Exploring The Impacts of Street Illuminance on Nighttime Crash Severity in Roadway Segments using A Random Parameter Ordered Probit Model

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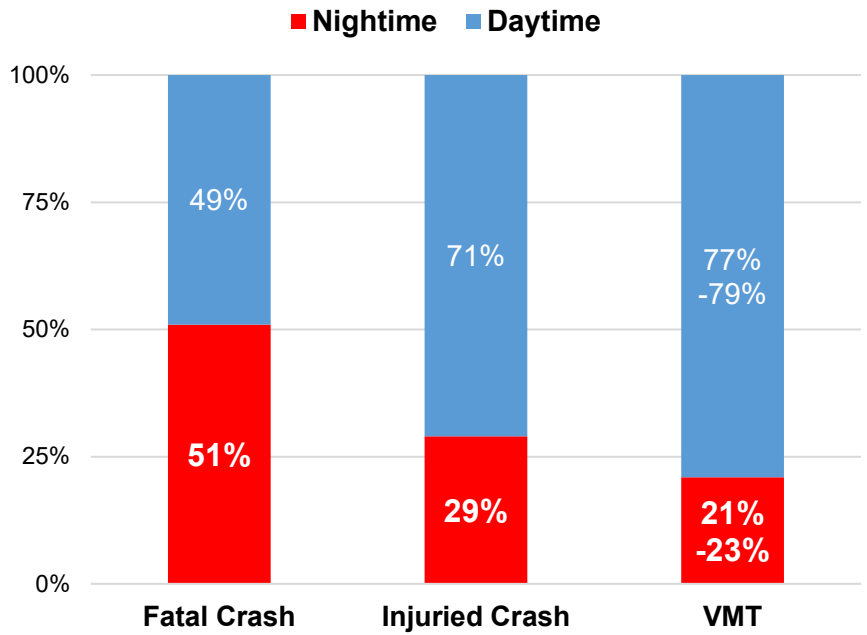
Outline

- Problem Statement
- Data Collection
- Methodology
- Results Discussion
- Conclusions

Problem Statement

- Nighttime Crash Facts
  - Overrepresented on the US highways
  - Particularly for fatal and injured crashes
- Major Causes
  - **Poor visibility**
  - Drowsy driving
  - Impaired driving



Sources: NHTSA Traffic Crash Facts 2015, and Monsere, C. M., and E. L. Fischer. Safety effects of reducing freeway illumination for energy conservation

Street Lighting

- An effective countermeasure to improve nighttime safety
  - To supplement vehicle headlights and extend the visibility range
  - To improve the visibility of objects on or near roads
  - To delineate the roadway ahead
- The safety effects of lighting photometric measures are not well documented
  - Most studies focused on lit presence or improvement
  - Limited studies explored nighttime injury severity

Reference: http://www.fdot.gov/structures/DesignExpo2012/Presentations/HighwayLightingIntro.pdf

Related Studies

- Wei, etc. (2016)
  - Street lighting vs. nighttime crash severity at signalized intersections
  - HFC ≥ 0.9, the risk of fatalities and severe injuries decreases by 5% (overall), 11% (pedestrian), 9% (head-on), and 6% (angle)
- Wang, etc. (2016)
  - Street lighting vs. nighttime crash occurrence on segments
  - N-D ratio based CMFs

