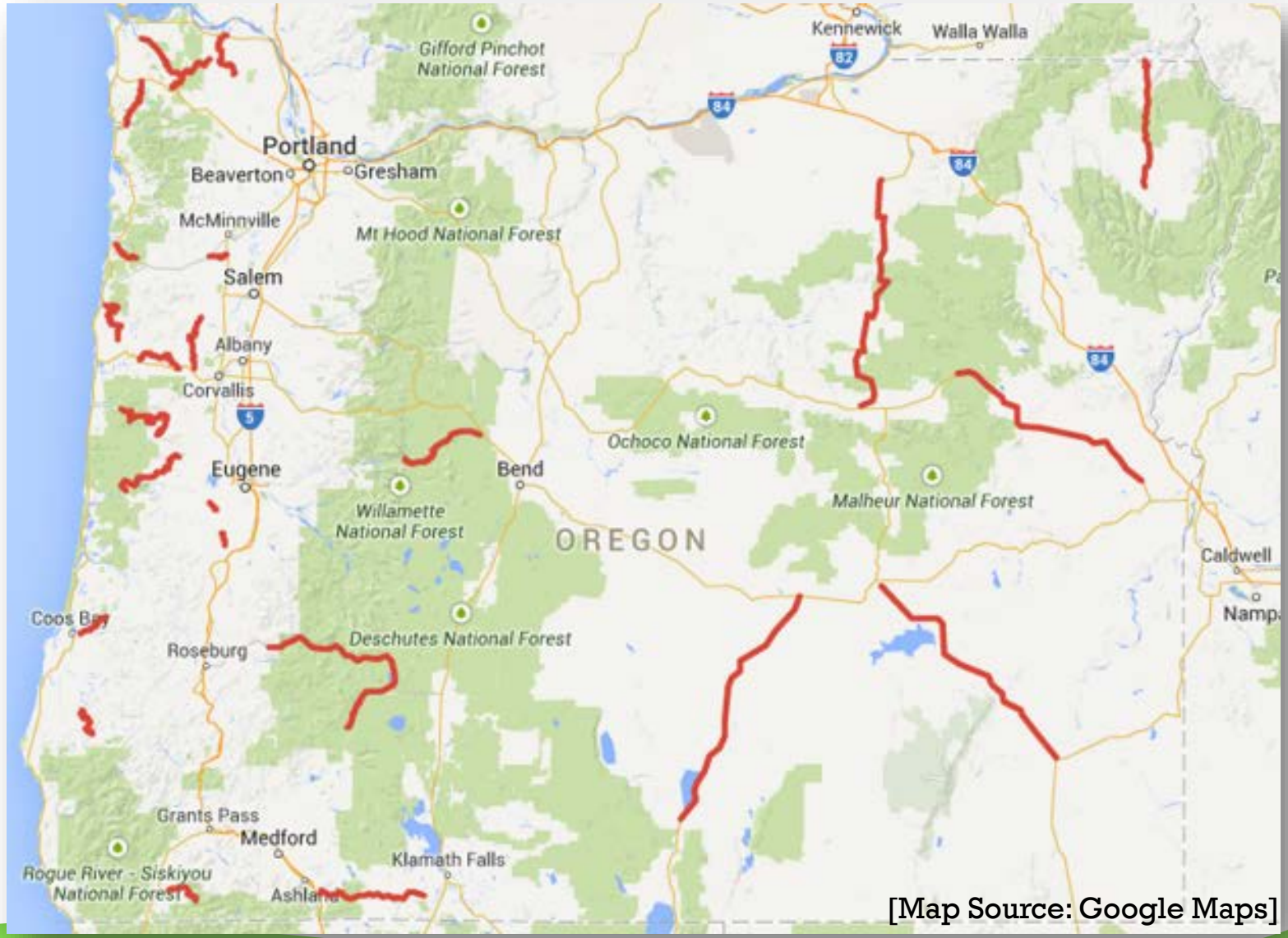
Sample Selection

- 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]

Sample Selection



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

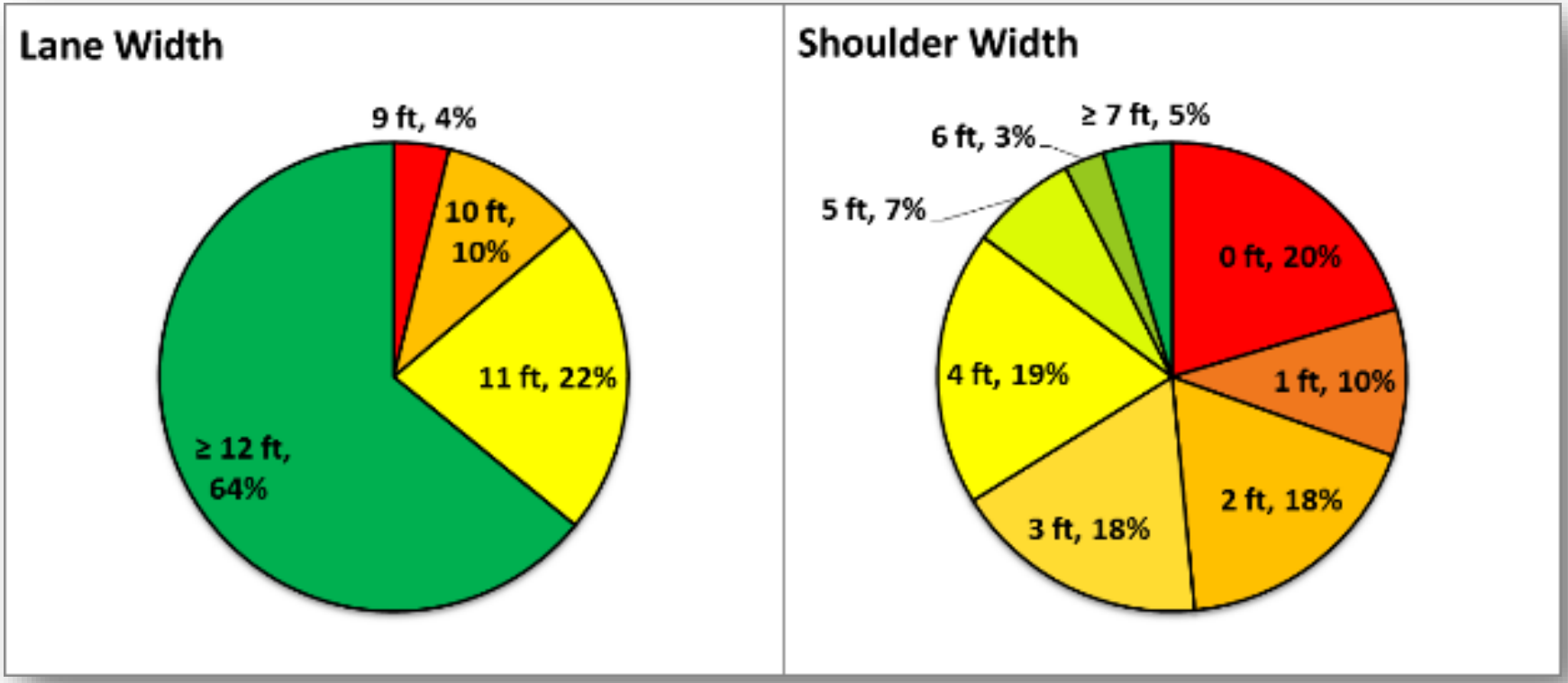
Data Sources

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

- 680.85 mi * 0.05 mi res. = 13,620 rows
- 62 column of road & crash data = 844,440 cells

Data Analysis

General Road Characteristics



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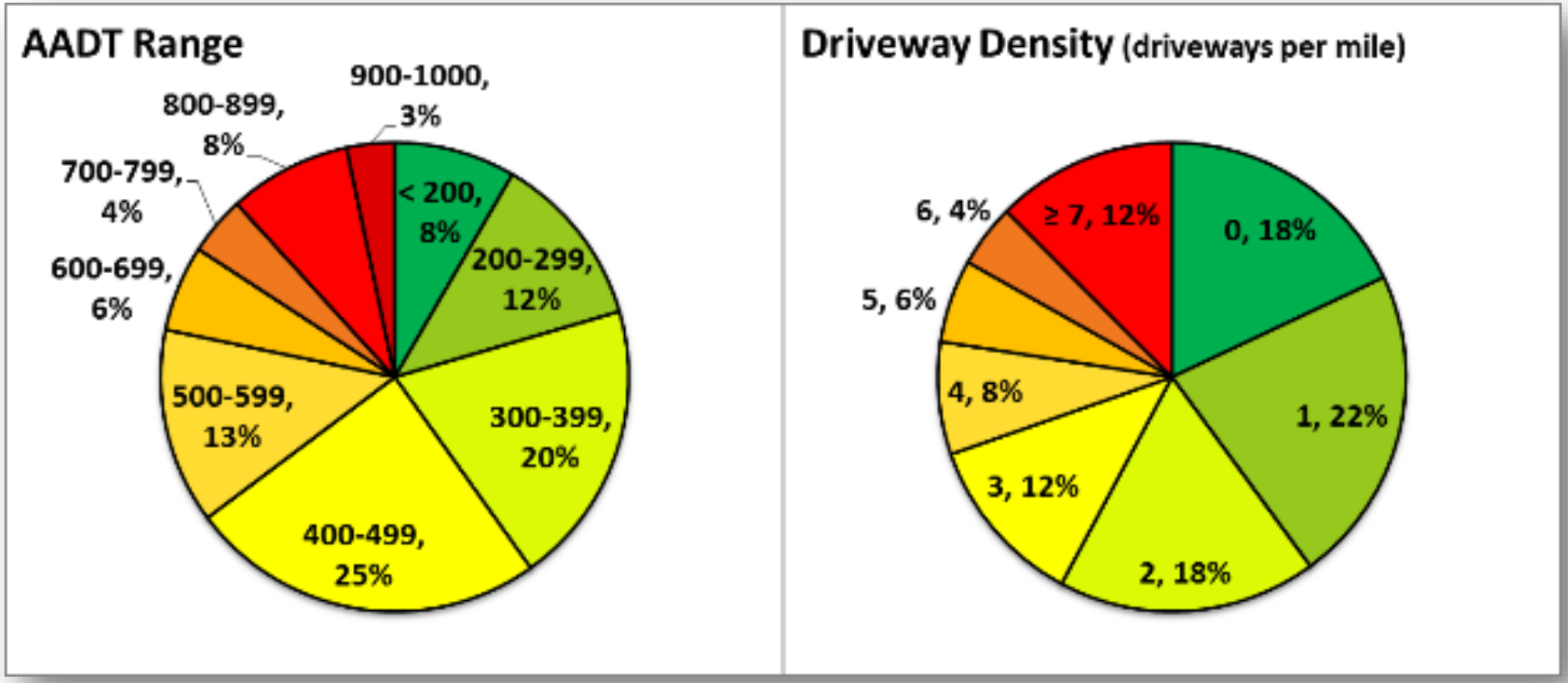

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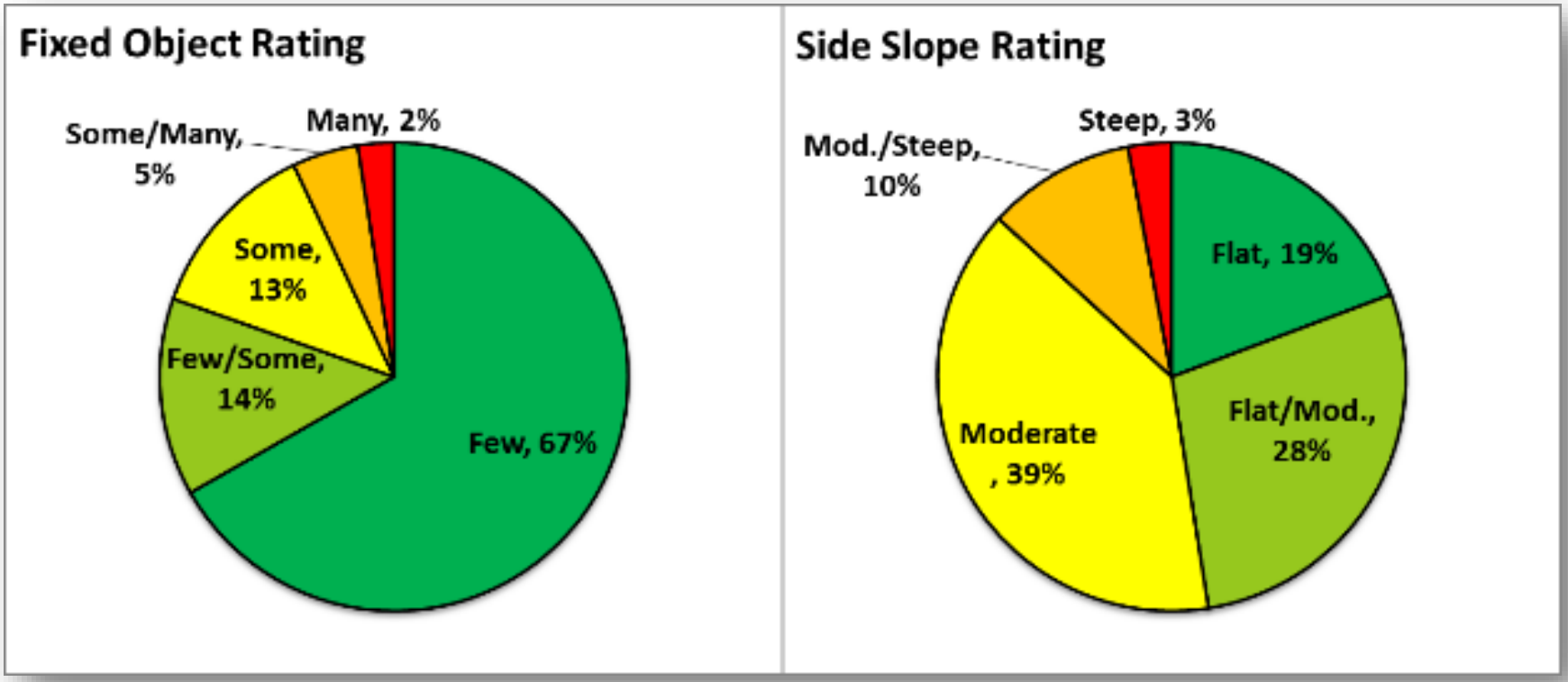

