Lighting Strategies to Improve Pedestrian Safety and Walkability

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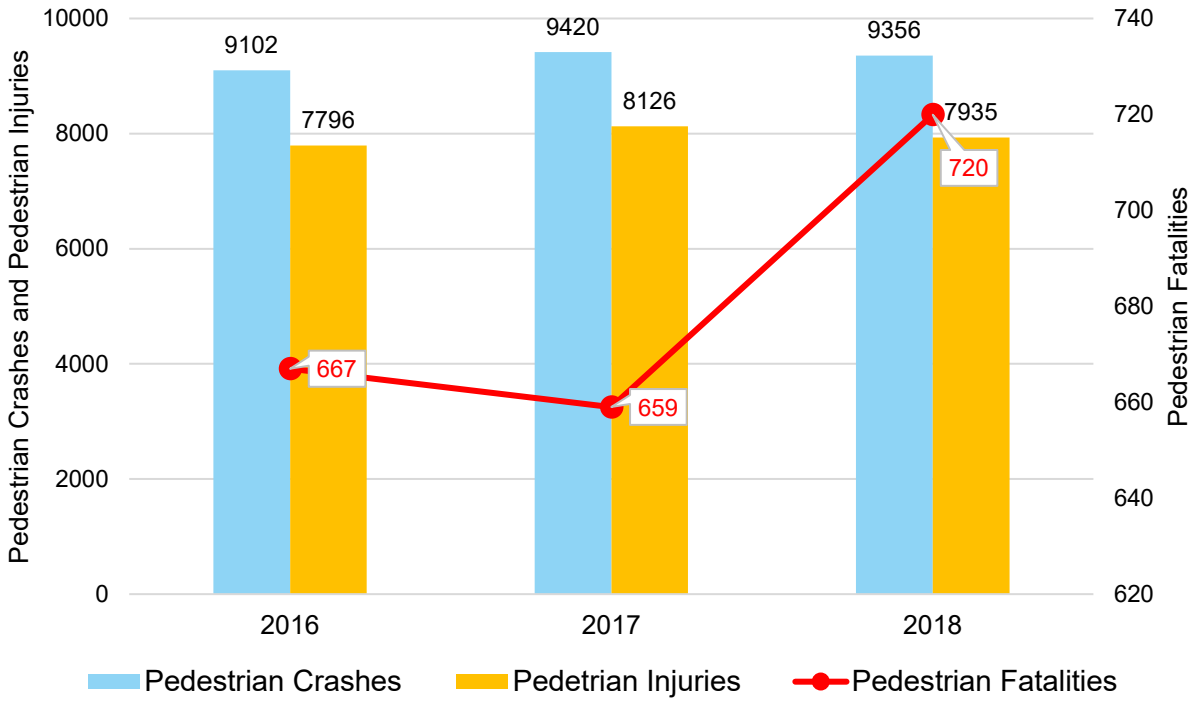
Outline

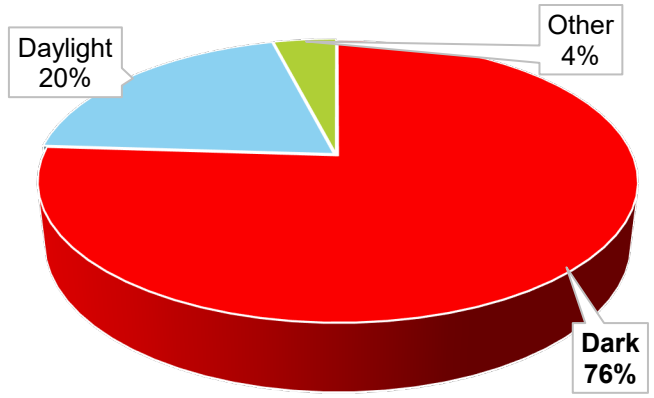
- Pedestrian Nighttime Crash Facts
- Pedestrian Visibility
- Roadway Lighting
- Advanced Lighting Measurement and Analysis
- Applications of Lighting Data in Pedestrian Nighttime Safety Management

Pedestrian Crash Facts

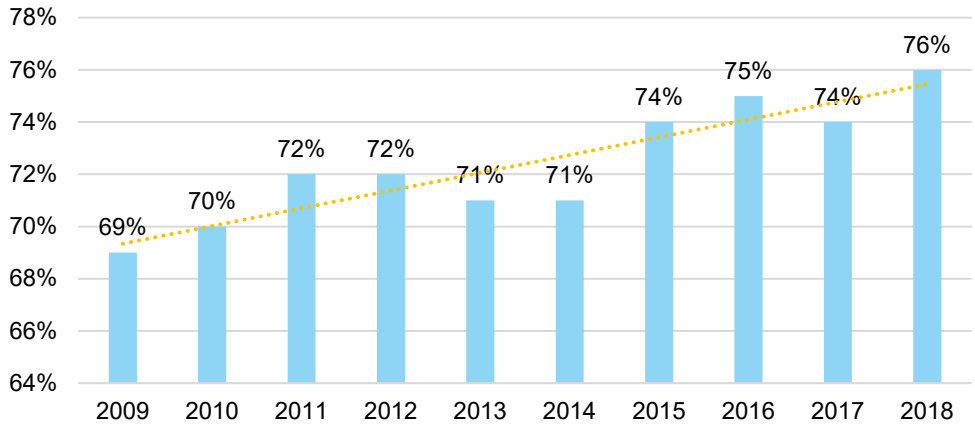


Source: FLHSMV Traffic Crash Facts, 2018

Pedestrian Fatalities by Lighting Condition, 2018



Percentage of Pedestrian Fatalities in the Dark



Source: FARS

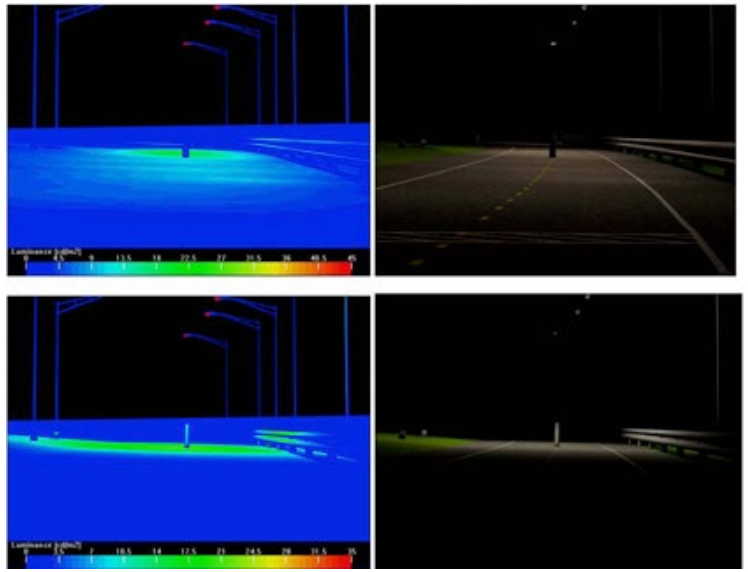
Major Contributing Factors to Nighttime Pedestrian Crashes

