Impact of Roadway Lighting on Nighttime Crash and Driver Performance

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SHRP 2 Implementation Assistance Program Round 4- FHWA Administration

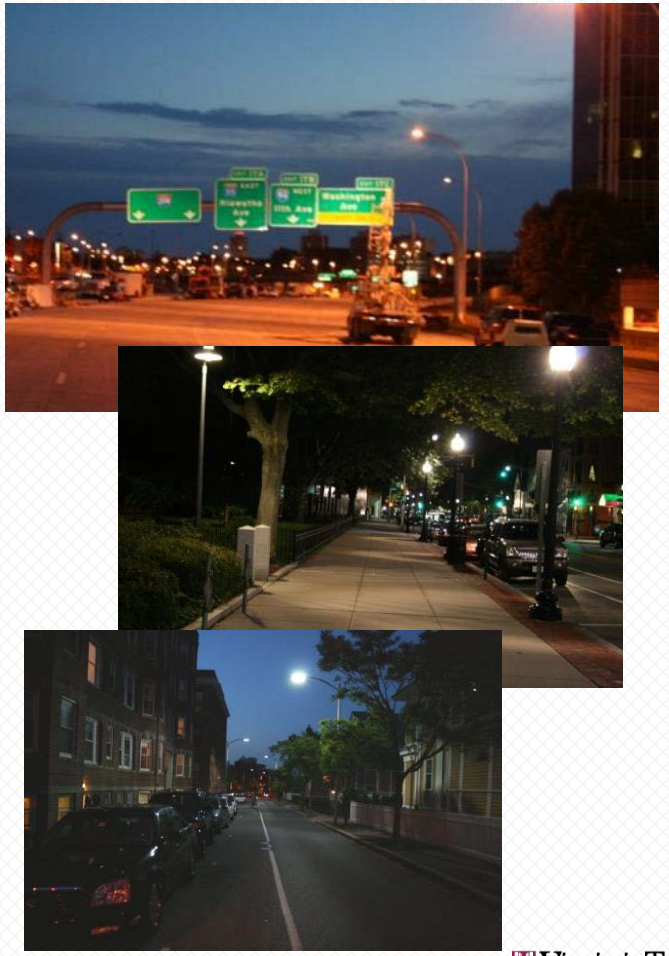
National Surface Transportation Safety Center for Excellence (NSTSCE)

Contents

- Background & Objective
- Research Approach
- Results of Phase I
- Preview of Phase II

Roadway / Street Lighting

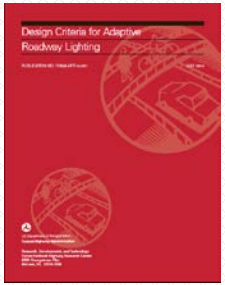
- **Roadway Lighting**
  - Freeways, Expressways and limited-access roadways
    - remain on the roadway, obstacle detection within and beyond the range of vehicle headlamps
- **Street Lighting**
  - *Major roads, collector, and local roads*
    - identify obstacles, adequate visibility of pedestrians and cyclists, and support visual search tasks
  - *Residential*
    - primarily pedestrians safety

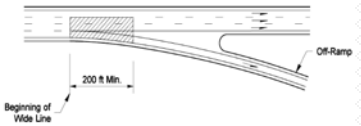


Lighting Design Process

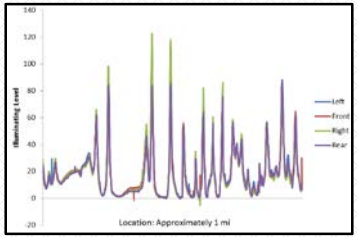
- **Lighting Warrants**
- **Design Criteria**
  - IESNA RP-8-2014,
    - AASHTO 2005
      - Ramp traffic
      - Commercial development
      - Crash Ratio
    - CIE 115
  - Lighting Metrics
- **Lighting System Selection**

What do we know already?





How we can use NDS and Lighting Data to provide new insights?