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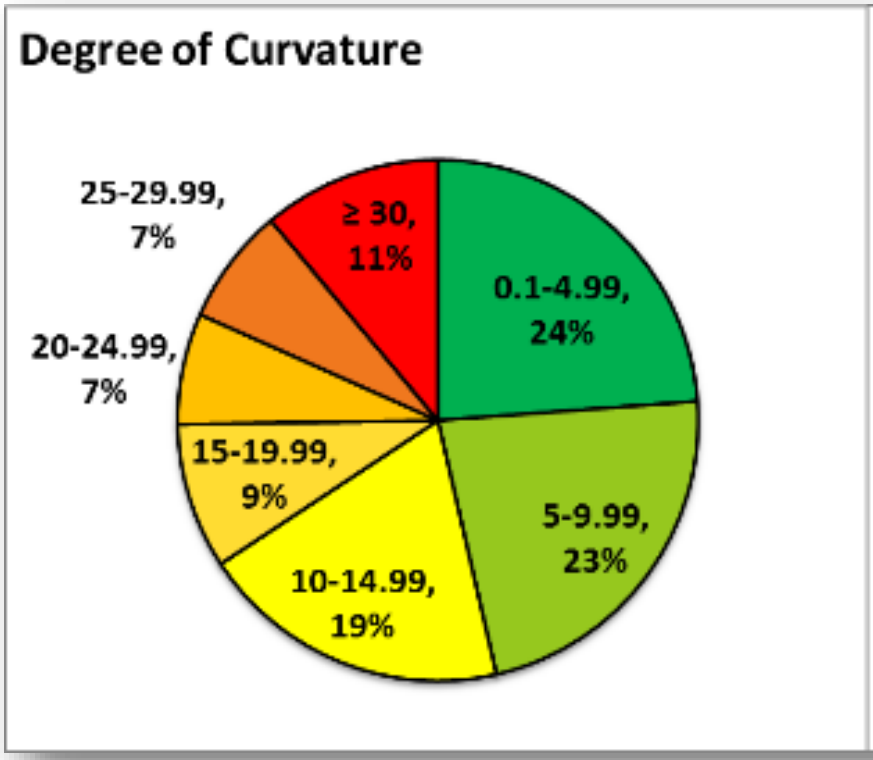

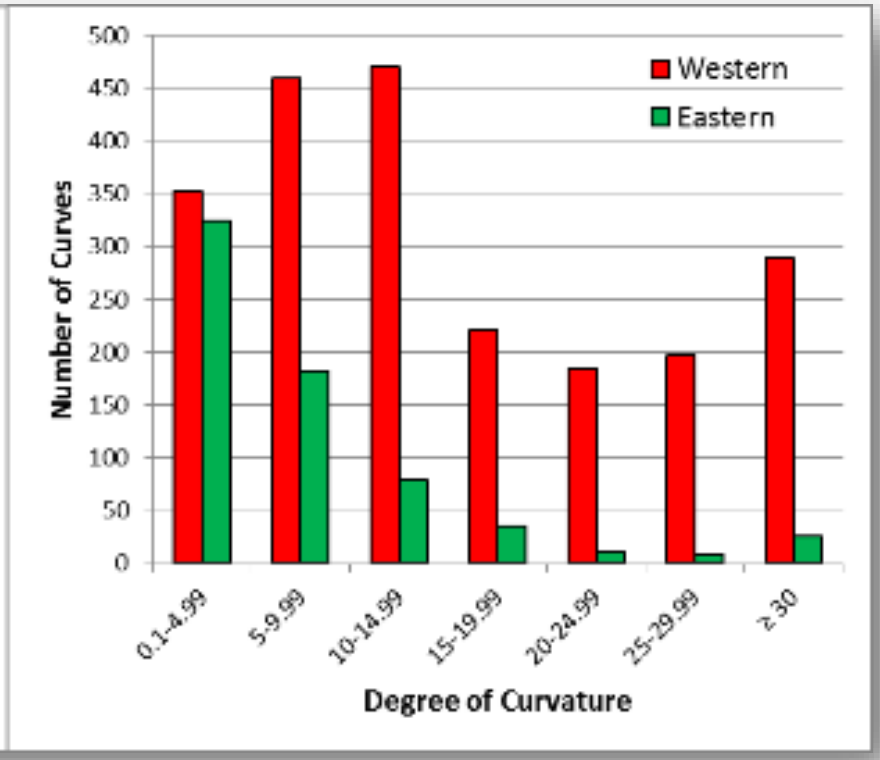

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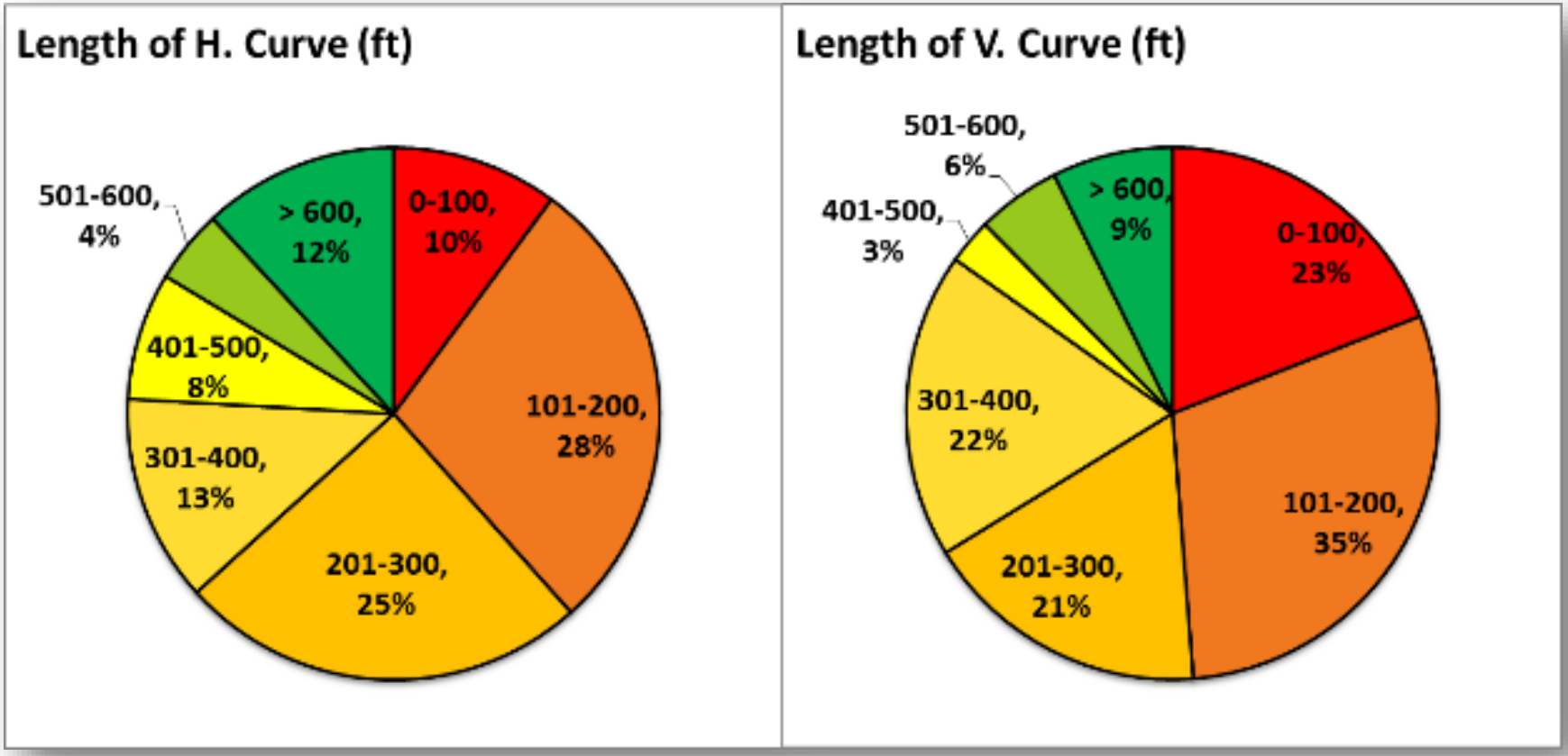

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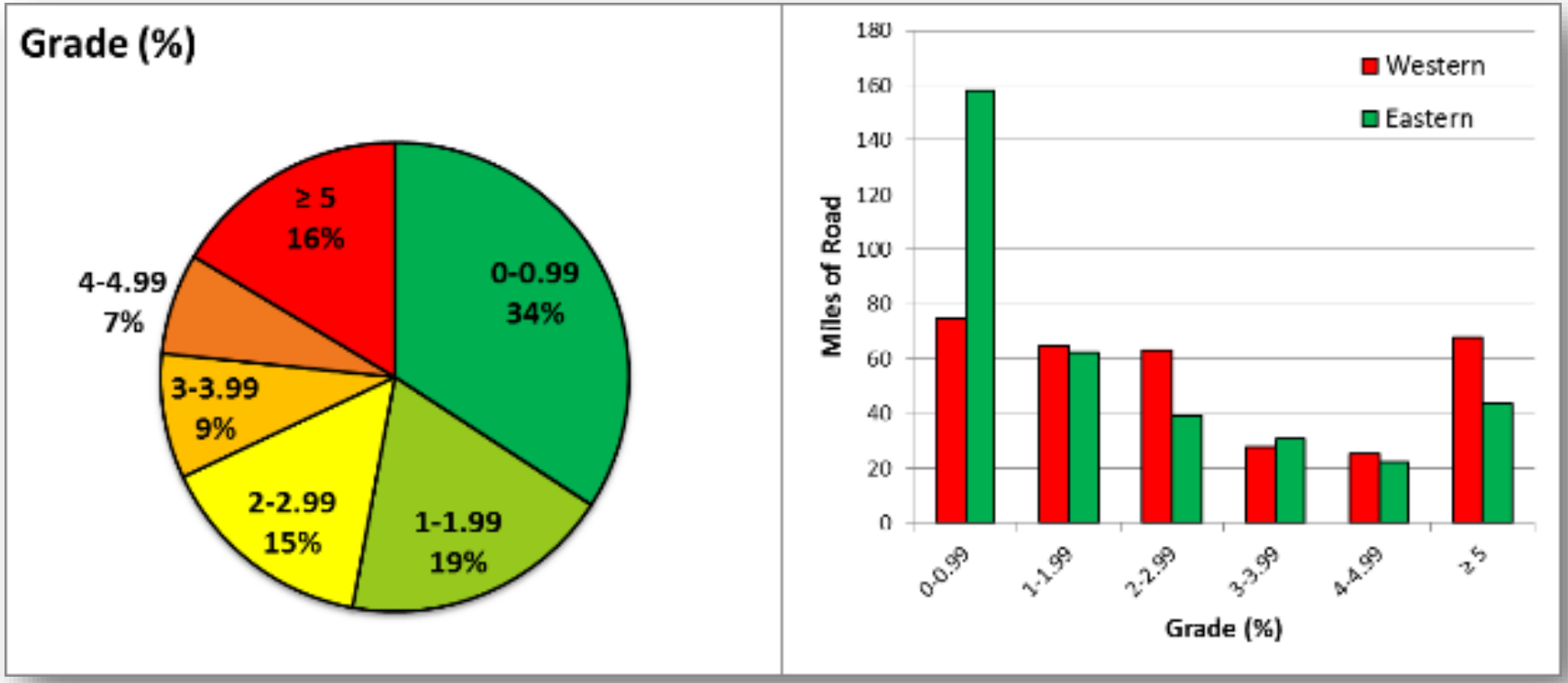
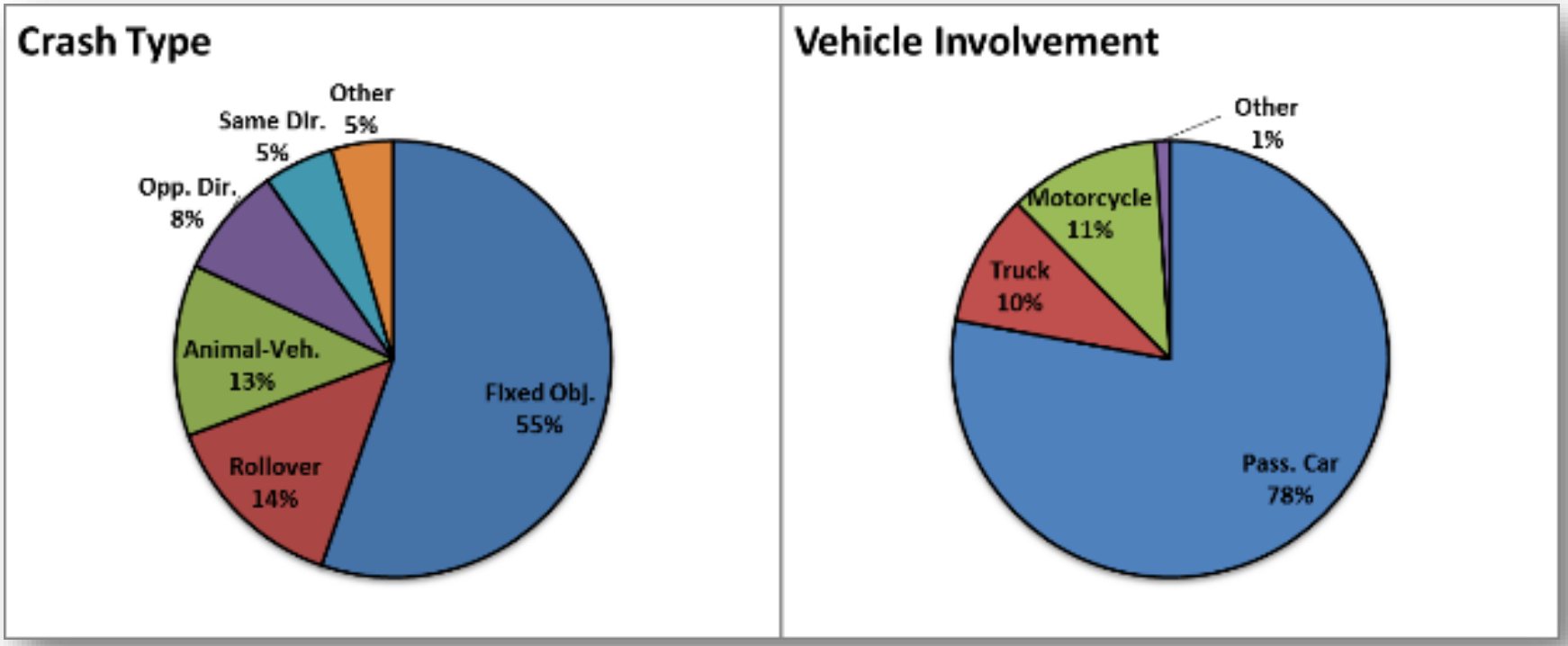