- Reduced pedestrian visibility
  - Driver's visual functions are degraded under low luminance conditions
  - The ability to detect and recognize objects is reduced
- Relatively high running speed
  - Few traffic at night
  - Long stopping sight distance is needed
- Pedestrian failed to follow Right-of-Way
- Other factors
  - Impaired driving
  - Drowsy driving

Hillsborough Ave, Tampa, FL

Pedestrian Visibility

- Pedestrian visibility is measured as the distance at which a driver can see a pedestrian to respond appropriately to the pedestrian
- Objects are seen by "**contrast**"
  - The visible difference between an object and its background
  - Luminance contrast is the primary means by which an object is detected
- Factors influencing illuminance contrast
  - **Roadway lighting**
  - Head lighting
  - Pedestrian clothing
  - Background



Luminance Contrast

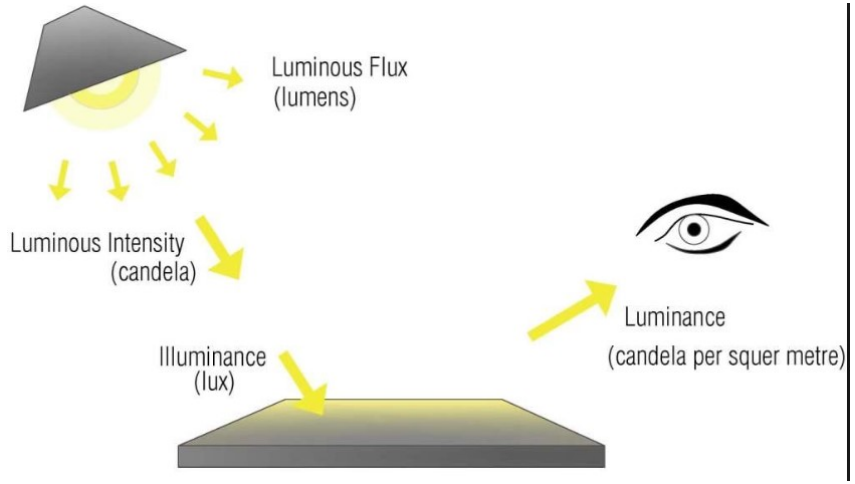
Color Contrast

Roadway Lighting

- Roadway lighting has been recognized as a vital countermeasure to improve pedestrian nighttime safety
  - Increase the visibility of pedestrians
  - Increases sight distance
  - Makes roadside objects more noticeable to the driver
  - Provides clear benefits of personal security for pedestrians during nighttime

Photometric Measures for Street Lighting

- Illuminance
  - The amount of light falling onto a surface, measured 6 inches above ground
  - foot-candles (lumens/ft^2) or lux (lumens/m^2)
- Vertical Illuminance
  - The amount of light landing on pedestrians, measured at 1.5m (face height)
- Uniformity
  - How evenly illumination is distributed along a road
  - Max-min ratio, Avg-min ratio
  - “Poor” lighting uniformity causes drivers’ long adaption and reduce driver vision



https://www.slideshare.net/hrishihrx/luminance-and-illuminance

Source: https://electricalnotes.wordpress.com/2019/06/01/how-to-design-efficient-street-lighting-part-4/

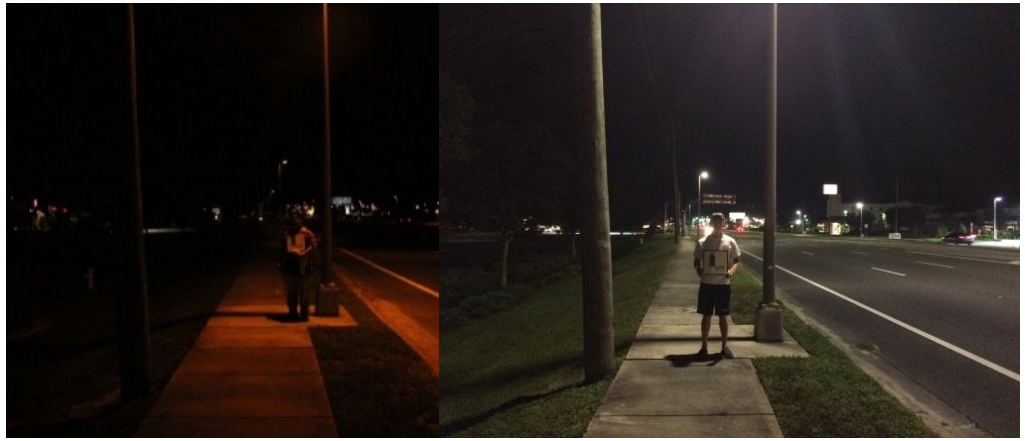
Roadway Lighting Design Standards

Roadway Classification	Average Illuminance Level (foot-candle)		Illumination Uniformity Ratios		Veiling Luminance Ratio
	Horizontal	*Vertical*	*Avg./Min.*	*Max./Min.*	$L_{v(max)}/L_{avg}$
Conventional Roadway Lighting					
Freeway	1.5	N/A	≤ 4:1	≤ 10:1	≤ 0.3:1
Major Arterials	1.5				
Other	1.0				
High Mast Roadway Lighting					
All Roads	0.8 – 1.0	N/A	≤ 3:1	≤ 10:1	N/A
Signalized Intersection Lighting					
New Construction	3.0	2.3	≤ 4:1	≤ 10:1	N/A
Lighting Retrofit	1.5 (std.) 1.0 (min.)	1.5 (std.) 1.0 (min.)			
Midblock Crosswalk Lighting					
Low Ambient Luminance	N/A	2.3	N/A	N/A	N/A
Medium & High Ambient Luminance		3.0			