Nighttime fatal crash rate three times higher than daytime

Objective

Exploring the feasibility of using SHRP2, VTTI in situ field lighting measurement and RID databases to study safety effects of lighting on nighttime traffic at freeway ramp locations

Research questions

- Roadway lighting impacts on driver behavior
- Roadway lighting impacts on different roadway configurations
- Recommended lighting design to ensure safety performance

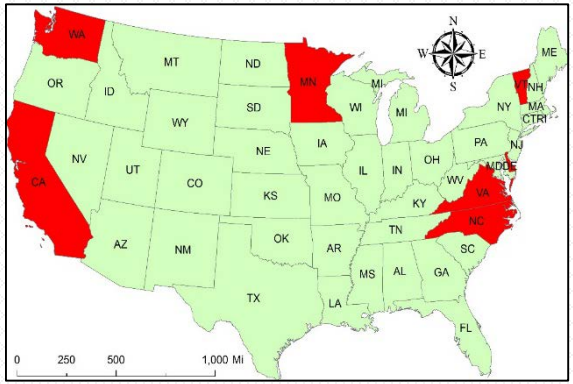
Three Approaches

- Time Series Data
- Event Data
- Crash Data

Events

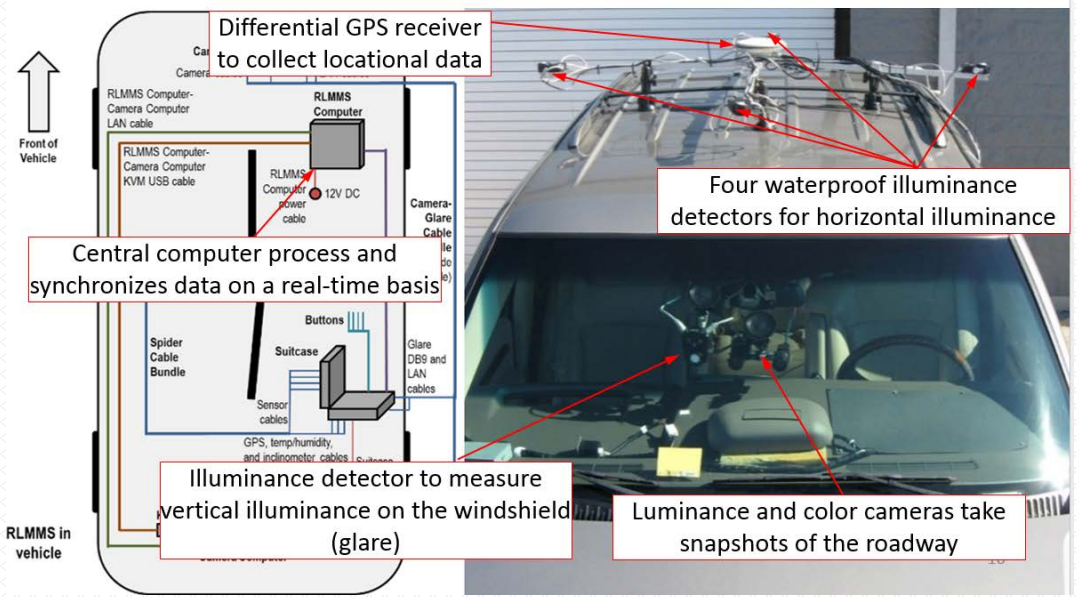
- Crashes, near crash, and baseline event records
- Events by type and severity
- Event viewer

VTTI In-Situ Lighting Data

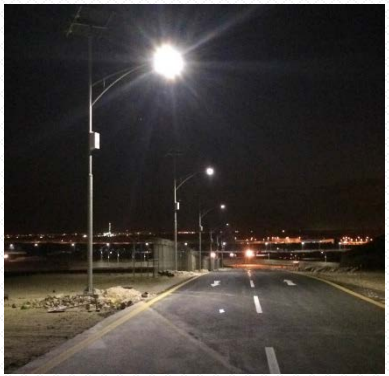


Roadway Type	CA	DE	MN	NC	VA	VT	WA	Total
Interstate	160	41	68	167	372	22	151	981
Other Freeways	77	27	27	59	61	7	101	359
Other Principal Arterial	31	155	7	51	102	47	98	490
Minor Arterial	--	47	51	30	52	25	28	232
Major Collector	--	--	--	9	26	--	16	52
Total	269	269	153	317	613	100	394	2,114

Roadway Lighting Mobile Measurement System (RLMMS)