$$CMF_{HFC} = x^{-0.0773} \times 100\%$$

$$CMF_{Uniformity} = 97.7\%$$

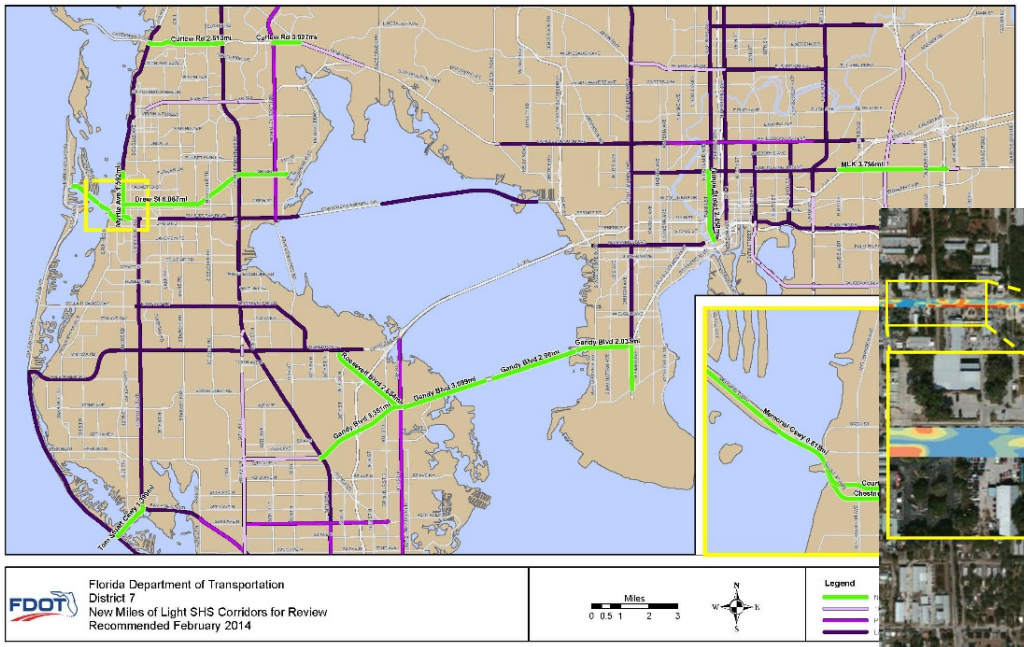
HFC – baseline is 0.2fc; Uniformity – Max/Min>6 vs. Max/Min≤6

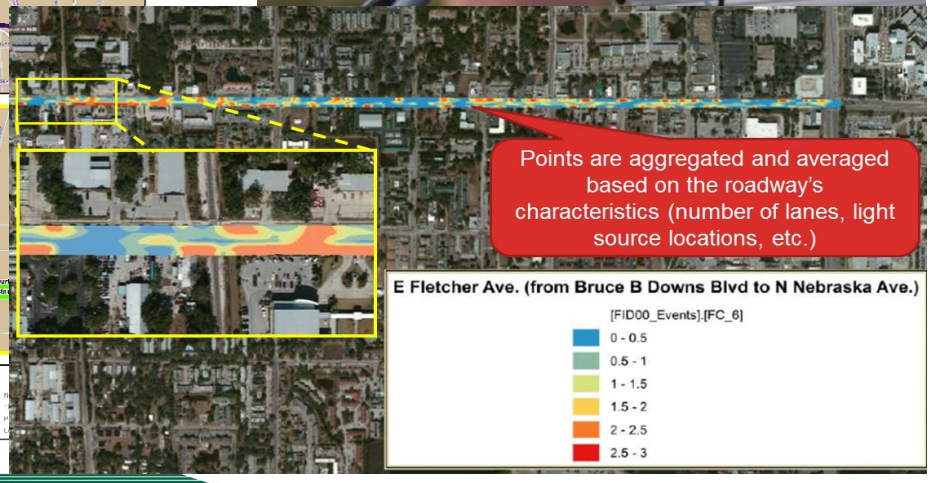
Research Objective

- To investigate the effects of street lighting photometric parameters on nighttime crash severity
  - Horizontal Illuminance
  - Uniformity
- To address the unobserved heterogeneity in samples
  - Random Parameter models
- To identify other factors contributing to nighttime crash severity