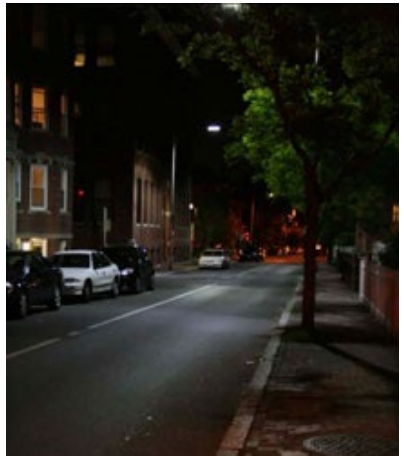
Source: FDOT Design Manual, Table 231.2.1

Lighting Level Monitoring and Maintenance

- Ensuring adequate illumination is critical to improve nighttime safety and security for pedestrians
- Roadway lighting illumination performance may deteriorate over time
- Possible causes
  - Natural bulb degradation and damage
  - Obstacles
  - External lighting resources
- A periodic lighting level checking is necessary



Comparison of lighting upgrade on Wesley Chapple Blvd, Tampa, Florida



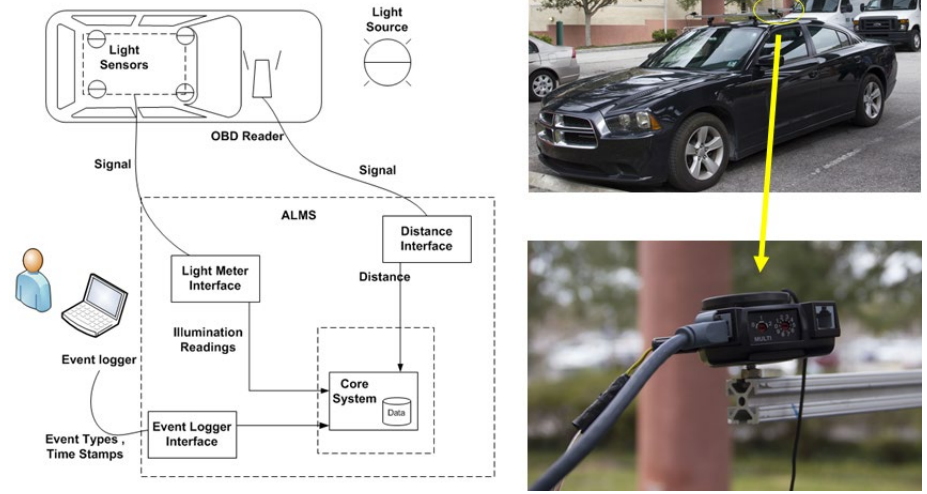
Source: FHWA Lighting Handbook

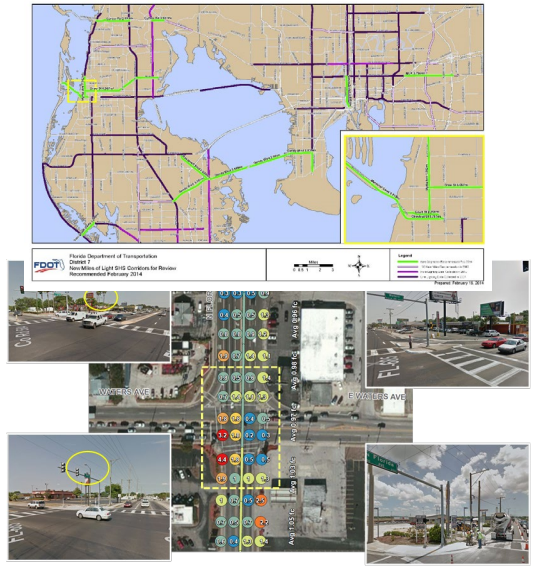
Advanced Lighting Measurement Technologies

- Traditional “manual” lighting measurement
  - Costly (**$5,000+/mile**)
  - Worker safety concerns
  - Driver safety concerns
  - Manpower
  - Accuracy/reliability

- Advanced lighting measurement System (ALMS)
  - Developed by CUTR
  - High-resolution (multiple readings per 10 feet per lane)
  - High efficiency (speed ≤ 80 mph)
  - Low cost ($300/mi)
  - Proactive Pedestrian Safety Management