Lighting Metrics



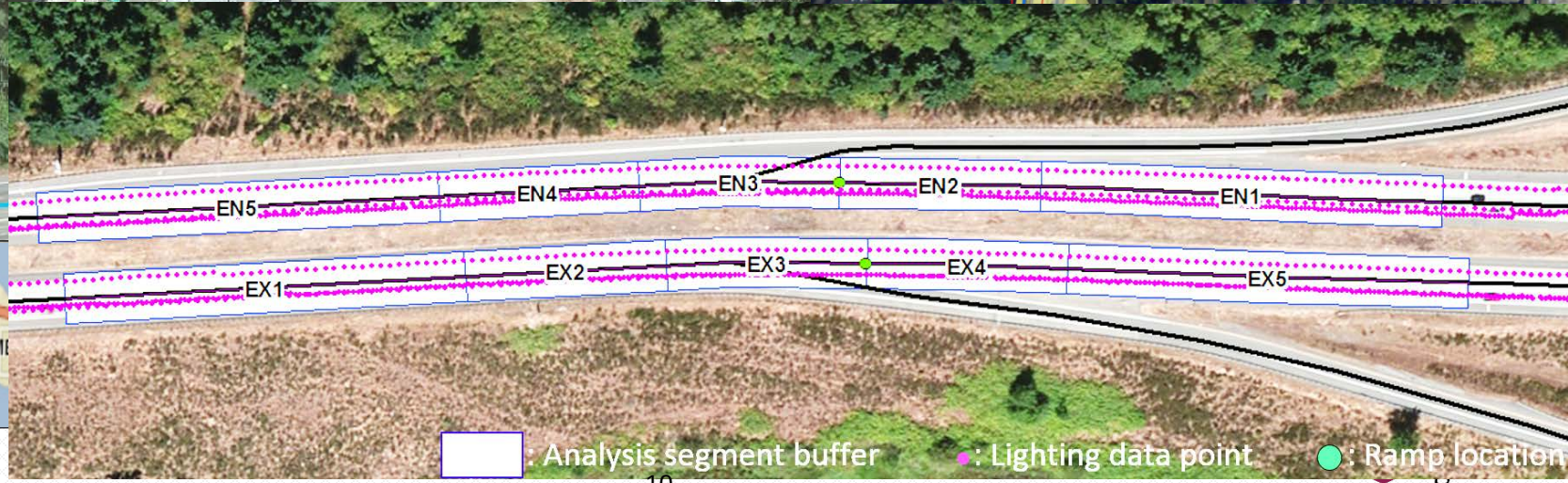
- Luminance
  - Luminance is the amount of light that reflects from a surface in the direction of the observer.
- Illuminance
  - Illuminance is the amount of light that falls onto a surface (lux-lumens/m2) Horizontal illuminance good indicator of overall lighting at the road surface
  - Vertical illuminance important indicator for determining glare and the amount of light landing on pedestrians

Project

- Horizontal illuminance
- Lighting uniformity
  - Is the ratio of the Average to the Minimum horizontal illuminance

Data Used for Phase I

Data Type	Sample Size	Description
Ramp data	Ramps mostly on two 10-mile freeway segments	Ramp type, main lane alignment, number of main lanes, number of ramp lanes, auxiliary lane length
Lighting data	Right lane and overall lighting measurements	Lighting data were based on field lighting measurements by VTTI
Time series data	1.8 million data points, 58,467 records, 1,270 trips, 313 drivers	Time series data were matched to lighting data using GIS. The large amount of data required significant computing resources and time
Events data	31 suitable events at interchange areas	Selected night-time events at interchange areas in Washington
RID crash data	46 ramp segments for analysis, 69 night crashes	2011-13 crash data used for analysis. Only a limited number on analysis segments


EN5
EN4
EN3
EN2
EN1
EX1
EX2
EX3
EX4
EX5
: Analysis segment buffer
: Lighting data point
: Ramp location