Data Analysis

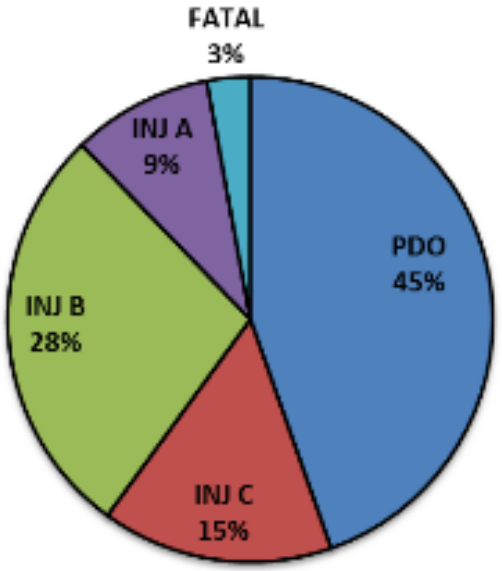
General Crash Characteristics



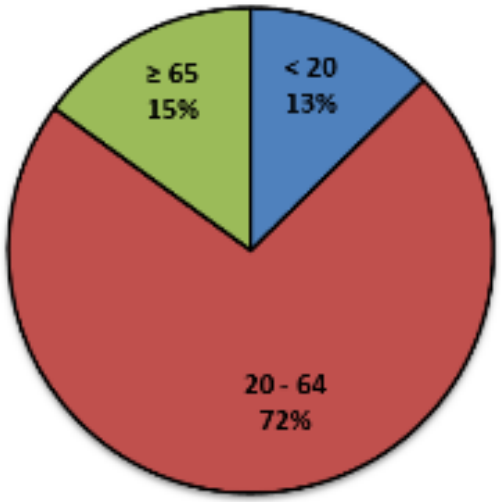
Data Analysis

General Crash Characteristics

Crash Severity

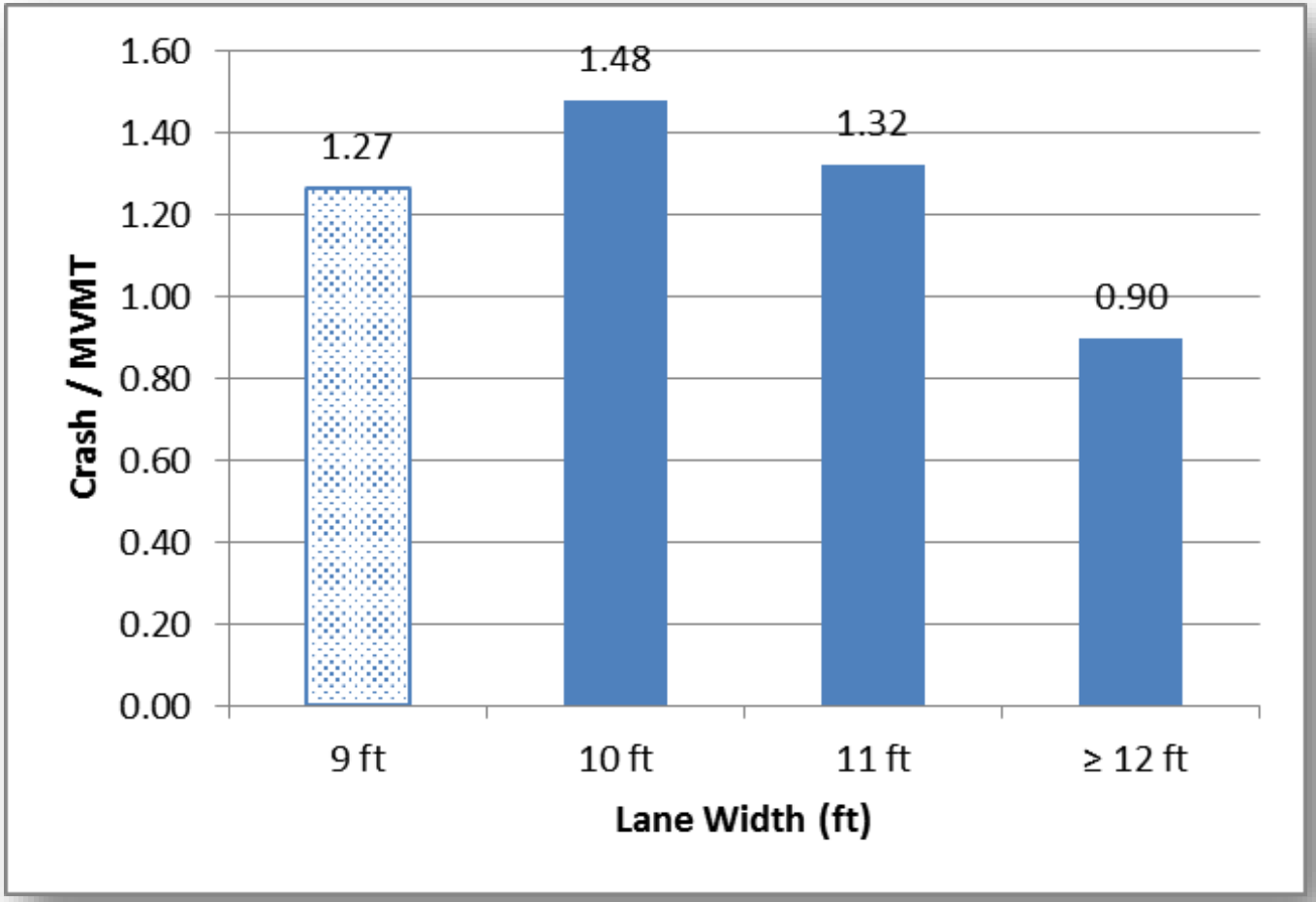


Driver Age



Data Analysis

Road Characteristic – Crash Rate Relationships



Shaded = less than 5% of the sample

Data Analysis

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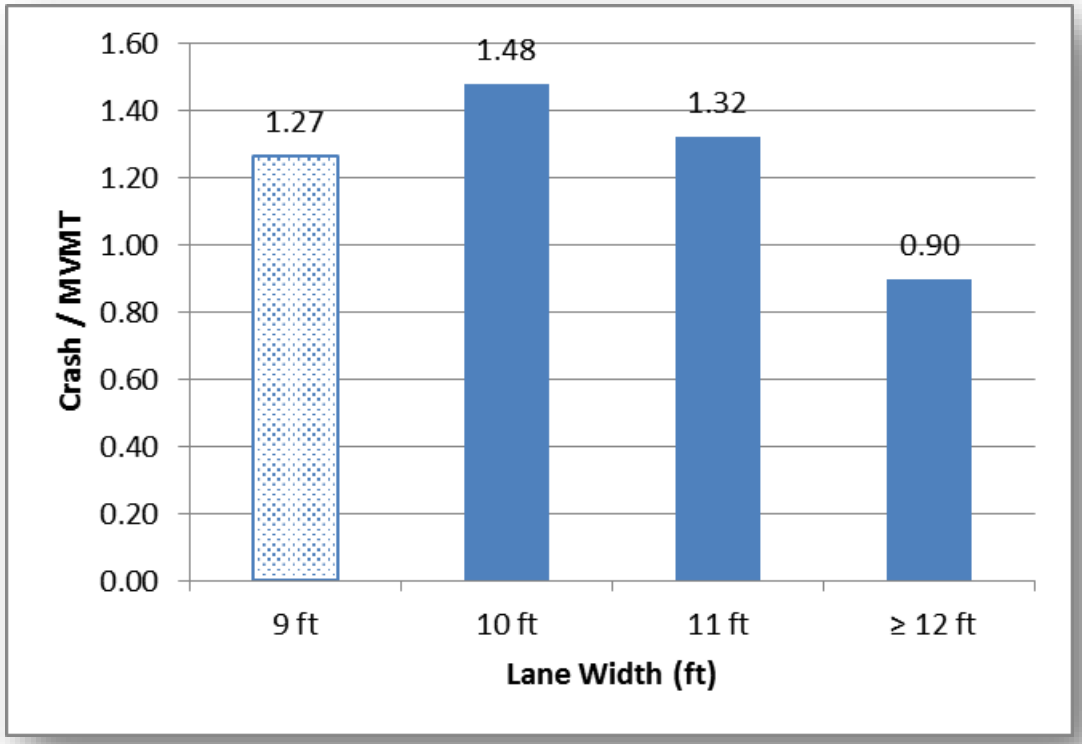

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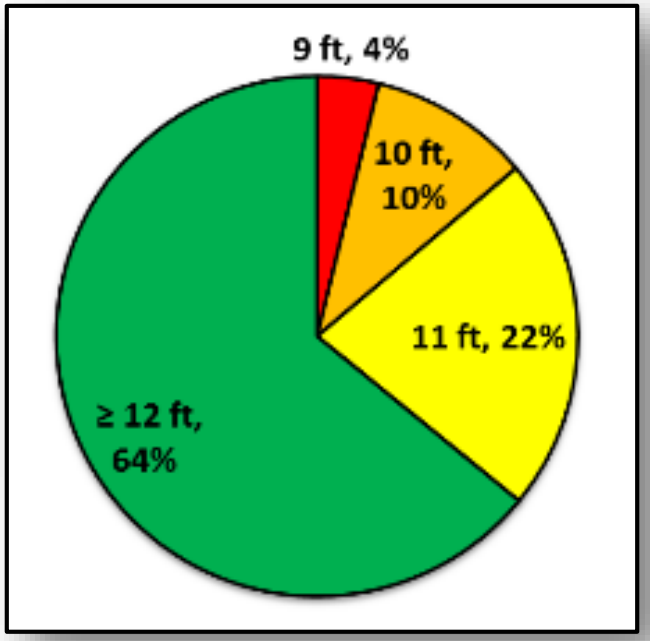

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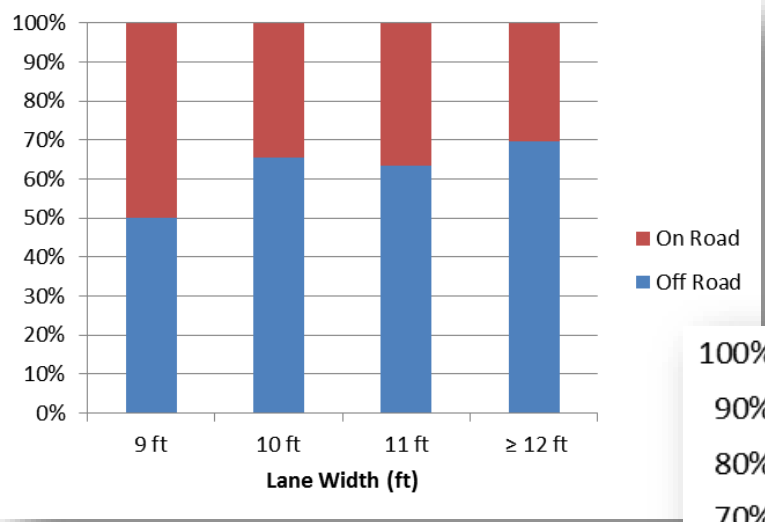