http://its.cutr.usf.edu/alms

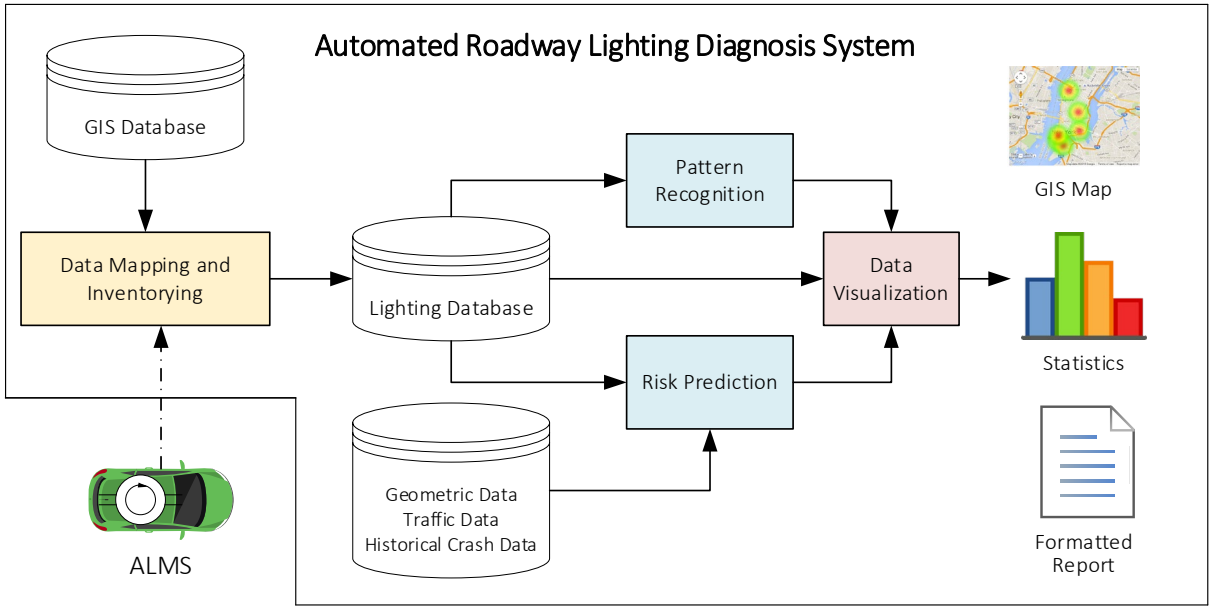


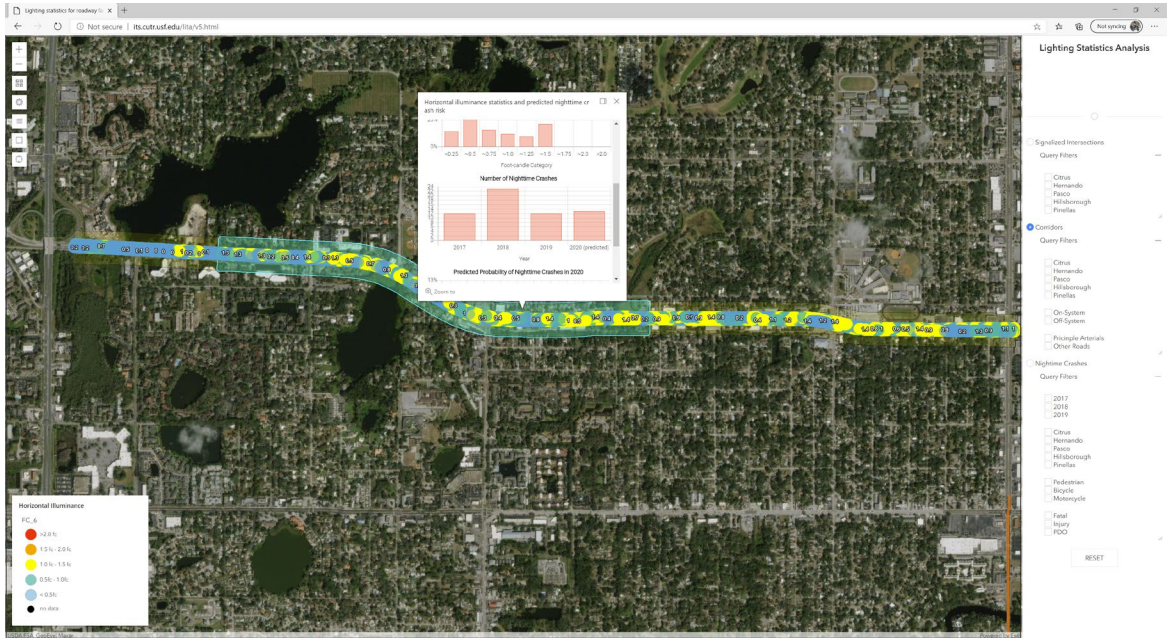


Lighting Data Analysis Tools

- A Web-GIS application to analyze “big” lighting data
- http://its.cutr.usf.edu/lita

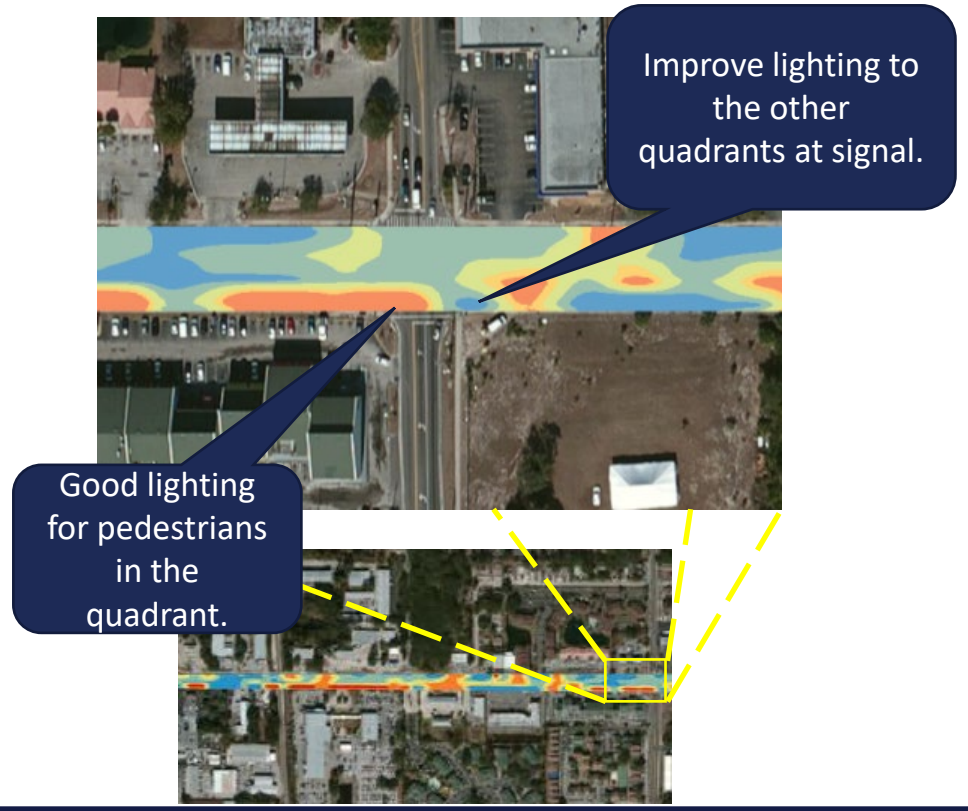
Function	Algorithm/Technology	Description
Lighting Pattern Diagnosis	Hierarchical Clustering Model	Distinguish lighting patterns that do not satisfy FDOT standards
Crash Risk Prediction	• Safety Performance Function • Empirical Bayesian Model • CMF developed by Case-Control Study	• Predict nighttime crash frequency by lighting, traffic, and geometry conditions • Estimate nighttime crash reduction due to lighting pattern improvement
Data Visualization	Web-GIS	Present analysis results on GIS map