SHRP 2 Time Series Data Analysis

Speed and speed variance

Longitudinal acceleration

Lateral acceleration

Lane offset

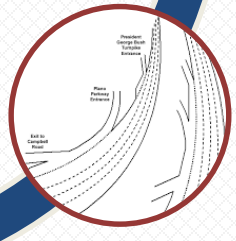
Driver head position and rotation

Time to collision

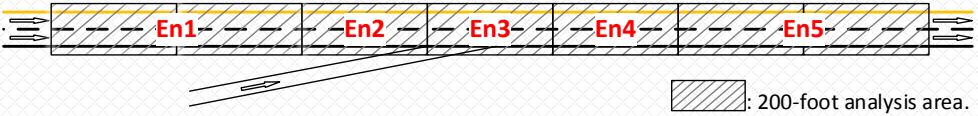
Surrogate Safety Measures

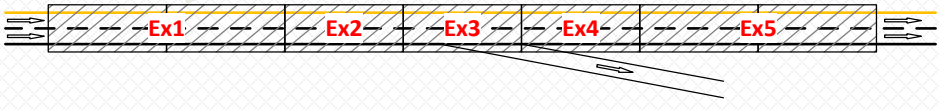
Entrance vs. Exit ramps

Through traffic vs. ramp traffic



No. of lanes
Auxiliary lane
Alignment
etc.

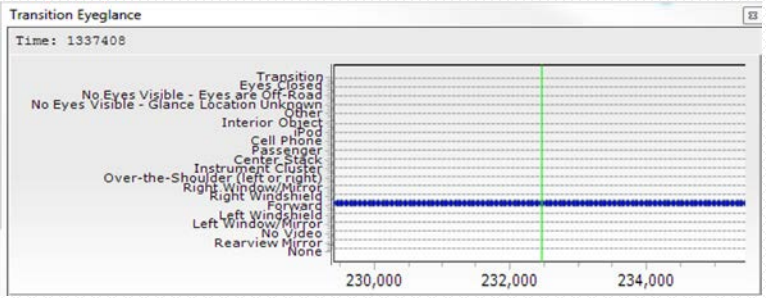


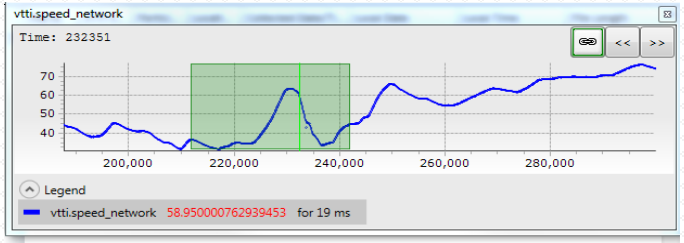


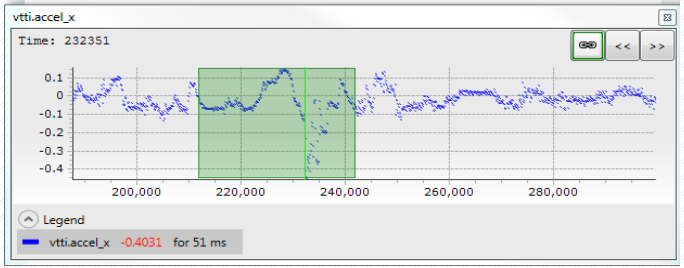
: 200-foot analysis area.

Event and Crash Data Analysis

- **Event analysis**
  - Event detail data and video data







- **RID crash data analysis**
  - Night-day crash ratio and proportion of severe crashes
  - Random parameter and regular negative binomial regression

Time Series Analysis **Results** – Entrance Ramp

Entrance Ramp: Driver Behavior - <u>Increase in Illuminance</u>

Analysis Segment	Traffic Type	Right-Lane Illuminance					Overall Illuminance				
		EN1	EN2	EN3	EN4	EN5	EN1	EN2	EN3	EN4	EN5
Speed	Ramp	-	-	↘	↘	NS	-	-	NS	↗	NS
	Through	NS	NS	NS	NS	NS	NS	NS	↗	NS	NS
Longitudinal Acceleration Rate	Ramp	-	-	↗	↗	↗	-	-	↗	↘	↘
	Through	NS	NS	NS	↗	↗	NS	NS	NS	↘	↘
Longitudinal Acceleration Variance	Ramp	-	-	NS	NS	NS	-	-	NS	NS	NS
	Through	NS	NS	NS	↘	NS	NS	NS	NS	NS	NS
Lateral Acceleration Rate	Ramp	-	-	↘	↘	↘	-	-	↗	↗	NS
	Through	↘	NS	↘	NS	↘	↗	NS	↗	↗	↗
Lateral Acceleration Variance	Ramp	-	-	NS	NS	NS	-	-	NS	NS	NS
	Through	NS	NS	↘	NS	NS	NS	NS	↗	NS	NS
Lane Offset	Ramp	-	-	NS	NS	↘	-	-	NS	NS	↗
	Through	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Time Series Analysis Results – Entrance Ramp