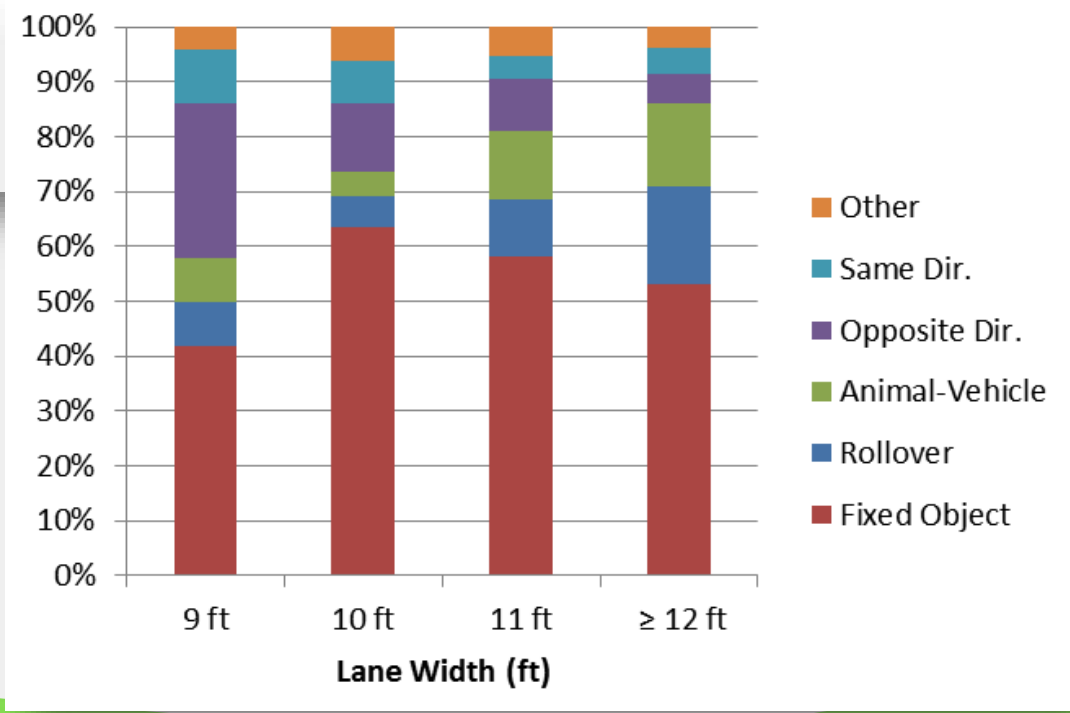

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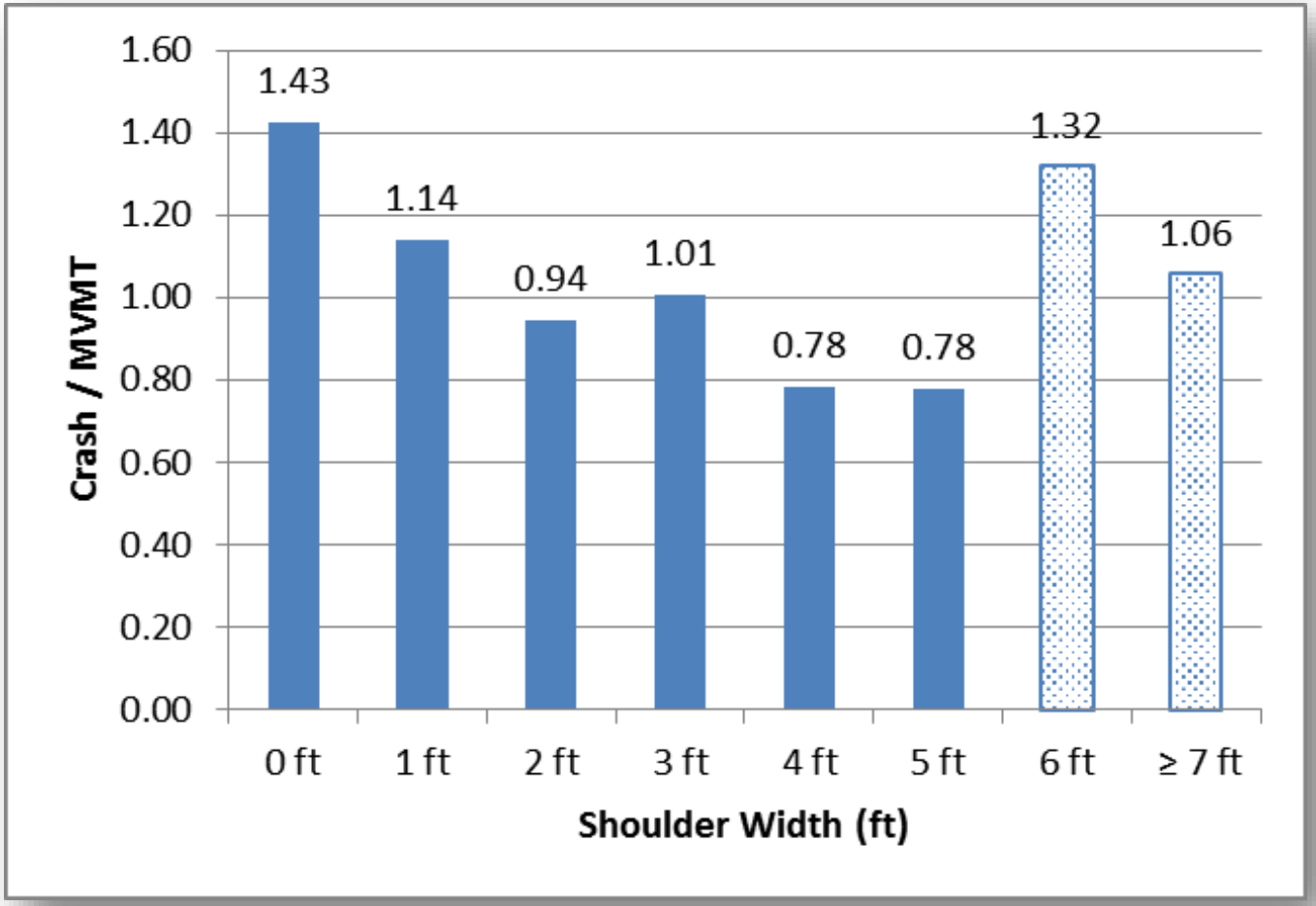

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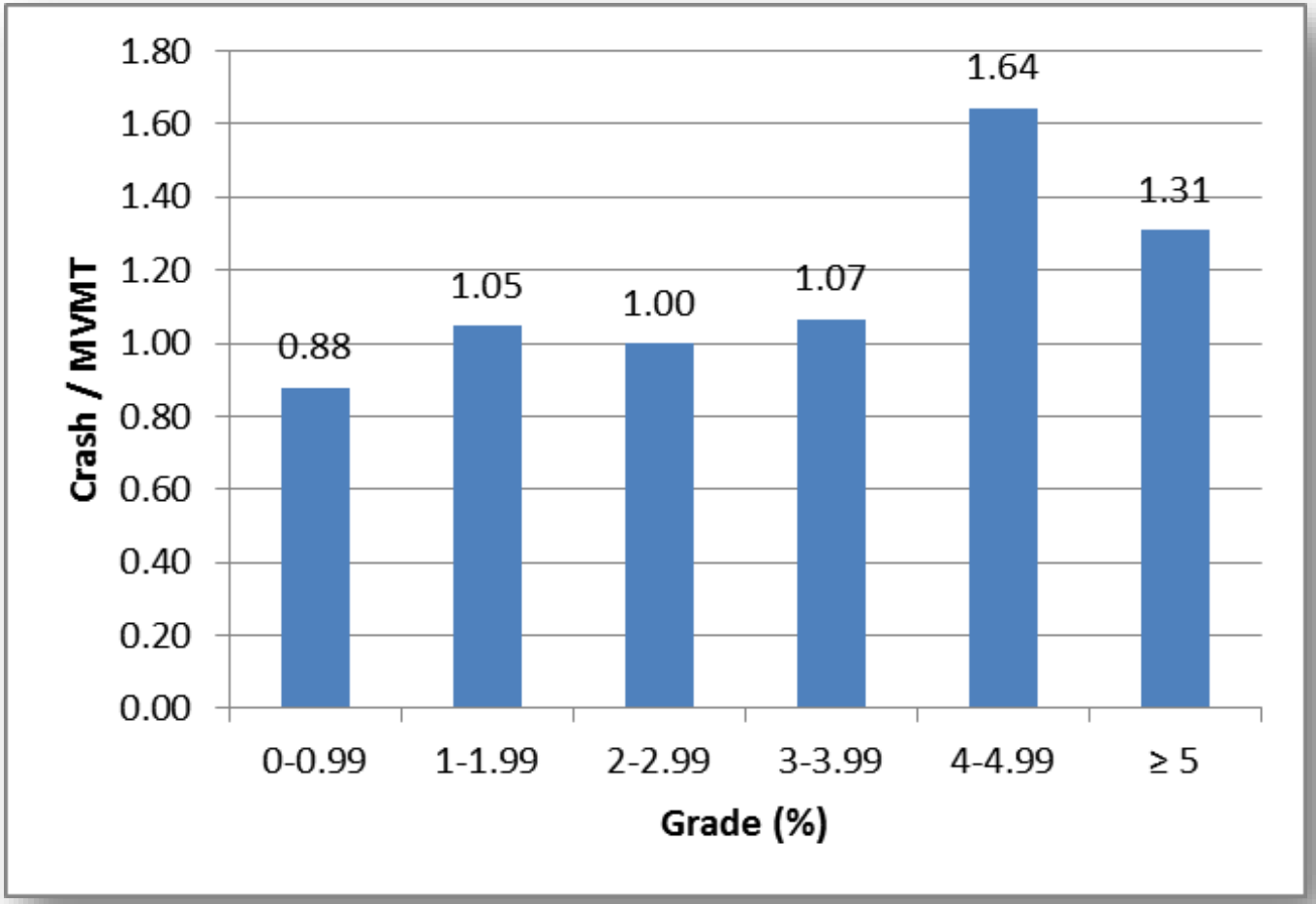

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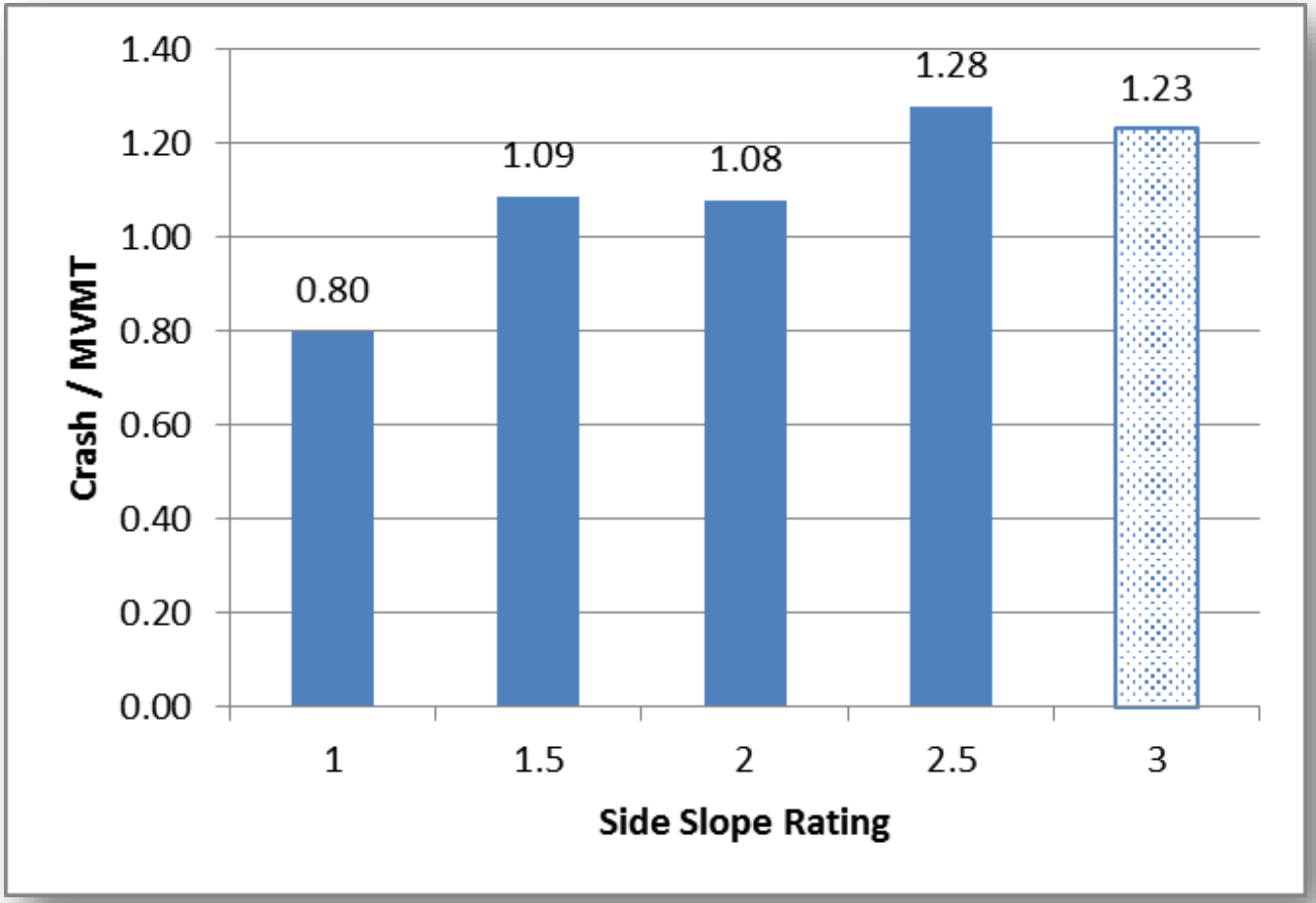

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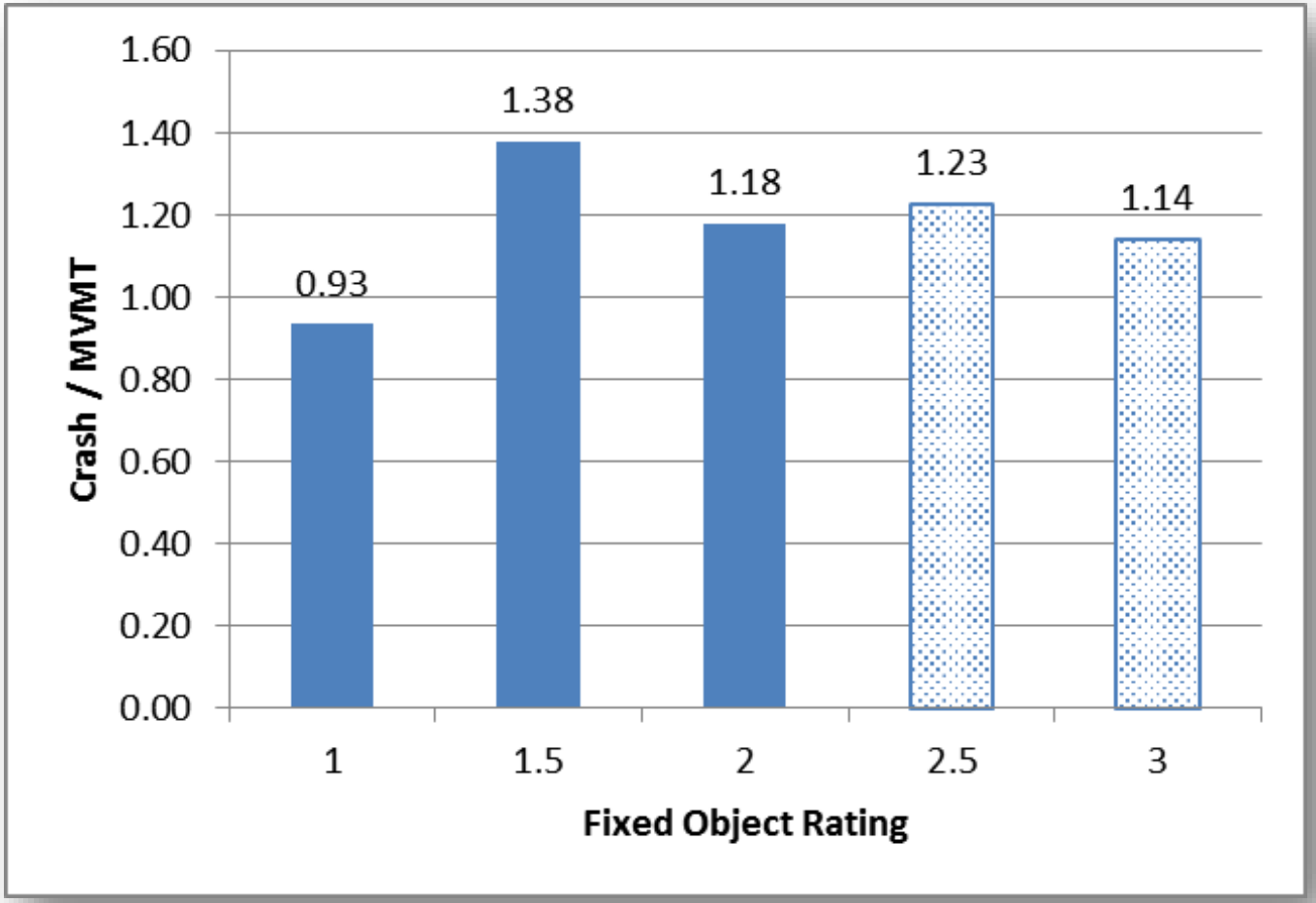