Data Collection – Lighting Data

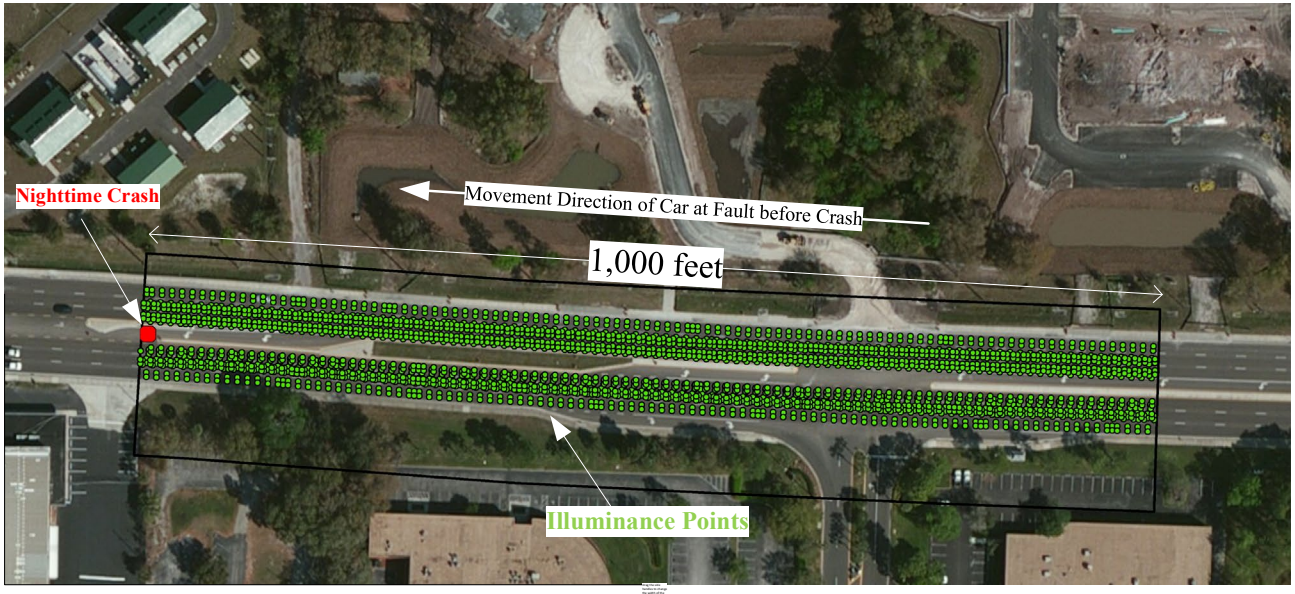
- Advanced Lighting Measurement System
- 400 centerline miles in Tampa Bay
- 2012 - now





Data Collection – Crash Data

- 1,739 nighttime crashes on roadway segments
  - Distance to adjacent signal ≥ 250 ft
  - High Pressure Sodium (HPS)
  - No upgrade within 2012 – 2014
- Matched to illuminance data in ArcGIS



Data Reduction

- Crash Severity
  - Severe (Fatal or Incapacitating)
  - Medium (non-incapacitating or possible injury)
  - PDO
- Average horizontal illuminance
  - High illuminance (> 0.8 fc)
  - Medium illuminance (0.4 – 0.8 fc)
  - Low illuminance (< 0.4 fc)
- Geometry, Traffic Control, Crash, Driver and Vehicle

Methodology

- Random Parameter Ordered Probit Model
  - Allowing some coefficients vary across observations (normally distributed)
  - Addressing the unobserved heterogeneity
  - Accounting for the ordinal feature of severity data

