The Effect of Road Characteristics on the Incidence of Farm Vehicle-related Crashes: A GIS-based Matched Case-Control Study

Shabbar I Ranapurwala, MPH, PhD; Elizabeth Mello, BA; Marizen R Ramirez, MPH, PhD

Injury Prevention Research Center, College of Public Health, University of Iowa, Iowa City, IA

THE UNIVERSITY OF IOWA — IPRC INJURY PREVENTION RESEARCH CENTER

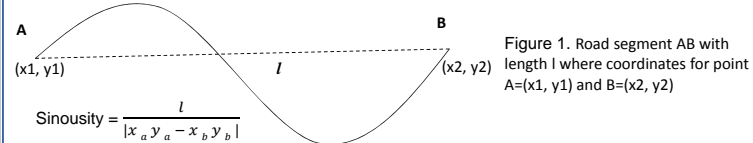GREAT PLAINS Center for Agricultural Health

Background
- Motor vehicle crashes on rural roads result in more fatalities and injuries than those on urban roads
- Large slow-moving farm vehicles are known hazards
- Road characteristics like number of lanes, road dividers, exits, shoulders may influence motor vehicle crashes
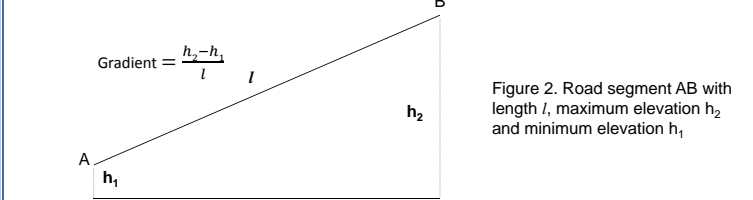
Methods
- Farm vehicle-related crashes (FVC) from nine Midwestern States, 2005-2010 – 6848 crashes with x and y coordinates
- Road segment data was collected from Environmental Systems Research Institute – almost 6.5 million road segments with information on length, elevation, ZIP code, road type, speed limits, state, and unique ID

Exposure Assessment
- Sinuosity of road segment is defined as the % deviance from a straight line, straight road segment has 0% sinuosity

$$Sinuosity = \frac{l}{|x_a y_a - x_b y_b|}$$

Figure 1. Road segment AB with length l where coordinates for point A=(x1, y1) and B=(x2, y2)

- Gradient of a road segment is the rise over run and is a measure of uphills and downhills, a road segment that is flat has 0% gradient

$$Gradient = \frac{h_2 - h_1}{l}$$

Figure 2. Road segment AB with length l, maximum elevation h_2 and minimum elevation h_1

Outcome assessment
- Case: A road segment that had a farm vehicle-related crash (6848 case road segments)
- Control: A road segment that did not have a farm vehicle-related crash

Matching: Based on potential confounders identified using directed acyclic graphs (figure 3): ZIP code, road segment length, type of road

Figure 3. Directed acyclic graph representing effect of road segment characteristics on FVC incidence
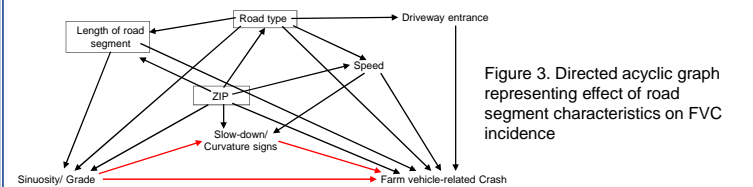
Sensitivity analysis
- 1:1 case-control matching – 6848 cases: 6808 controls
- 1:2 case-control matching – 6848 cases: 13566 controls
- Comparing all road segments with FVCs to non-FVCs segments – 6848 FVCs: 6484963 non-FVCs

Statistical Analyses
- Matched data – Conditional logistic regression adjusted for ZIP code, segment length, & road type
- Unmatched data – Log linear (risk) regression adjusted for state, segment length, & road type
- Odds and risk ratios with 95% CI are reported
- Since the outcome is rare (0.1% of all road segments had FVCs) odds ratios approximate risk ratios

Table 1: Effect of gradient of road segments on the incidence of FVCs

Exposure categories		Cases	Controls	cOR (95% CI)	aOR* (95% CI)
Matched data (1:1) - 6848 cases: 6808 controls*					
Grade	< 1%	3030	2889	Referent	Referent
	1-5%	3002	2926	0.98 (0.91, 1.05)	0.93 (0.85, 1.01)
	6% - 10%	569	686	0.79 (0.70, 0.89)	0.68 (0.58, 0.79)
	>10%	247	307	0.77 (0.64, 0.91)	0.60 (0.49, 0.75)
Matched data (1:2) - 6848 cases: 13566 controls*					
Grade	< 1%	3030	5742	Referent	Referent
	1-5%	3002	5858	0.97 (0.91, 1.03)	0.91 (0.85, 0.99)
	6% - 10%	569	1348	0.80 (0.72, 0.89)	0.68 (0.59, 0.77)
	>10%	247	618	0.76 (0.65, 0.88)	0.60 (0.49, 0.72)
All data – 6848 FVC segments: 6484963 non-FVC segments*					
		FVC	Non-FVC	cRR (95% CI)	aRR** (95% CI)
Grade	< 1%	3030	2731114	Referent	Referent
	1-5%	3002	2833649	0.96 (0.91, 1.00)	0.95 (0.90, 1.00)
	6% - 10%	569	618737	0.83 (0.76, 0.91)	0.83 (0.75, 0.92)
	>10%	247	301463	0.74 (0.65, 0.84)	0.86 (0.75, 0.99)