Entrance Ramp: Driver Behavior - Increase in Uniformity

Analysis Segment	Traffic Type	Right-Lane Uniformity					Overall Uniformity				
		EN1	EN2	EN3	EN4	EN5	EN1	EN2	EN3	EN4	EN5
Speed	Ramp	-	-	NS	NS	↗	-	-	NS	NS	↗
	Through	↗	NS	NS	NS	NS	NS	NS	NS	NS	NS
Longitudinal Acceleration Rate	Ramp	-	-	NS	↗	↘	-	-	NS	NS	↘
	Through	NS	NS	NS	↗	NS	NS	NS	NS	NS	↘
Longitudinal Acceleration Variance	Ramp	-	-	NS	NS	NS	-	-	NS	NS	NS
	Through	NS	NS	NS	NS	NS	↗	NS	NS	NS	NS
Lateral Acceleration	Ramp	-	-	NS	NS	↗	-	-	NS	NS	NS
	Through	↘	NS	↘	↘	NS	↘	NS	NS	↗	↗
Lateral Acceleration Variance	Ramp	-	-	NS	NS	NS	-	-	↗	NS	NS
	Through	NS	NS	↘	NS	NS	NS	NS	NS	NS	NS
Lane Offset	Ramp	-	-	NS	NS	↗	-	-	NS	NS	↗
	Through	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Time Series Data Analysis Results

- Illuminance seemed to have more impact than uniformity
- Lighting effects seemed to be more evident for entrance than exit ramps
- Higher right-lane illuminance and uniformity correlated with lower speed, and fewer/less abrupt lane changes
- Higher overall illuminance and uniformity likely resulted in more lane changes and higher speeds
- Lighting effects were more evident on segments prior to ramps for exiting ramps and after ramps for entrance ramps

Time Series Data Analysis Results (cont.)

- Effects of lighting likely extended to more than 400 ft. from painted gore nose
- Lighting effects were more evident for drivers over 50 and on segments with complex geometries
- In most cases, main lane and ramp geometric characteristics had significant impact on driver behavior
- Most lighting effects were on speed, longitudinal and lateral acceleration, and lane offset
- No significant correlations found for lighting effects on head movements and time to collision

Current Research - Phase II Data

Data Type	Proposed Data for Phase II
Ramp data	300 ramps from 30 roadway corridors and 50 intersections in different geographic regions and with different roadway configurations (WA and NC)
Time series data	30 trip segments for each of the 300 ramps and 50 intersections, including 25 nighttime trips and 5 daytime non-peak hour trips
Events data	All nighttime crashes (17), near crashes (87), and 200 baseline events that are interchange or ramp related; All nighttime crashes (125) and nighttime near crashes (160) and 200 baseline events at intersections
Eye glance data	1,000 time series trips randomly selected for the studied ramps and 500 trips for the 50 intersections; All studied crashes and near crashes and baseline events
Crash data	2010-2014 crashes on the selected ramps and intersections

SHRP2 Naturalistic Data value

- Thorough understanding of how roadway lighting influences driver behavior.
- Detailed lighting design guidelines
  - Required minimum values for specific lighting metrics (illuminance and uniformity)
  - Most cost-effective locations to apply lighting
  - Critical points/sections to be lit at specific locations
  - Lighting transition design
  - Warranties and criteria

Potential recommendations:

- Safety performance of higher right-lane lighting levels at ramp locations
- Determination of lighting needs upstream of exit ramps or downstream of entrance ramps
- Consider controlling design minimums where complex roadway features are located
- Safety performance of lighting as a function of traffic volume

- Great potential to improve current National and State lighting design guidelines and relevant manuals

Questions?

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