$$Y_n^* = \beta_n X_n + \varepsilon_n$$

$$Y_n = j \; if \; \mu_{n,j-1} < Y_n^* \leq \mu_{n,j}$$

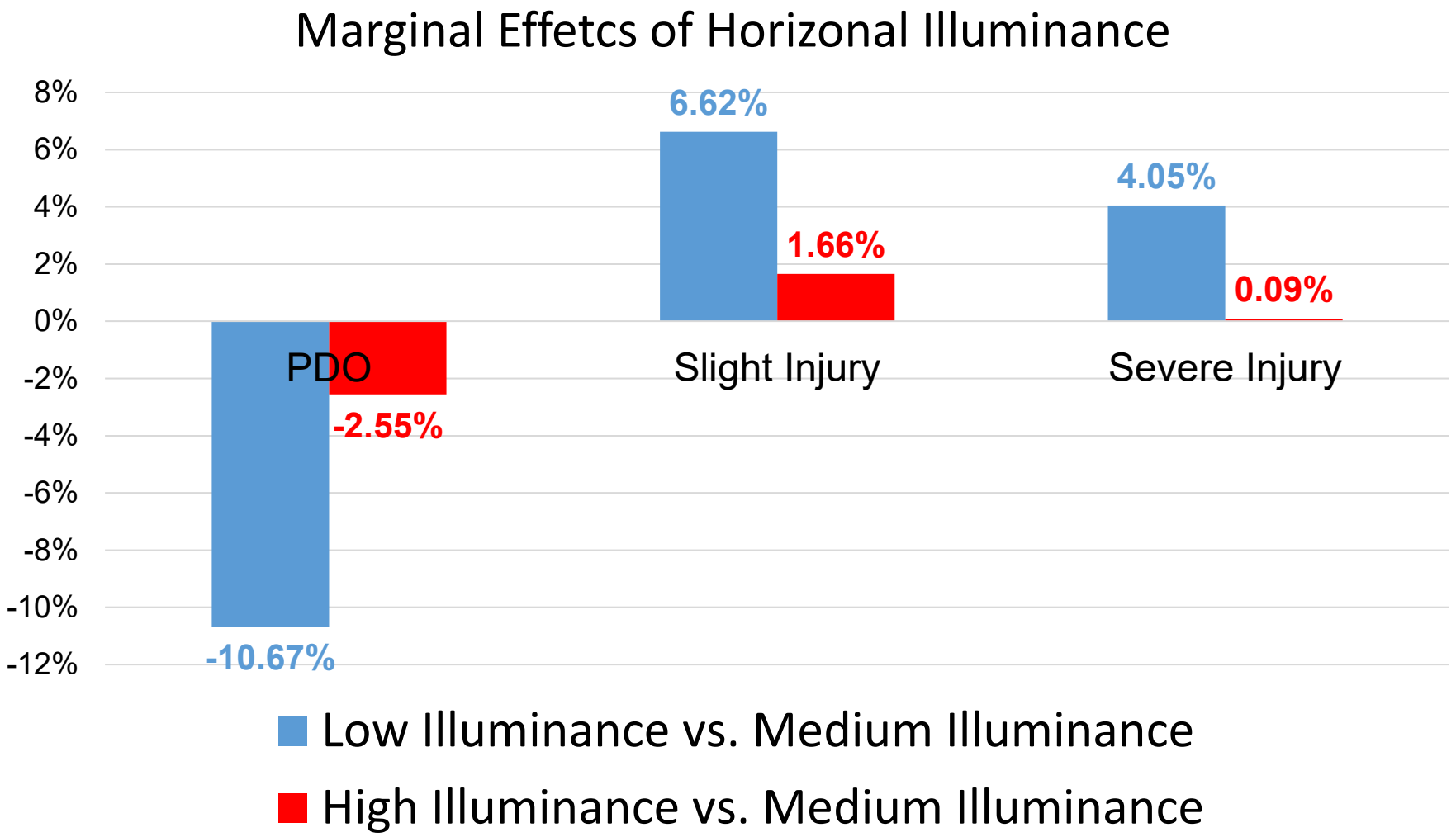
$$P(Y_n = j) = \int_{\beta} \int_{\tau} \left[\Phi\left(\mu_{n,j} - \beta_n X_n\right) - \Phi\left(\mu_{n,j-1} - \beta_n X_n\right)\right] f(\beta|\varphi) d\beta$$

where μ_n are estimable thresholds $(\mu_{n,0} = -\infty, \mu_{n,J} = +\infty)$ defining observed injury severity level j ; $\Phi(\cdot)$ is the cumulative normal distribution, $f(\beta|\phi)$ is the density function of random parameter β with distribution parameter ϕ (mean and variance).