cOR- crude odds ratio; aOR – adjusted odds ratio; cRR – crude risk ratio; aRR – adjusted risk ratio; CI – confidence intervals; * - matched for ZIP code, road type, and segment length; ** - adjusted for state, road type, and segment length
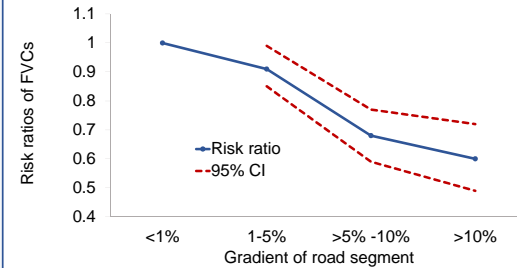

Figure 4: Risk of FVC decreases as gradient increases (1:2 matching)
Risk of FVC was 40% less for segments with >10% gradient relative to a flat road segment

Table 2: Effect of sinuosity of road segments on the incidence of FVCs

Exposure categories		Cases	Controls	cOR (95% CI)	aOR* (95% CI)
Matched data (1:1) - 6848 cases: 6808 controls					
Sinuosity (% deviation)	< 1%	5990	5462	Referent	Referent
	1-10%	737	1057	0.64 (0.58, 0.70)	0.57 (0.51, 0.64)
	11-20%	65	147	0.40 (0.30, 0.54)	0.33 (0.24, 0.45)
	21-30%	35	74	0.43 (0.29, 0.65)	0.37 (0.24, 0.56)
	> 30%	21	68	0.28 (0.17, 0.46)	0.21 (0.13, 0.36)
Matched data (1:2) - 6848 cases: 13566 controls					
Sinuosity (% deviation)	< 1%	5990	10837	Referent	Referent
	1-10%	737	2107	0.63 (0.58, 0.69)	0.55 (0.50, 0.61)
	11-20%	65	306	0.38 (0.29, 0.50)	0.31 (0.24, 0.41)
	21-30%	35	156	0.41 (0.28, 0.59)	0.33 (0.22, 0.48)
	> 30%	21	160	0.24 (0.15, 0.38)	0.18 (0.11, 0.28)
All data – 6848 FVC segments: 6484963 non-FVC segments					
		FVC	Non-FVC	cRR (95% CI)	aRR** (95% CI)
Sinuosity (% deviation)	< 1%	5990	5046010	Referent	Referent
	1-10%	737	1100437	0.56 (0.52, 0.61)	0.57 (0.52, 0.61)
	11-20%	65	174897	0.31 (0.25, 0.40)	0.33 (0.26, 0.42)
	21-30%	35	78209	0.38 (0.27, 0.53)	0.38 (0.27, 0.53)
	> 30%	21	85410	0.21 (0.14, 0.32)	0.21 (0.14, 0.32)

cOR- crude odds ratio; aOR – adjusted odds ratio; cRR – crude risk ratio; aRR – adjusted risk ratio; CI – confidence intervals; * - matched for ZIP code, road type, and segment length; ** - adjusted for state, road type, and segment length
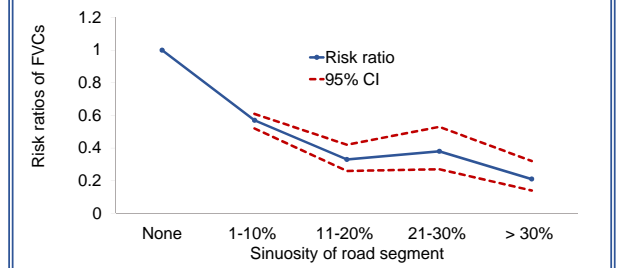

Figure 5: Risk of FVC decreases as sinuosity increases (1:2 matching)
Risk of FVC was reduced to a fifth for segments with >30% sinuosity relative to a straight road segment

Limitations
- Per our definition of sinuosity, we assume that all road segments with similar deviation from a straight line are same
- Intersections could be potential confounders - the number of intersections is hard to estimate from Esri data
- Could not measure the number of farm vehicles on a road – maybe highly sinuous and hilly roads witness less farm vehicles

Conclusions
- Increased sinuosity of road segments reduces incidence of farm vehicle-related crashes
- Increased gradient of road segments reduces incidence of farm vehicle-related crashes

Acknowledgements

Nine State Farm Vehicle Related Crashes (2005 - 2010)

Legend
- Farm Vehicle Related Crash

Map Created by: Elizabeth Mello, Injury Prevention Research Center, University of Iowa, 2014.

For more information, contact Dr. Shabbar Ranapurwala: shabbar-ranapurwala@uiowa.edu