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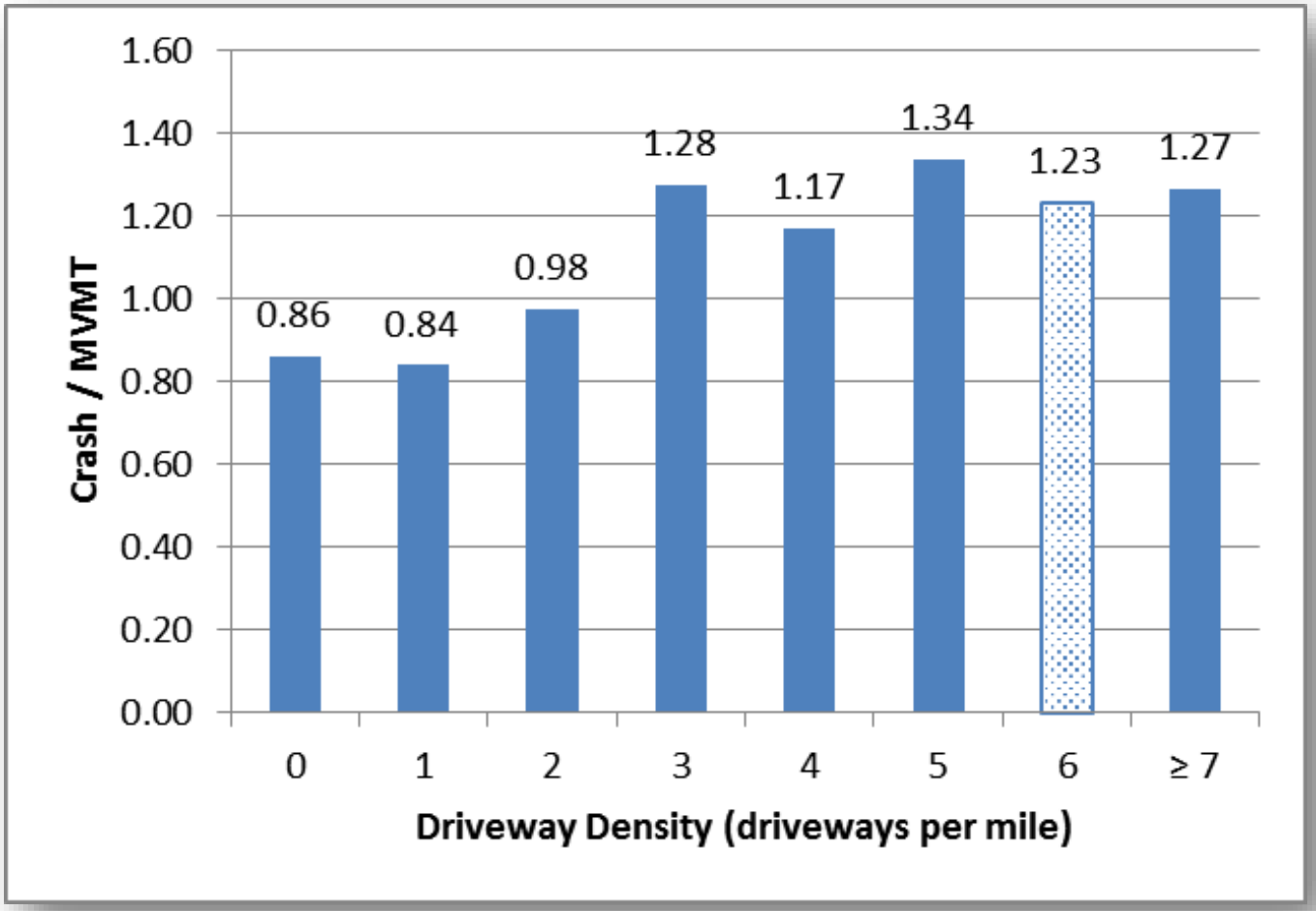

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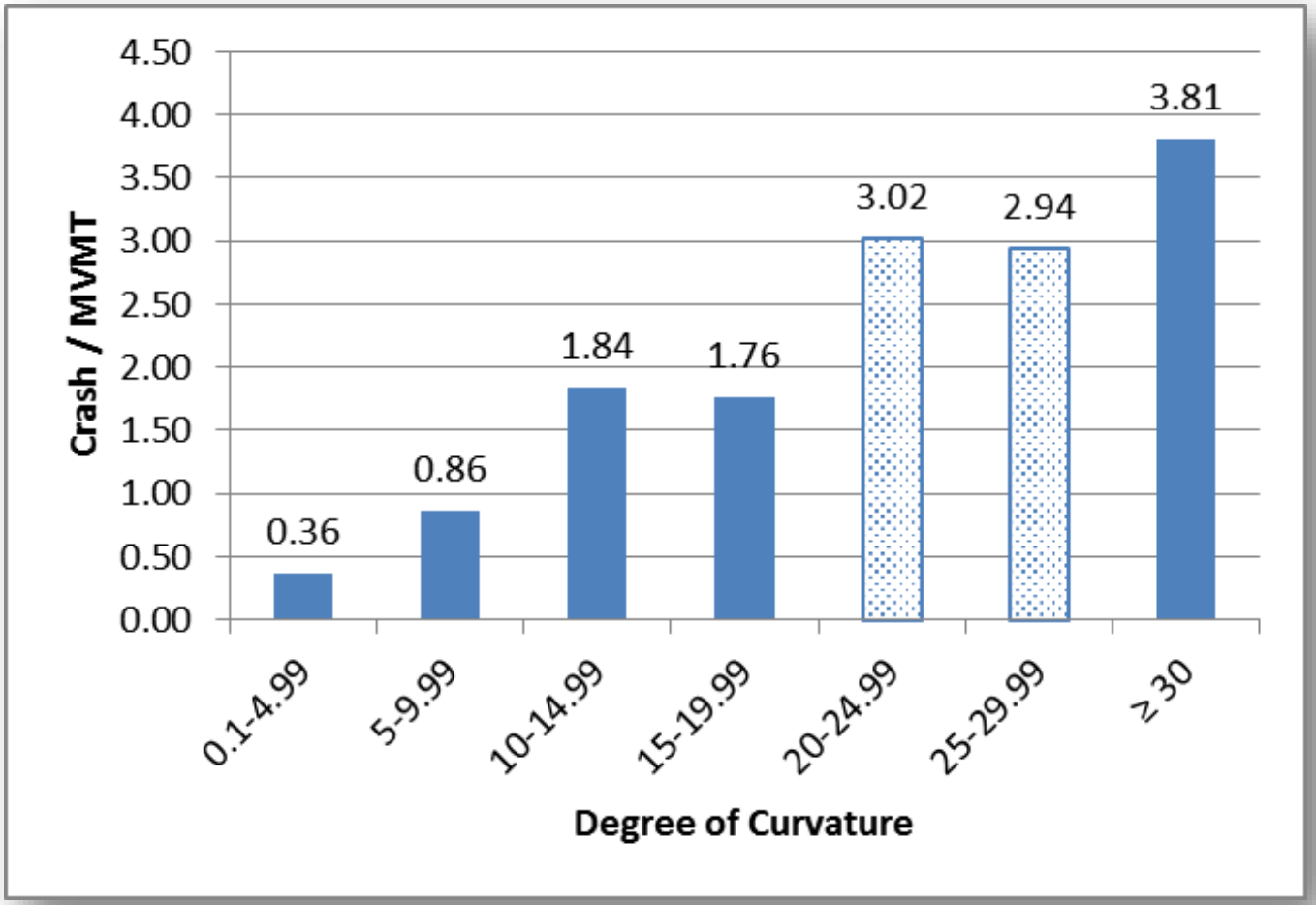

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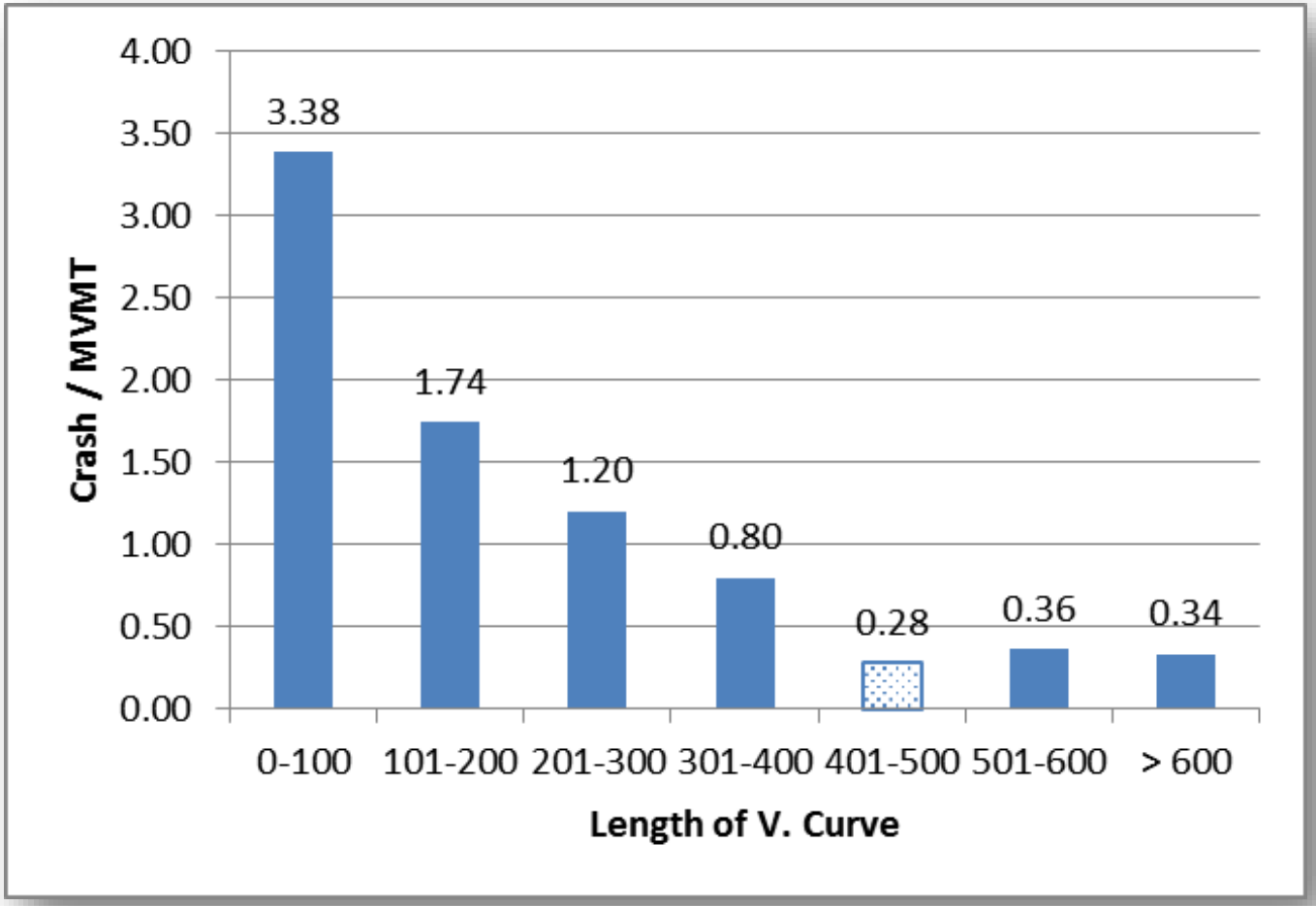
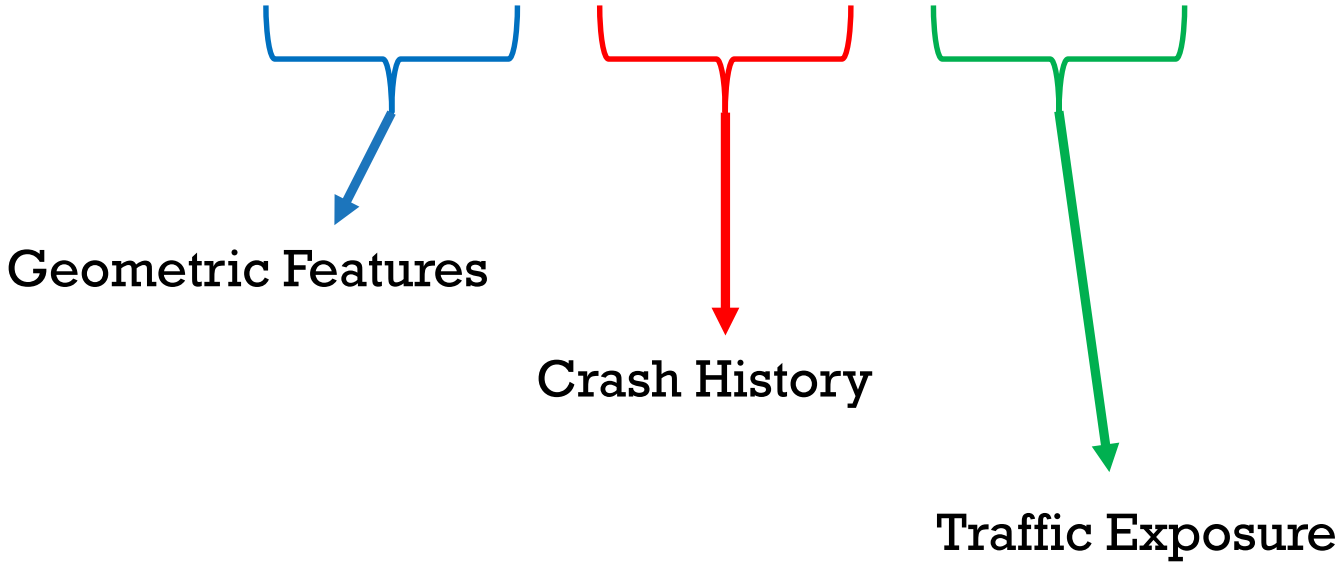