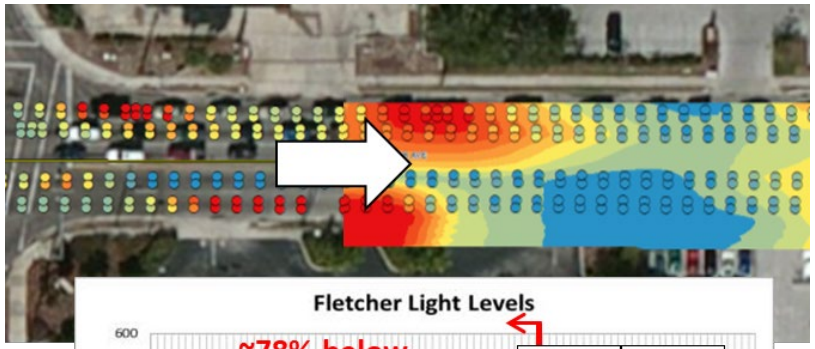


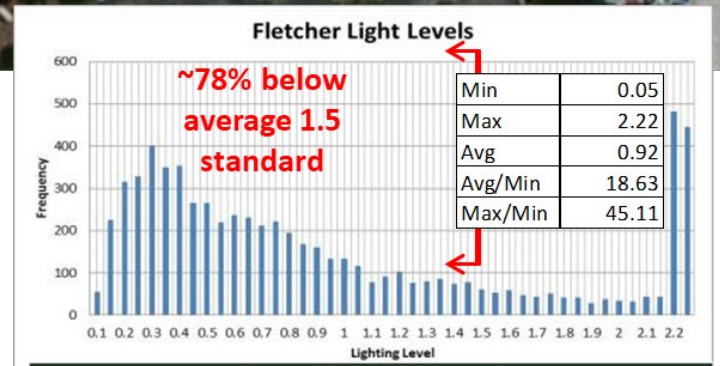
Applications – Lighting Level Assessment

- Lighting level data showed lighting variance at intersection quadrants.



- Determine corridor lighting levels

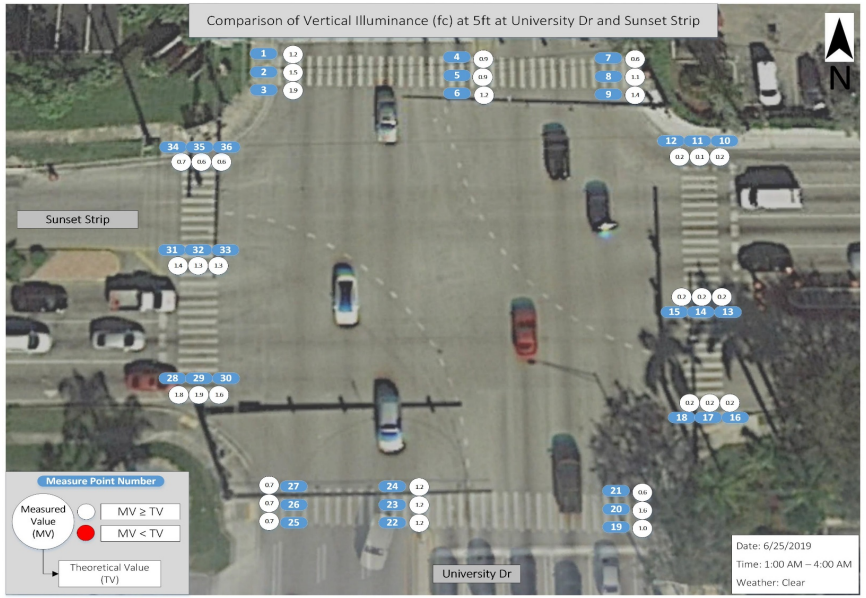


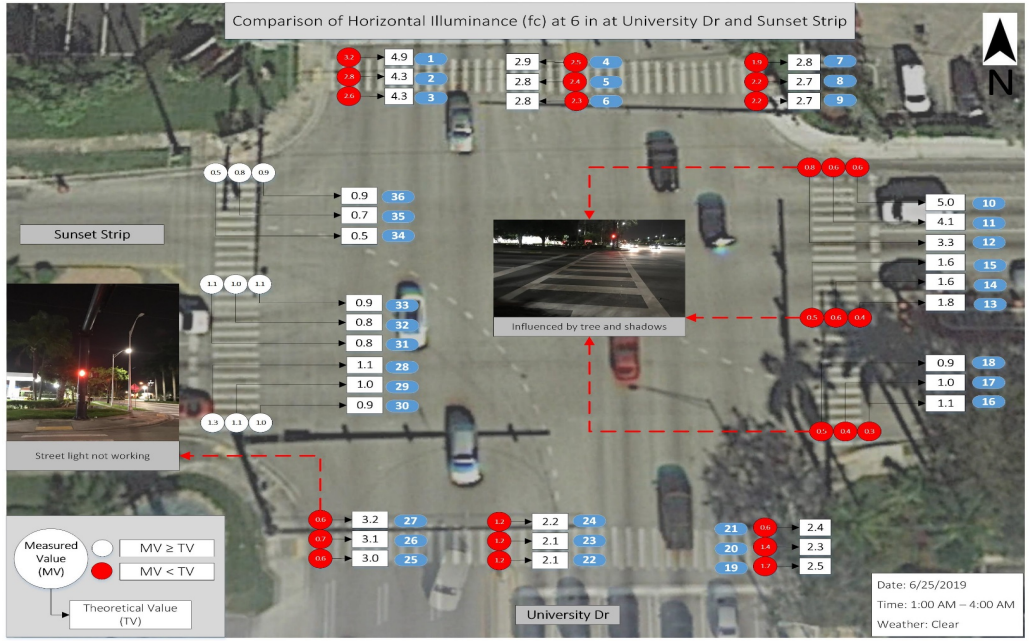


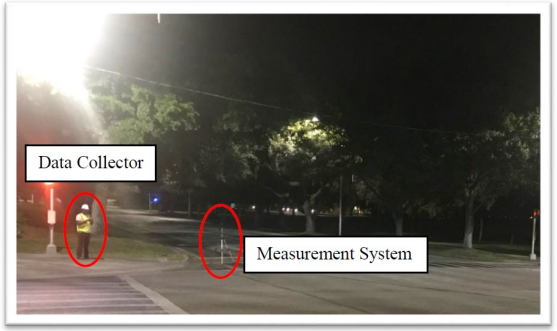
Road Classification	Illumination Level Average Initial Horizontal Foot Candle (HFC)	Avg/ Min	Max/Min
Interstates, Expressways, Freeways, and Major Arterials	1.5	4:1 or less	10:1 or less
All other Roadways	1.0	4:1 or less	10:1 or less
Pedestrian Ways and Bicycle Lanes	2.5	4:1 or less	10:1 or less

Application – Validating Intersection Lighting Retrofits

- FDOT is conducting lighting retrofit projects at more than 2,000 signalized intersection for pedestrian safety
- New and reconstructed signalized intersections with crosswalks will have vertical illumination
- A quality assurance review of intersection lighting retrofits is crucial.