Fitted Model

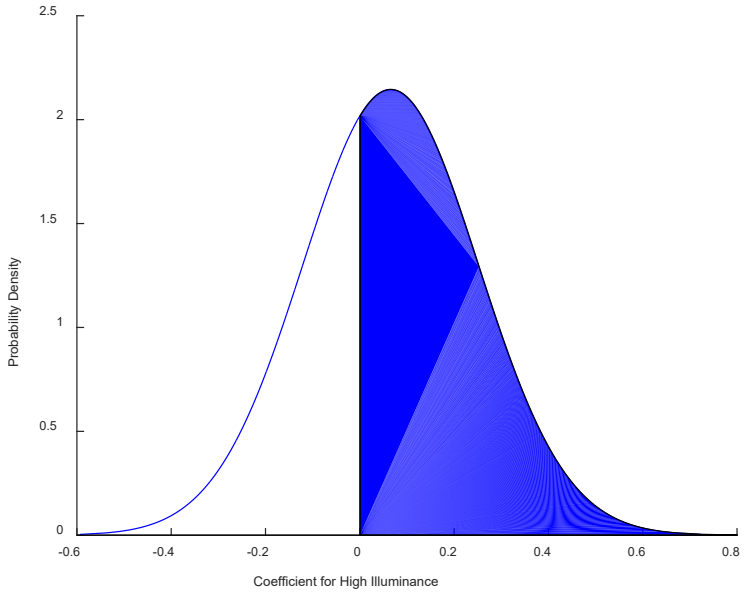
Variable Description	Estimated Parameter	t-Statistic
Constant	-0.704	-6.01
Low average illuminance indicator (< 0.4 fc)	0.276	3.57
High average illuminance indicator (> 0.8 fc)	0.065	0.91
(Standard deviation for random parameter)	(0.186)	(3.55)
Female person indicator	0.287	4.58
Vulnerable road user involvement indicator	1.692	15.15
Proper driving indicator	0.744	10.83
Older driver at fault indicator	0.300	3.03
Aggressive driving involvement indicator	0.899	3.87
Alcohol or drugs involvement indicator	0.373	4.74
Seat-belt unrestrained indicator	0.306	3.67
Hit-and-run crash indicator	-0.433	-4.86
Same-direction sideswipe crash	-0.450	-3.74
Air-bag not activated in crash indicator	-0.349	-5.21
Off roadway indicator	0.406	4.00
Multi-vehicle crash indicator	0.382	4.95
Severe vehicle damage indicator	0.445	6.42
High speed limit indicator	0.200	2.96
Multiple lanes indicator	0.213	3.00
High friction pavement indicator	-0.315	-2.76
Weekend indicator	-0.168	-2.60
Year 2011 indicator	0.221	3.09

Discussion


Marginal Effetcs of Horizonal Illuminance
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
-12%
6.62%
4.05%
1.66%
0.09%
PDO
-2.55%
Slight Injury
Severe Injury
-10.67%
Low Illuminance vs. Medium Illuminance
High Illuminance vs. Medium Illuminance

Discussion – Coefficient for High Illuminance

- Normally distributed
  - Mean: 0.065, SD: 0.186
  - Pr(>0): 64%
  - Pr(<0): 36%
  - Insignificant on average



- High illuminance associates with
  - High visibility → reduce the risk of severe injury
  - Multiple lanes, high speed, … → increase the risk
  - Safety compensation → increase the risk

Other Factors

Factor	AME for Severe Injury
Vulnerable road user involvement indicator	45.7%
Aggressive driving involvement indicator	21.0%
Proper driving indicator	11.8%
Off roadway indicator	6.9%
Severe vehicle damage indicator	6.1%
Alcohol or drugs involvement indicator	6.0%
Seat-belt unrestrained indicator	4.8%
Older driver at fault indicator	4.8%
Multi-vehicle crash indicator	4.5%
Female person indicator	4.0%
High speed limit indicator	2.8%
Multiple lanes indicator	2.7%

Other Factors

Factor	AMF for Severe Injury
Air-bag not activated in crash indicator	-4.9%
Hit-and-run crash indicator	-4.8%
Same-direction sideswipe crash	-4.6%
High friction pavement indicator	-3.5%

Conclusions

- Compared to a low illuminance (<0.4 fc), a medium illuminance (0.4 – 0.8 fc) significantly to reduce severe injury (4.05%) on roadway segments
- A high illuminance (>0.8 fc) has a insignificant and random effect compared to the medium level
  - Joint effects of contradictory factors
  - A further study is needed

Conclusions

- Vulnerable road users and aggressive are the top two factors contributing to severe injury in nighttime crashes on segments
  - Appreciate countermeasures
  - Engineering, Education, and Enforcement

Thank You!

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