Risk Index

General Form

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



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

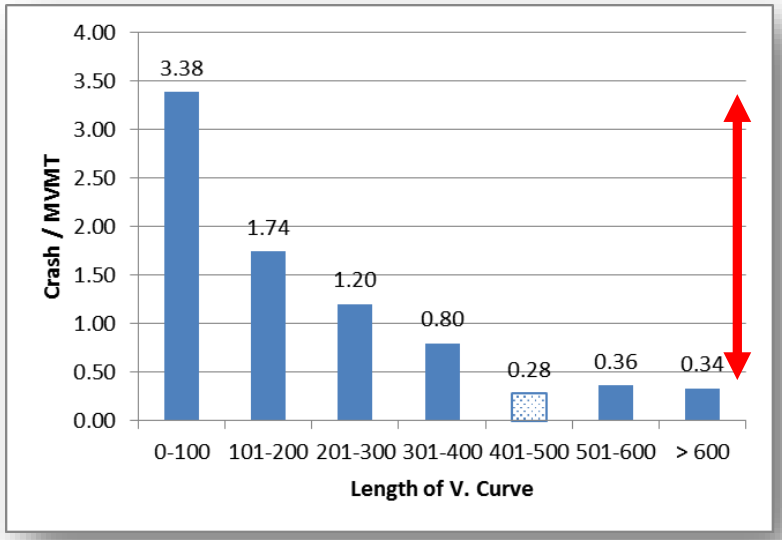
$$X_G \quad \frac{1}{8}(y_{dc}) + \frac{1}{8}(y_{lvc}) + \frac{1}{8}(y_{lw}) + \frac{1}{8}(y_g) + \frac{1}{8}(y_{sw}) + \frac{1}{8}(y_{dd}) + \frac{1}{8}(y_{ss}) + \frac{1}{8}(y_{fo})$$

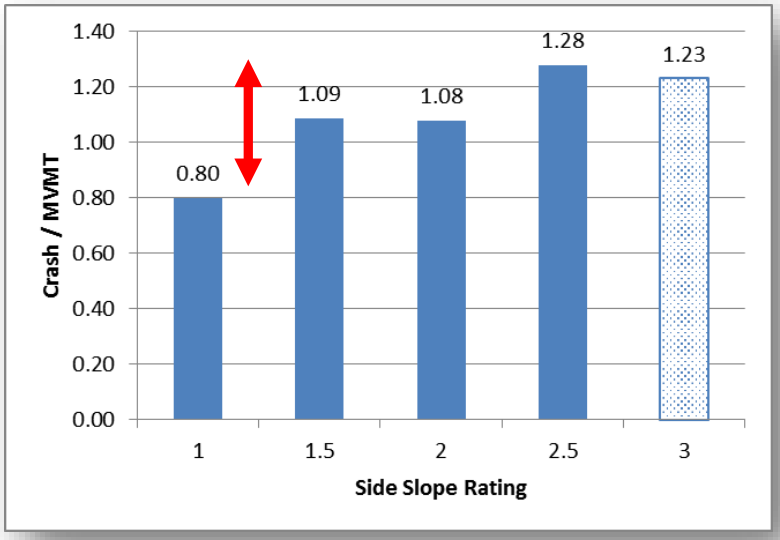
- If all characteristics influenced crash rate equally then all 8 weights would be equal.

Risk Index

$$X_G$$

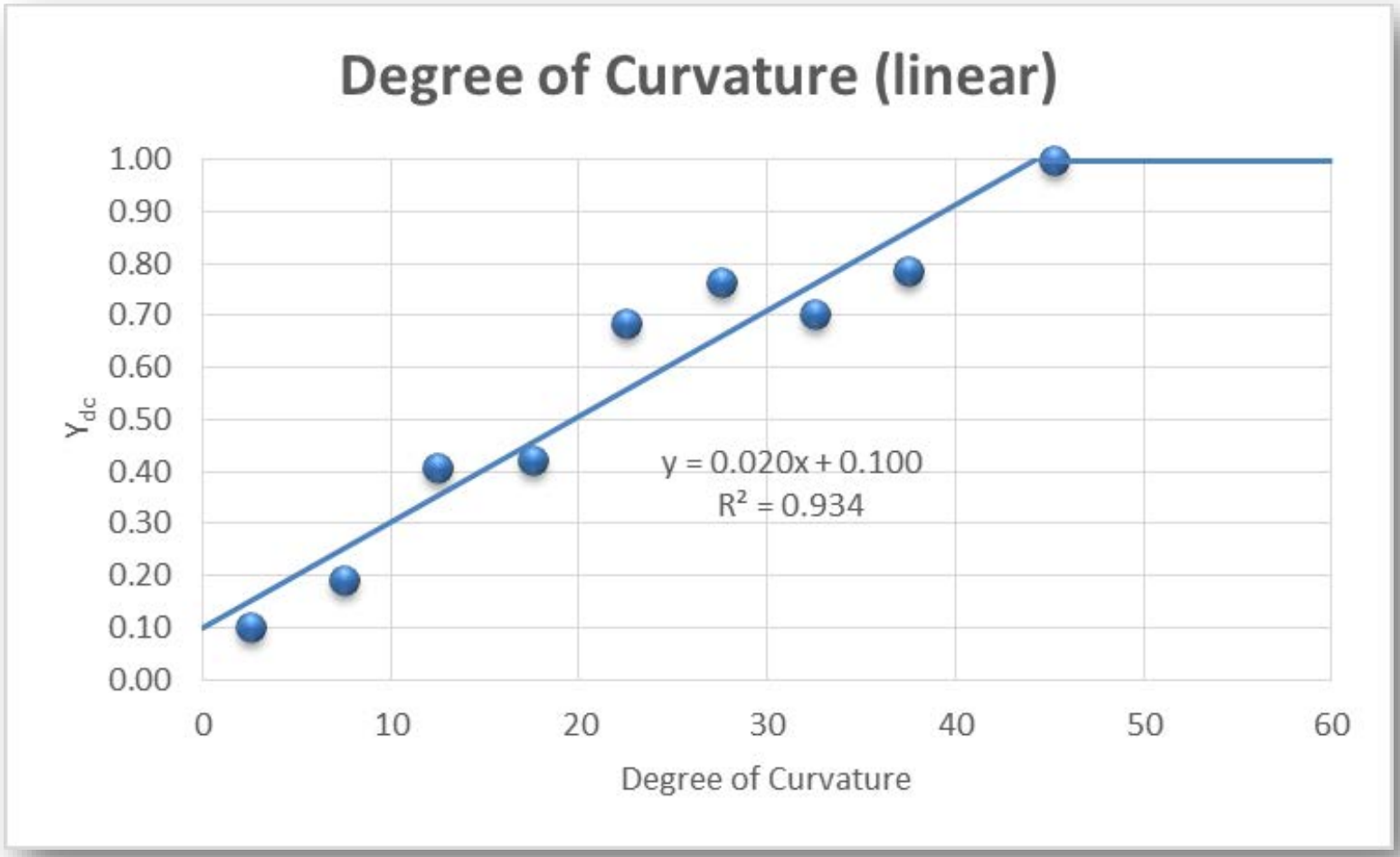
$$\mathbf{0.36}(y_{dc}) + \mathbf{0.30}(y_{lvc}) + \mathbf{0.06}(y_{lw}) + \mathbf{0.06}(y_g) + \mathbf{0.07}(y_{sw}) + \mathbf{0.06}(y_{dd}) + \mathbf{0.05}(y_{ss}) + \mathbf{0.04}(y_{fo})$$





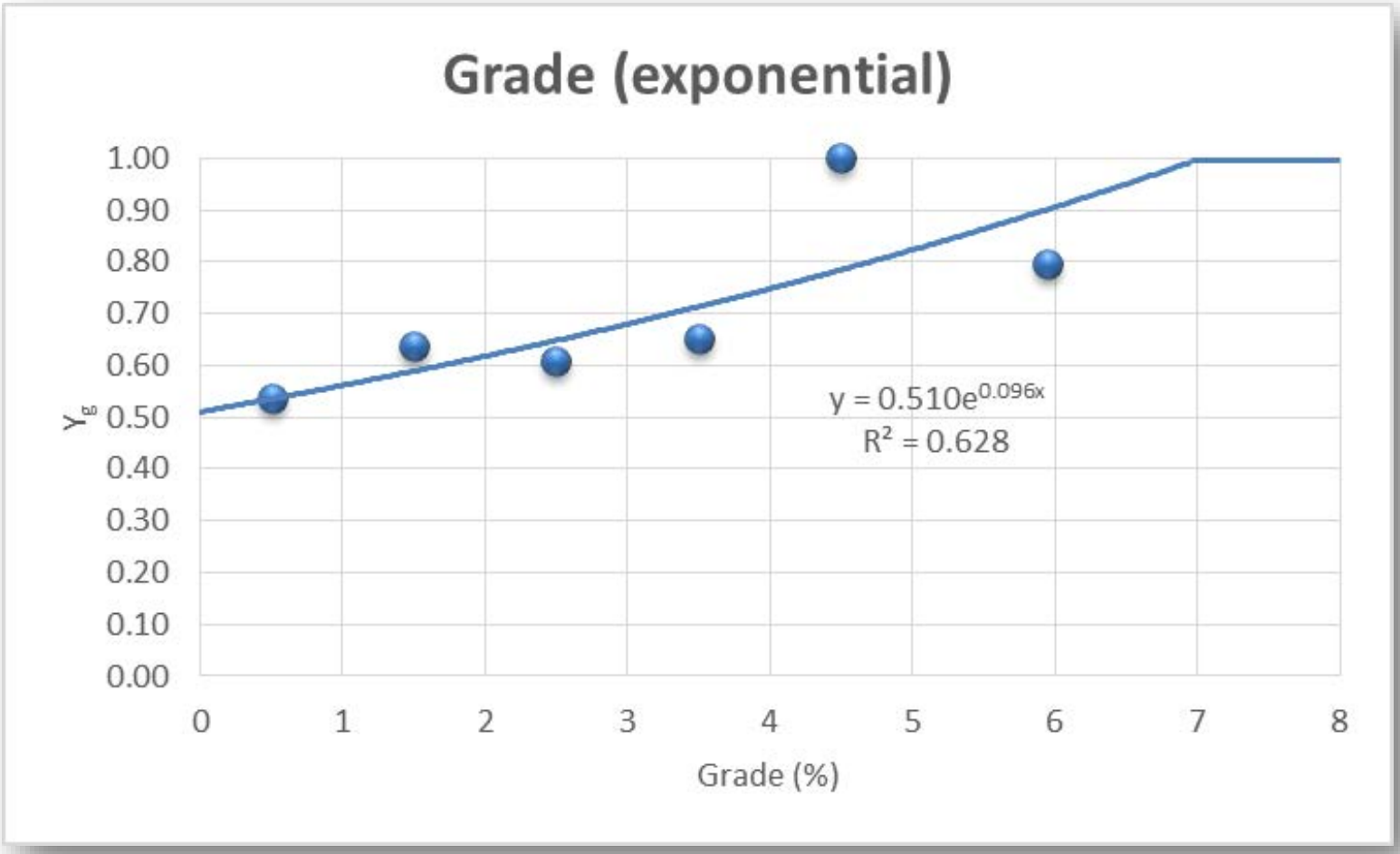
Risk Index

y_{dc}



Risk Index

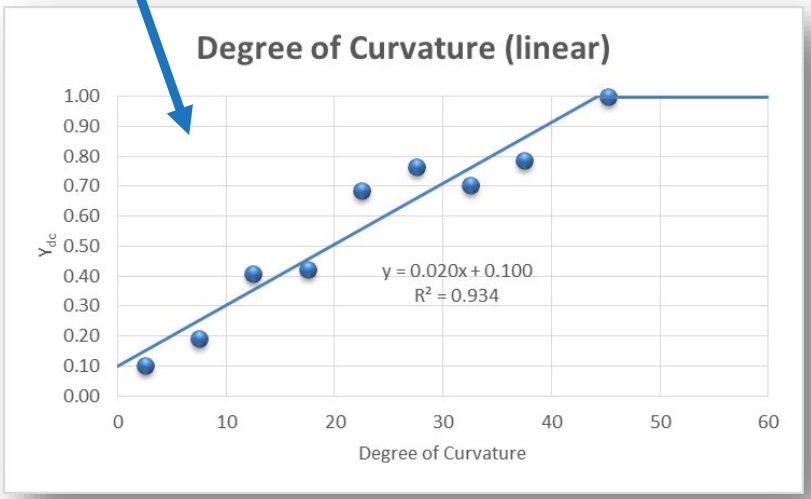
y_g



Risk Index

$$CRI = \underbrace{0.45(x_G)}_{\text{Geometric Features}} + \underbrace{0.25(x_C)}_{\text{Crash History}} + \underbrace{0.30(x_T)}_{\text{Traffic Exposure}}$$

$$0.36(y_{dc}) + 0.30(y_{lvc}) + 0.06(y_{lw}) + 0.06(y_g) + 0.07(y_{sw}) + 0.06(y_{dd}) + 0.05(y_{ss}) + 0.04(y_{fo})$$