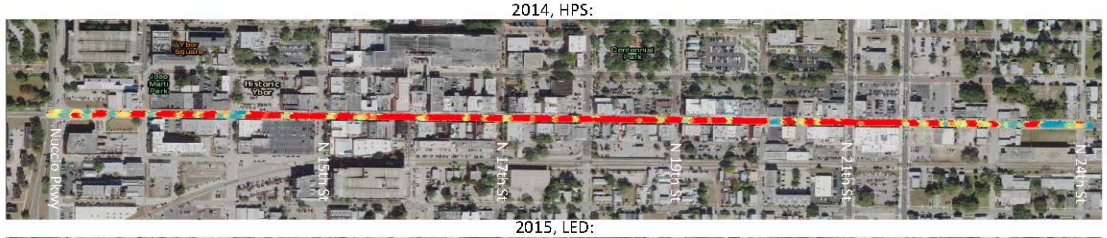




Application – LED and HPS Comparison

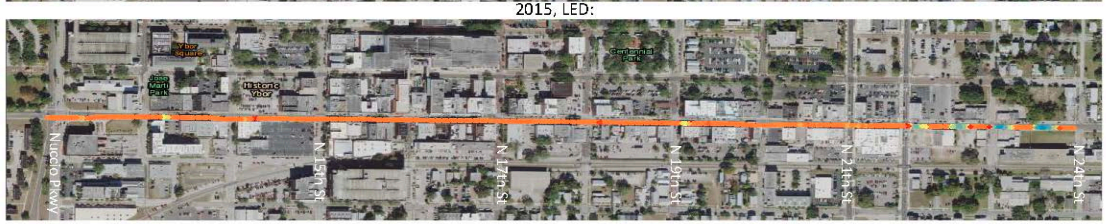
Street Lighting Level Measurement (foot candle) on 7th Avenue E

2014, HPS:



Max	2.29
Min	0.01
Avg	1.71
Avg/Min	106.88
Max/Min	143.06

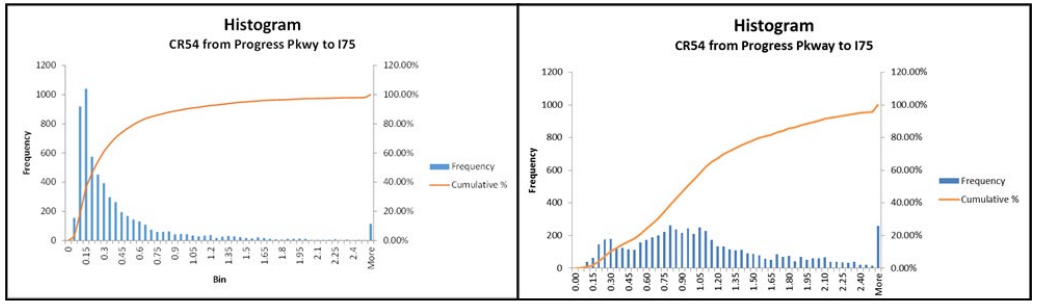
2015, LED:



Max	1.41
Min	0.13
Avg	1.30
Avg/Min	9.74
Max/Min	10.52

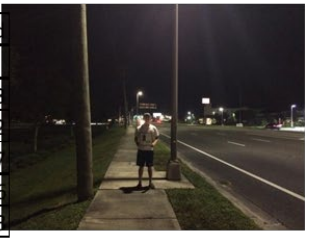
2019, LED:

Max	1.41
Min	0.15
Avg	1.32
Avg/Min	8.77
Max/Min	9.40

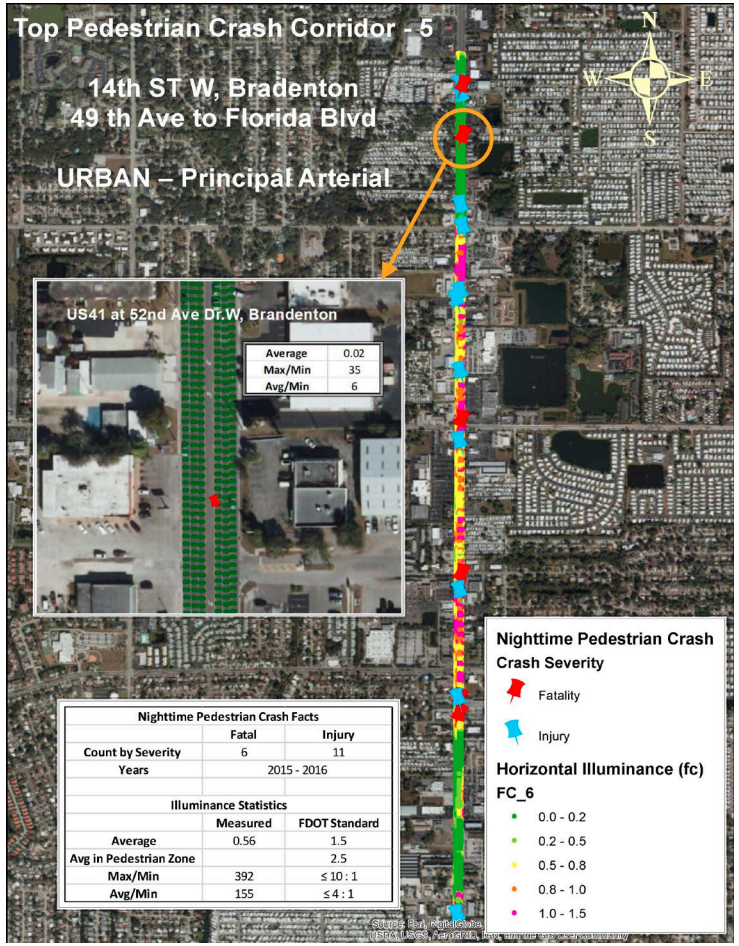


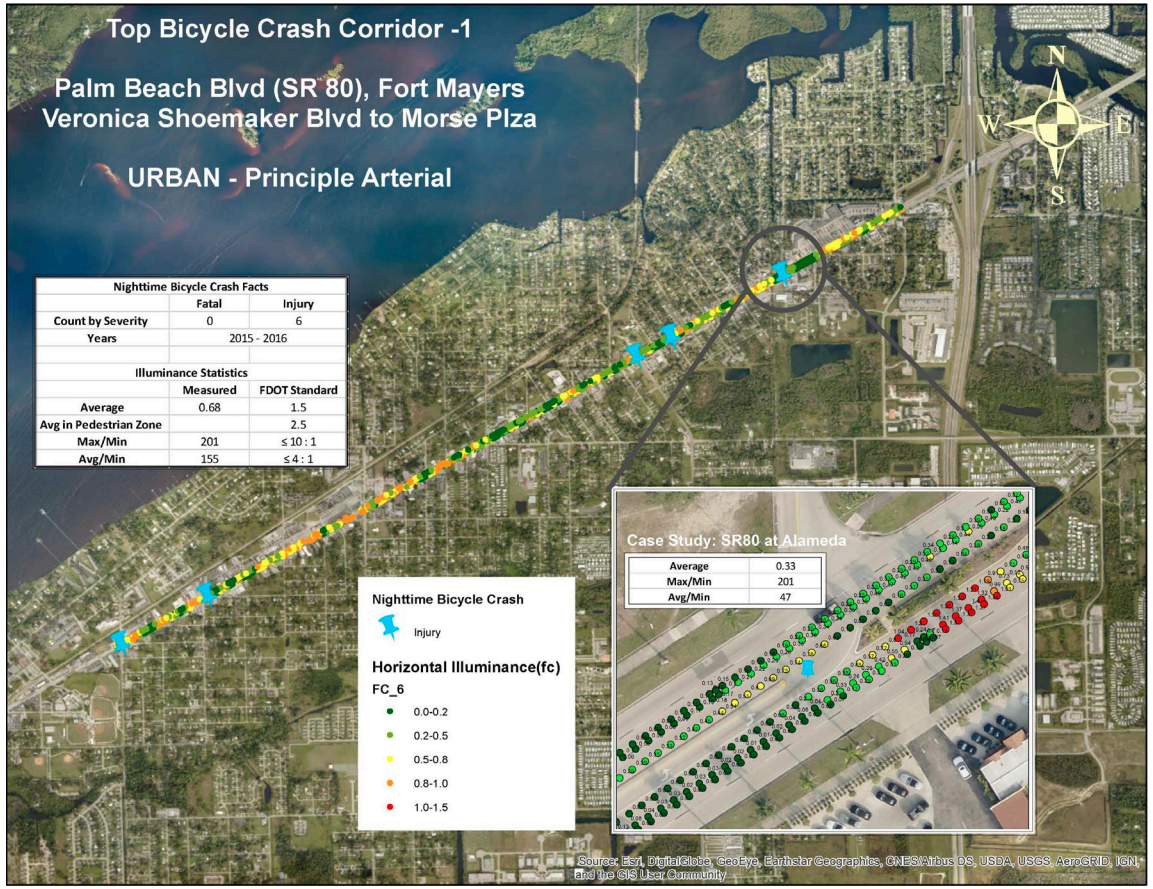
Wesley Chapel Blvd	
HPS	
Min	0.03
Max	4.05
Avg	0.43
Avg/Min	13.29
Max/Min	126.69

Wesley Chapel Blvd	
LED	
Min	0.03
Max	2.92
Avg	1.07
Avg/Min	35.66
Max/Min	97.33



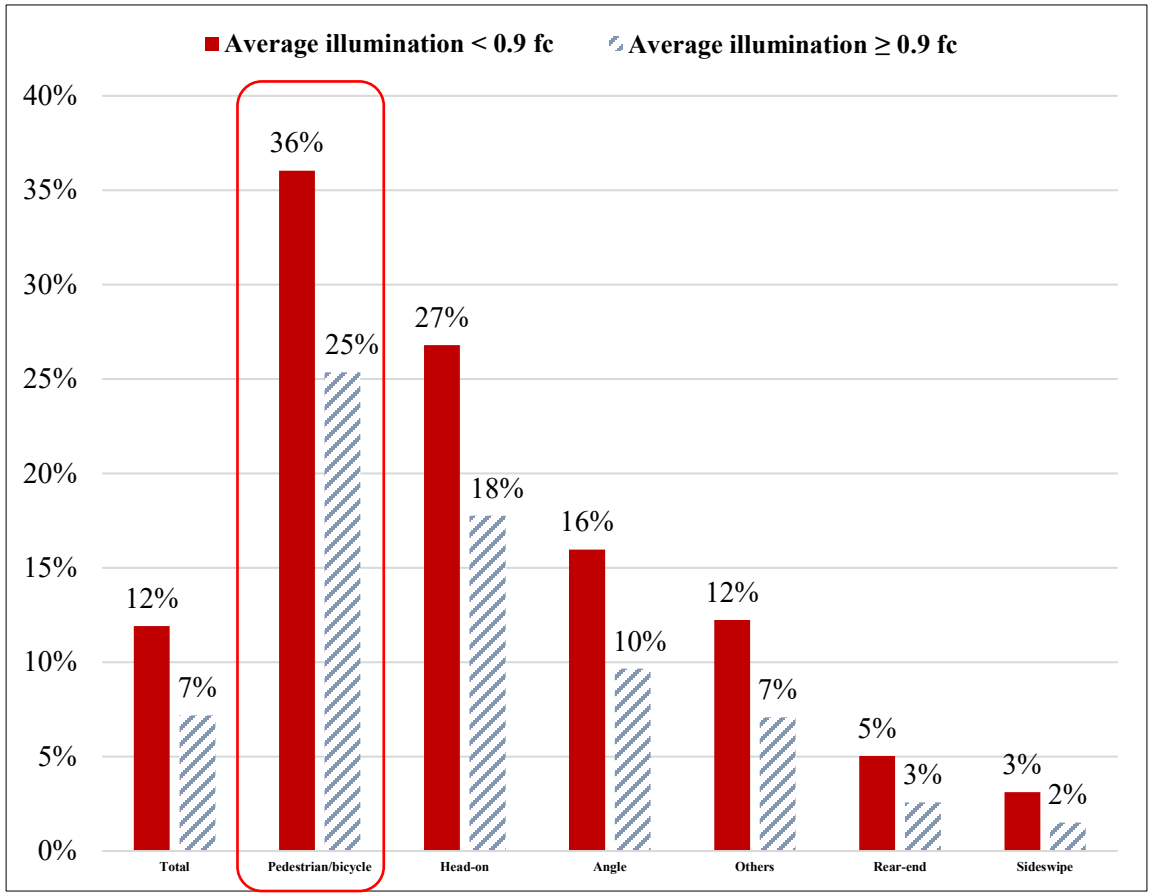
Application – Lighting Diagnosis for Pedestrian Crashes