- 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

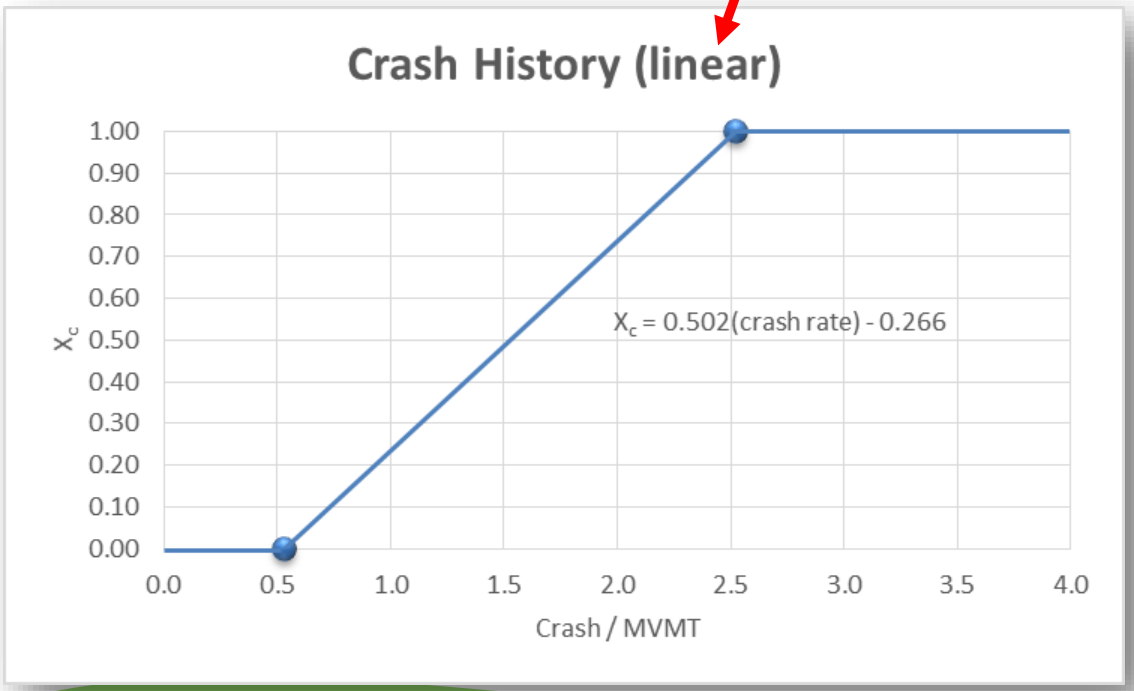
Risk Index

$$CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T)$$

Geometric Features

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

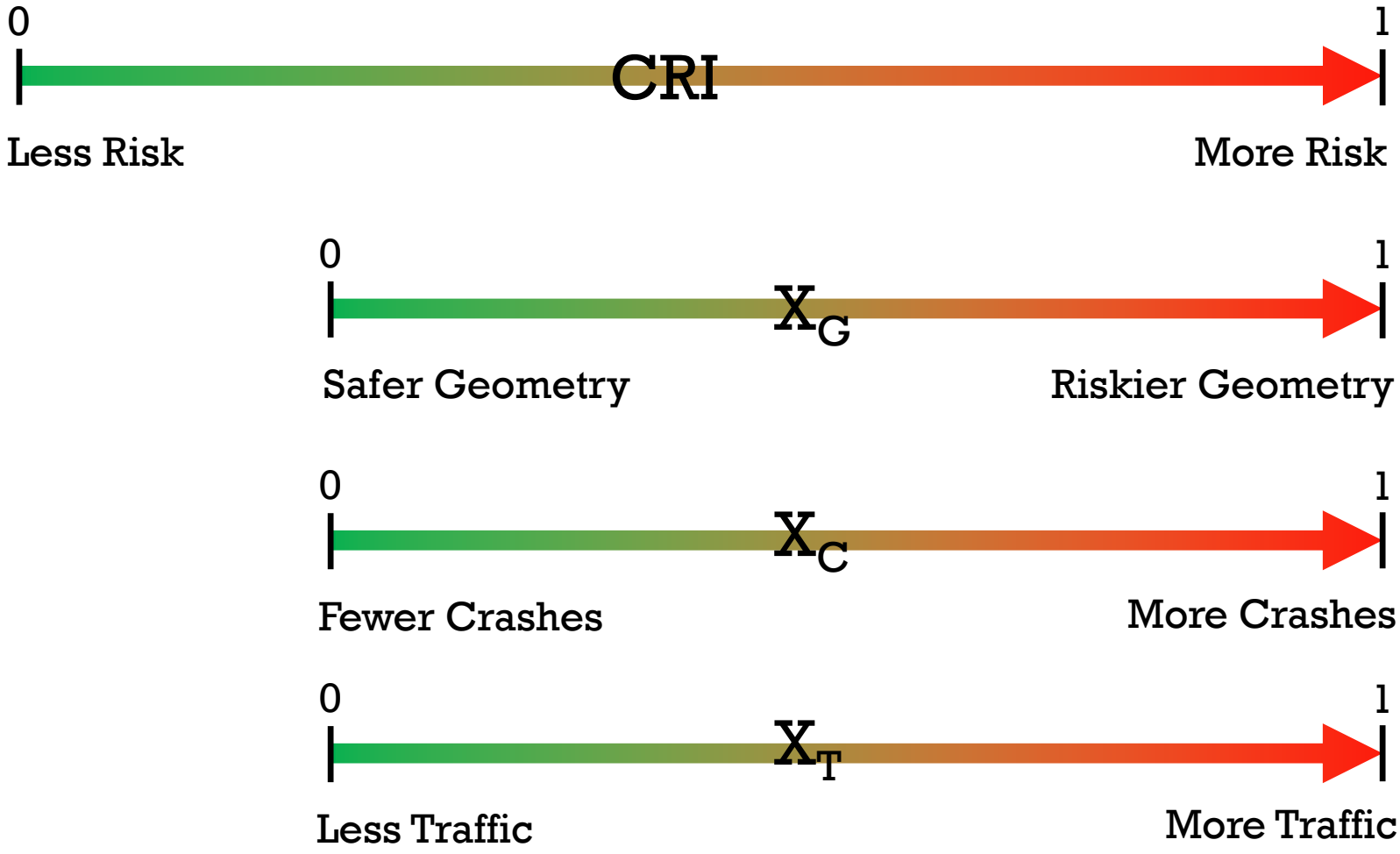
	Percent Trucks		
AADT (vpd)	< 29%	29% - 39%	>39%
< 300	0.20	0.30	0.40
300 – 499	0.40	0.50	0.60
500 – 699	0.60	0.70	0.80
700 – 900	0.80	0.90	1.00
> 900	1.00	1.00	1.00

Defined by:

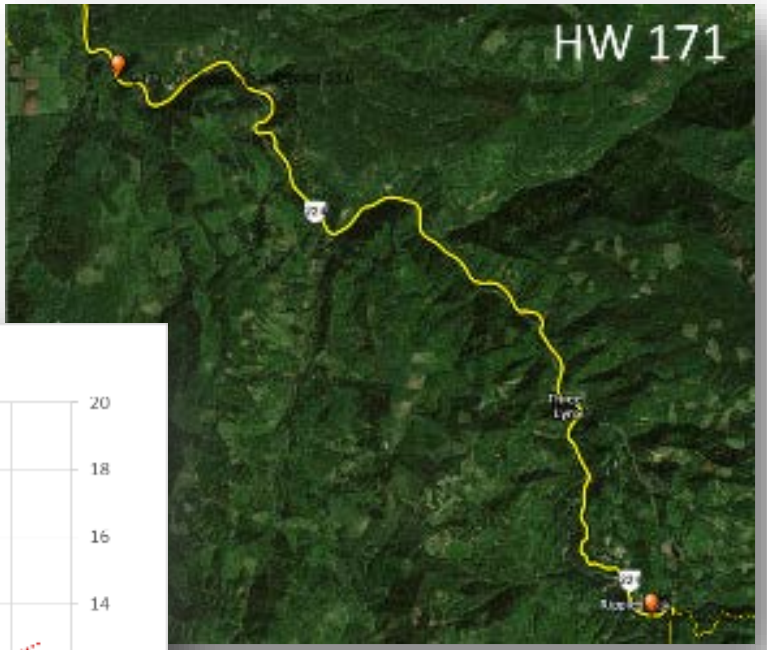
- Total volumes on the sample
- Truck traffic (ave. = 29% std. dev. = 10%)

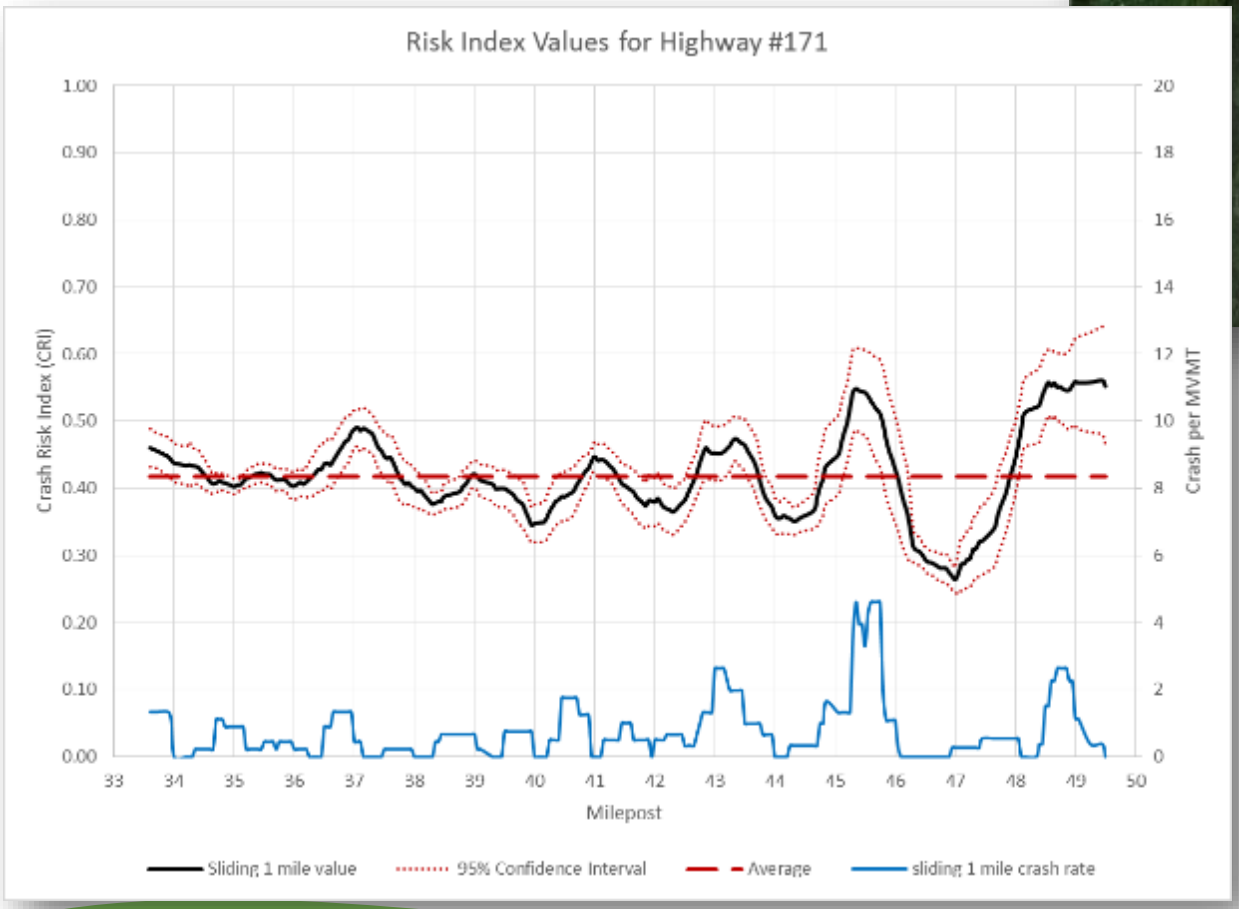
Risk Index

$$CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T)$$



Risk Index – Case Study





Risk Index – 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

Directing Your Questions via the Chat Pod

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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.

Low-cost Safety Countermeasures

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:

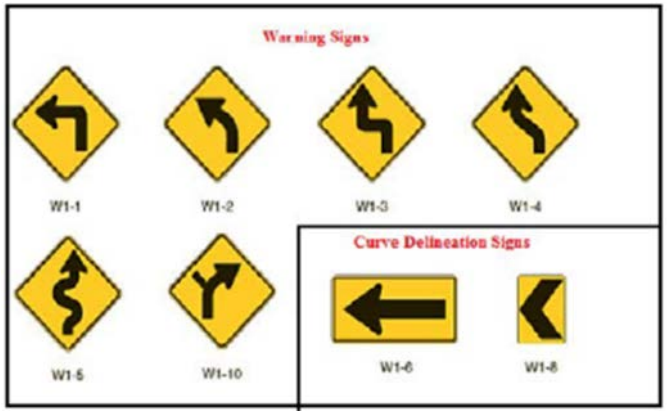
- http://ruralsafetycenter.org/resources/list/crash-modification-factors-clearinghouse/

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

- http://ruralsafetycenter.org/resources/list/manual-for-selecting-safety-improvements-on-high-risk-rural-roads/

Economic Analysis of Countermeasures

- Alignment
  - Horizontal Alignment Signs
  - Flashing Beacons
  - Chevrons
  - Post Mounted Delineators
  - Raised Pavement Markers



Countermeasure Example Images from FHWA HRRR Manual (Atkinson, et. al., 2014)

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

Treatment (Source)	Setting	Analysis	Effectiveness
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

Treatment	CRF			
	All	PDO	Injury	Fatal
Install Safety Edge	6%			
Improve Roadside Hazard Rating	6% to 33%			
Install Object Markers for Objects Near the Roadway	16%	14%	17%	41%
Relocate Objects Near the Roadway	25% to 55%		25%	40%
Remove Objects Near the Roadway	18% to 61%		30%	50%

Economic Analysis of Countermeasures

– Sample treatment costs

Treatment	Initial Cost	Maintenance / Life Cycle Cost
Horizontal Alignment Sign	$300 to $3,500 per installation	$1,300 / 5 years
Flashing Beacon for Curve Warning	$2,400 per installation	$1,000 / 2 years
Chevrons	$600 to $7,200 per installation	$3,600 / 5 years
Post Mounted Delineators for Curves	$5,600 per installation	Life ≥ 10 years
Raised Pavement Markers for Curves	$600 per installation	$600 / 2 years
Dynamic Speed Feedback Display on Approach to Curves	$2,300 to $12,600 per installation	$1,000 / 2 years

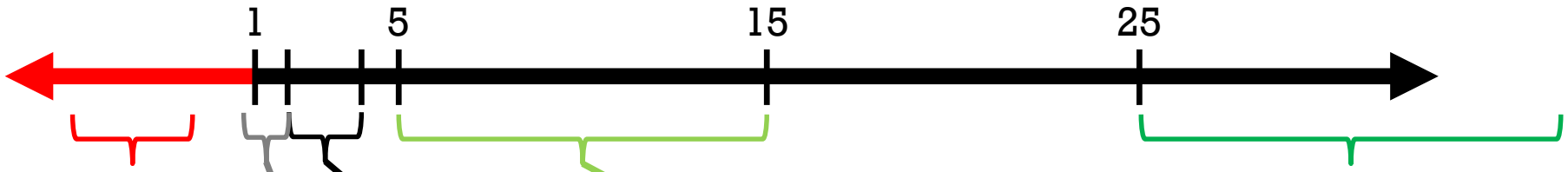
Economic Analysis of Countermeasures

– Sample Benefit/Cost Ratios

Treatment	B/C (ODOT $)	B/C (HSM $)
Horizontal Alignment Sign	1.64	1.10
Flashing Beacon for Curve Warning	1.46	1.14
Chevrons	1.08	0.84
Post Mounted Delineators for Curves	1.42	1.10
Raised Pavement Markers for Curves	0.85	0.66
Dynamic Speed Feedback Display on Curves	0.10	0.08

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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Levi Ewan,
WTI

National Center for Rural Road Safety

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.