Application – Pedestrian Nighttime Safety Analysis

Probability of Fatality and Severe Injury by Crash Types



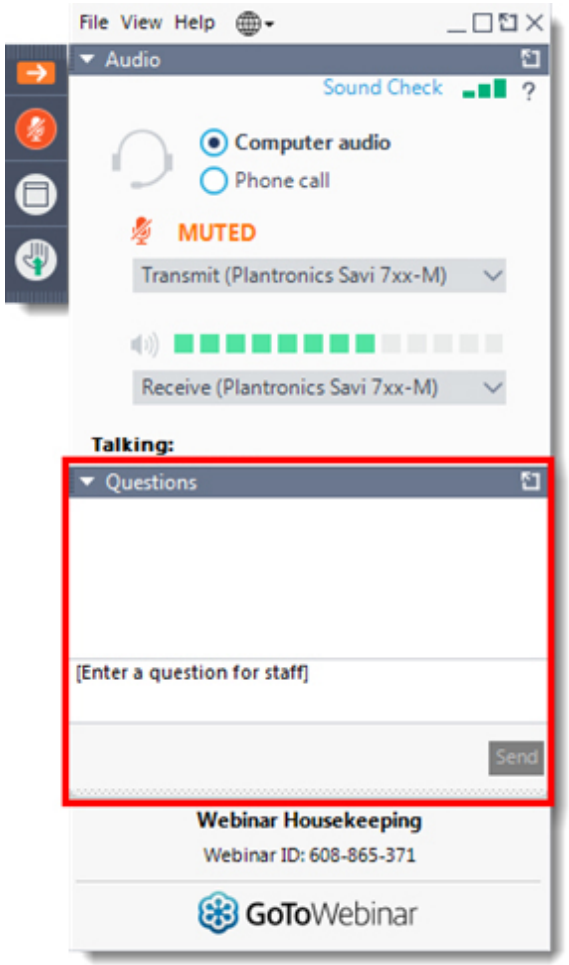
CMF for Vehicle Crashes

CMFs for Lighting Patterns on Corridors
from a matched case-control study

Lighting Statistics	Change	CMF	95% CI for CMF
Mean of horizontal illuminance (fc)	< 0.5 fc → (0.5 fc, 1.0 fc)	0.679	[0.468, 0.984]
	< 0.5 fc → > 1.0 fc	0.581	[0.367, 0.922]
Uniformity Max-Min Ratio	> 10 → < 10	0.719	[0.533, 0.970]

- CMFs for Pedestrian Crashes are in developing

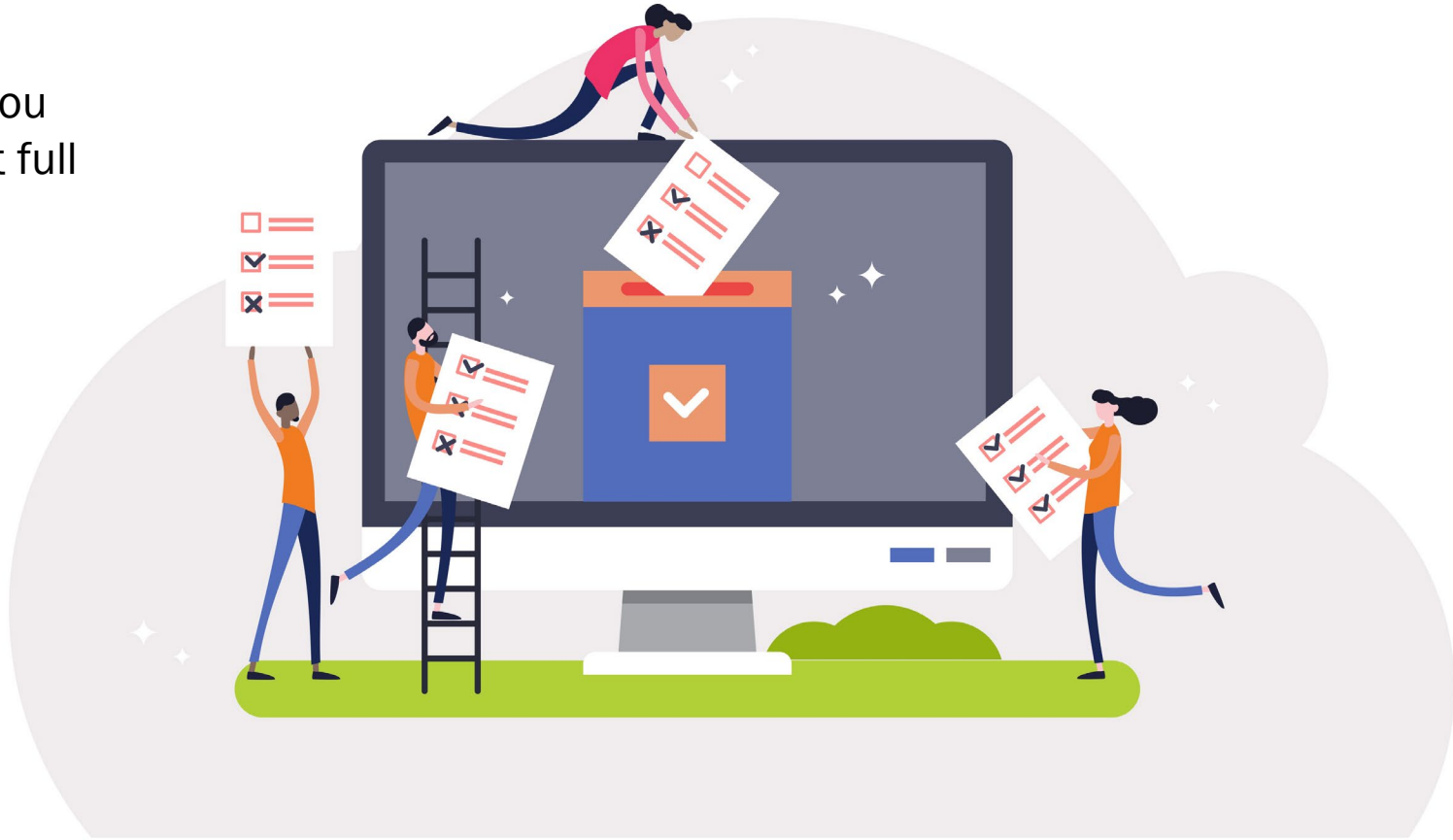
Questions?



Send follow-up questions to:
FloridaLTAP@cutr.usf.edu

Poll Question

Cast your vote on-screen.
If you are in full-screen mode, you may need to press “ESC” to exit full screen mode in order to vote.



THANK YOU

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