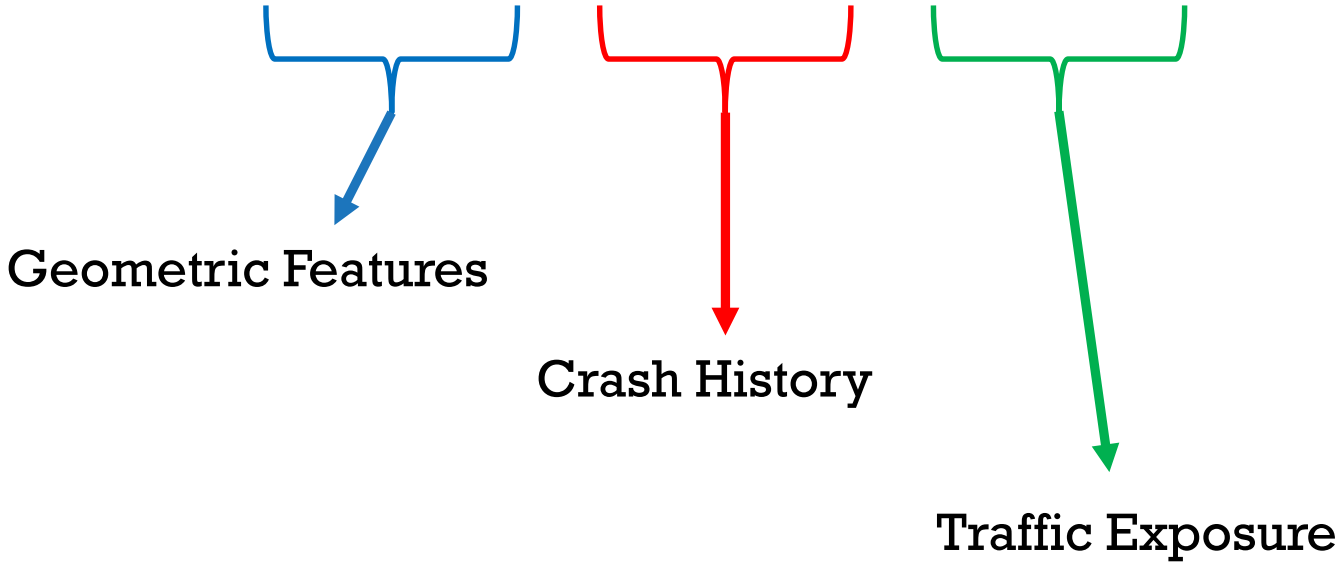
Developing a Crash Risk Index

- 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

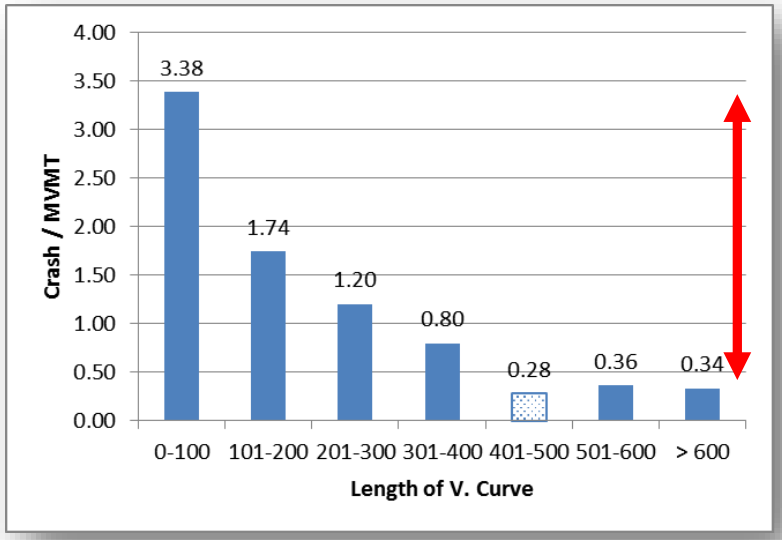
- $CRI = W_G(x_G) + W_C(x_C) + W_T(x_T)$

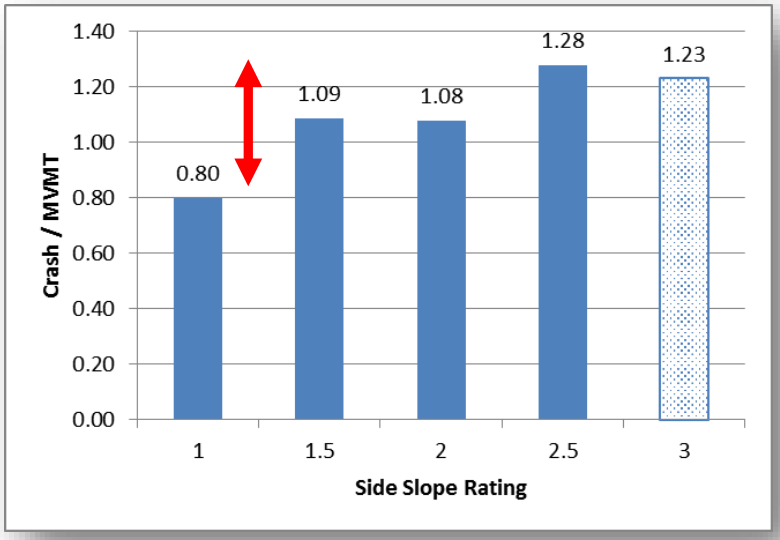


Risk Index

$$X_G$$

$$\mathbf{0.36}(y_{dc}) + \mathbf{0.30}(y_{lvc}) + \mathbf{0.06}(y_{lw}) + \mathbf{0.06}(y_g) + \mathbf{0.07}(y_{sw}) + \mathbf{0.06}(y_{dd}) + \mathbf{0.05}(y_{ss}) + \mathbf{0.04}(y_{fo})$$

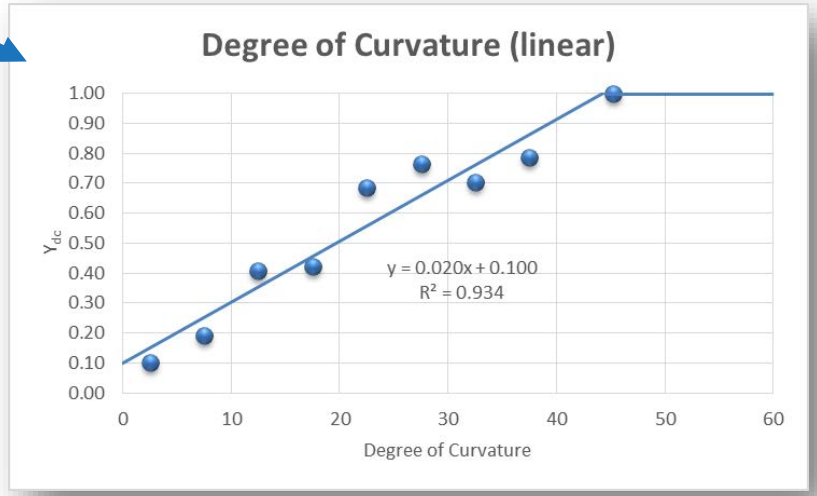




Risk Index

$$CRI = \underbrace{0.45(x_G)}_{\text{Geometric Features}} + \underbrace{0.25(x_C)}_{\text{Crash History}} + \underbrace{0.30(x_T)}_{\text{Traffic Exposure}}$$

$$0.36(y_{dc}) + 0.30(y_{lvc}) + 0.06(y_{lw}) + 0.06(y_g) + 0.07(y_{sw}) + 0.06(y_{dd}) + 0.05(y_{ss}) + 0.04(y_{fo})$$



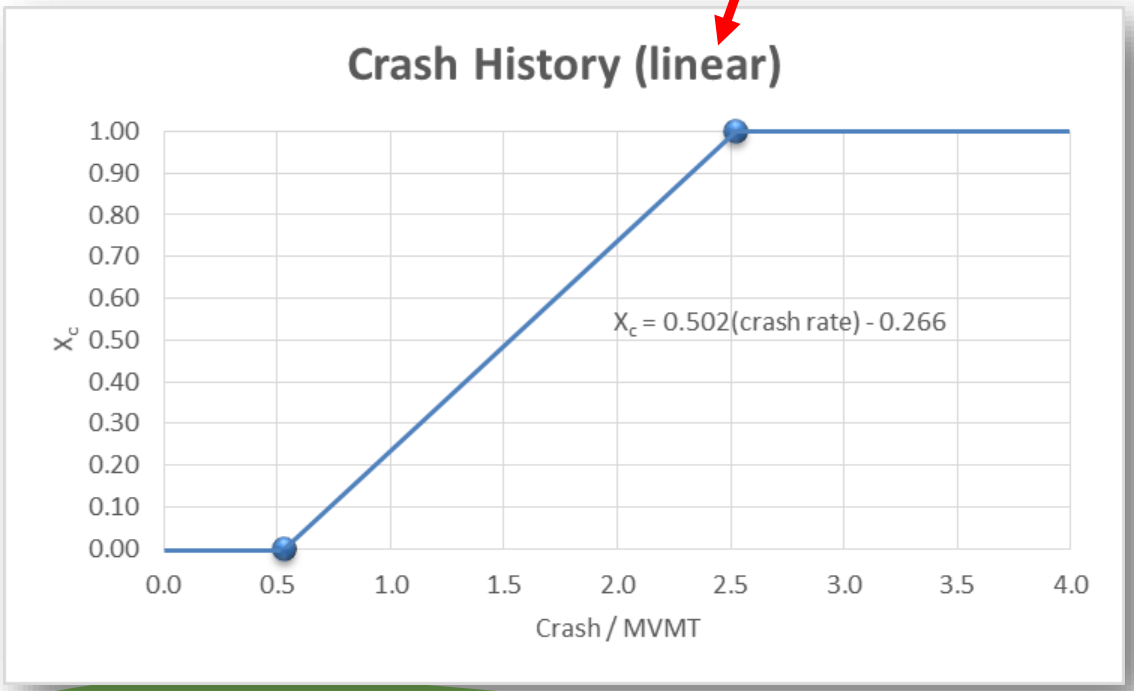
Risk Index

$$CRI = 0.45(x_G) + 0.25(x_C) + 0.30(x_T)$$

Geometric Features

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

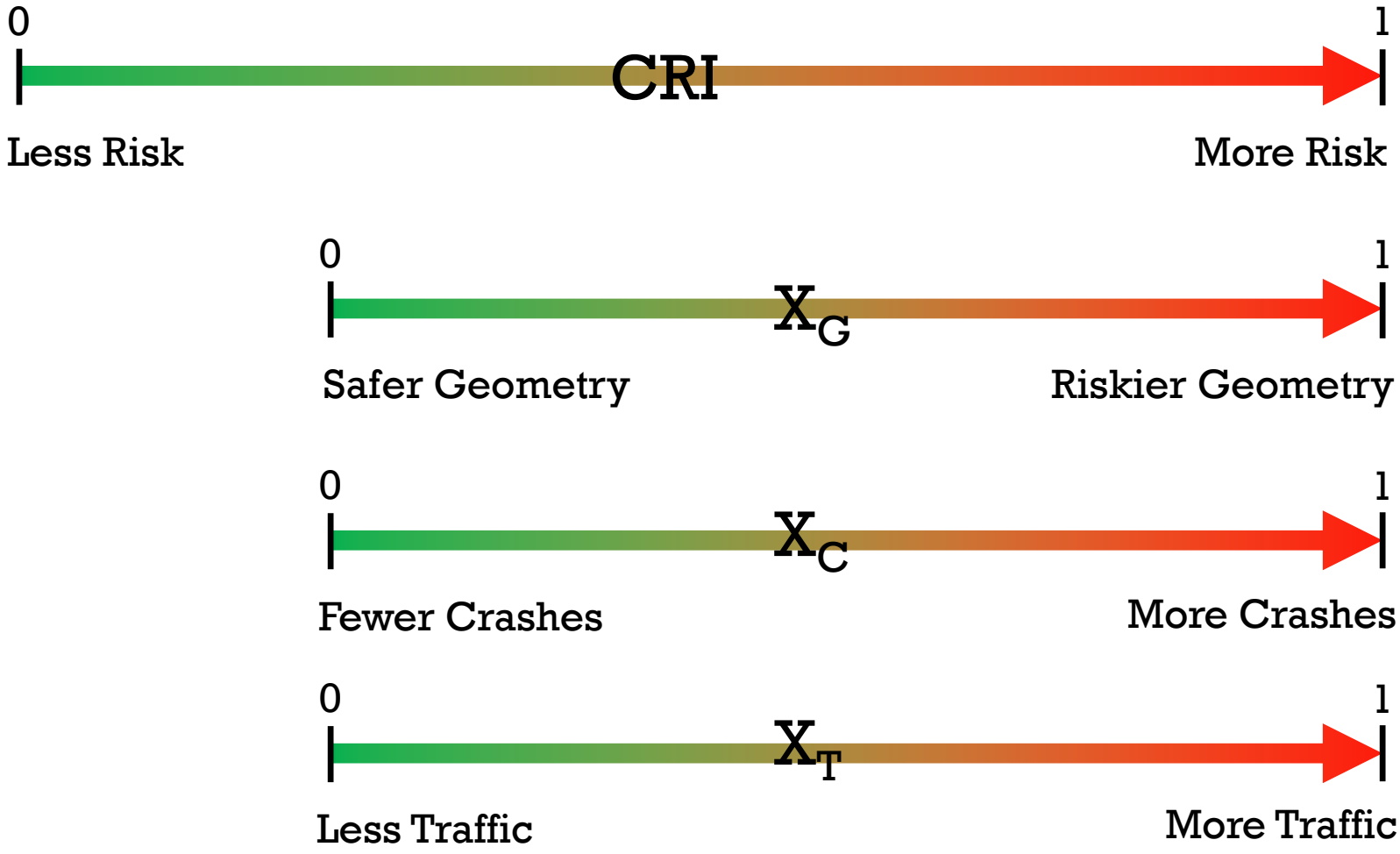
	Percent Trucks		
AADT (vpd)	< 29%	29% - 39%	>39%
< 300	0.20	0.30	0.40
300 – 499	0.40	0.50	0.60
500 – 699	0.60	0.70	0.80
700 – 900	0.80	0.90	1.00
> 900	1.00	1.00	1.00

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

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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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Contact Information

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Or contact the Safety Center help desk at:

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