

Guidelines for Nighttime Visibility of Overhead Guide Signs

**Report Number 828
NCHRP Project 05-20**

TRB Webinar – March 2017

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Objectives

- ◉ When is sign lighting needed?
- ◉ How much is needed?



Research Approach

- Background
 - › National policies / guidelines
 - › Sign sheeting materials
 - › Sign lighting options
- Visual Complexity
- Closed-Course Legibility Study
- Open-Road Recognition Study
- Recommendations
- Implementation

Current MUTCD Language (2009 Edition)

Section 2E.06:

Overhead sign installations should be illuminated unless an engineering study shows that retroreflectorization alone will perform effectively. The type of illumination chosen should provide effective and reasonably uniform illumination of the sign face and message.

Current AASHTO Guidelines

- *Sign Lighting is not needed when:*
 - *The sign is in an area that contains a low-to-intermediate ambient light level, and*
 - *There is at least 1200 feet (366 meters) or more of tangent sight distance in advance of the overhead sign.*

Ambient Luminance	Sign Illuminance		Sign Luminance**	
	Footcandles	Lux	Candelas per Square Meter	Candelas per Square Foot
Low	10–20	100–200	22–44	2.2–4.4
Medium	20–40	200–400	44–89	4.4–8.9
High	40–80	400–800	89–78	8.9–17.8

* Adapted from *The IESNA Lighting Handbook, Reference & Application*, 9th Edition, Illuminating Engineering Society of North America. Used by permission.

** Based on a maintained reflectance of 70 percent for white sign letters.

Current IESNA Guidelines

- No warrants but photometric recommendations:

Ambient Light Level	Sign Illuminance		Sign Luminance*	
	Footcandelas	Lux	Candelas per meter square	Candelas per feet square
Low	13	140	20	1.9
Medium	26	280	40	3.7
High	52	560	80	7.4

* Based on maintained (diffuse) reflectance of 45 percent for white legend

Current Sign Legend

Luminance Recommendations

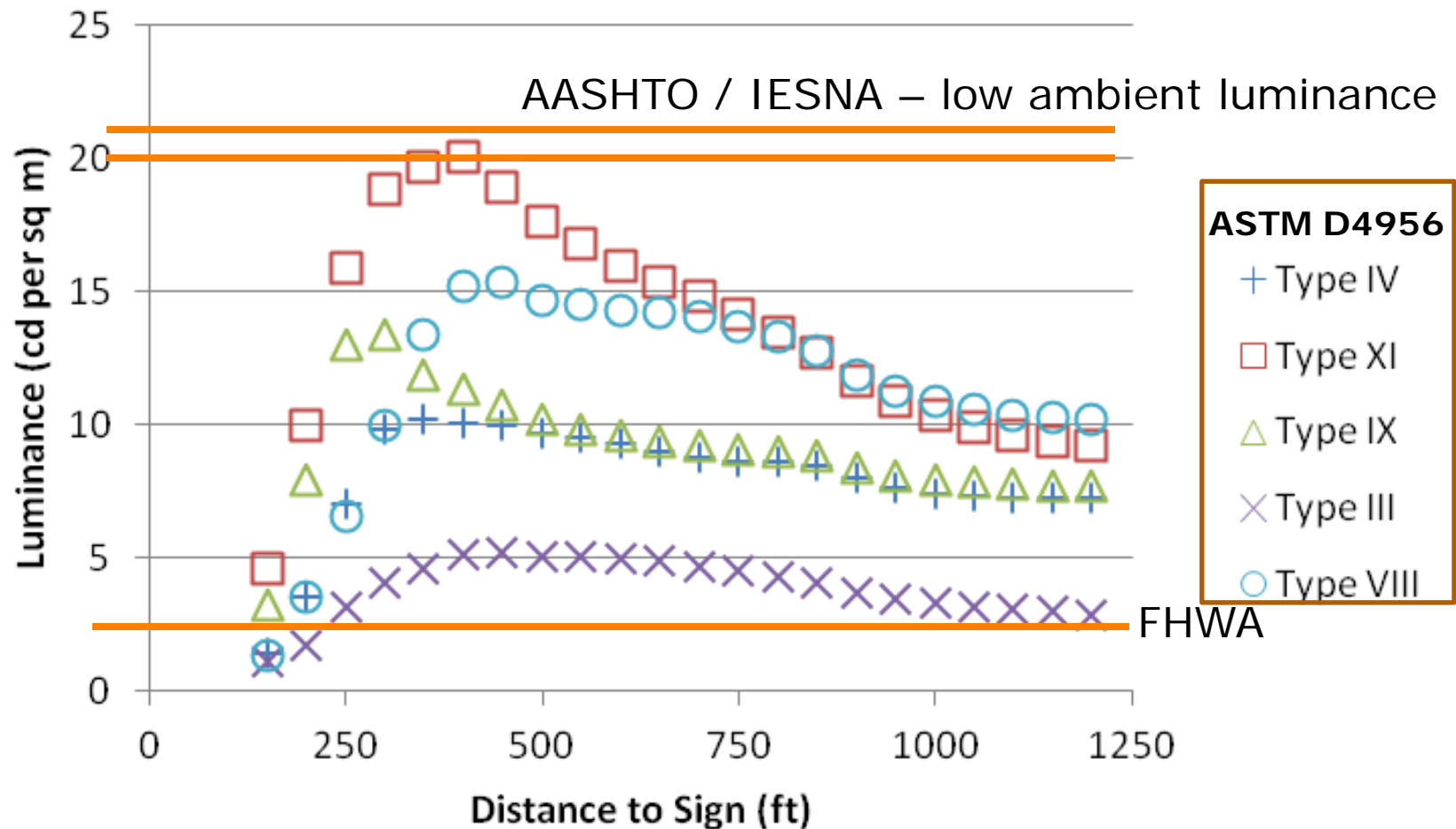
Ambient Luminance	AASHTO*	IESNA*
Low	22-44	20
Medium	44-88	40
High	88-176	80

* cd/sq m

- FHWA minimum retroreflectivity levels derived from luminance of 2.3 cd per sq m
 - Based on dark rural conditions (i.e., low ambient luminance)

Lack of Clarity

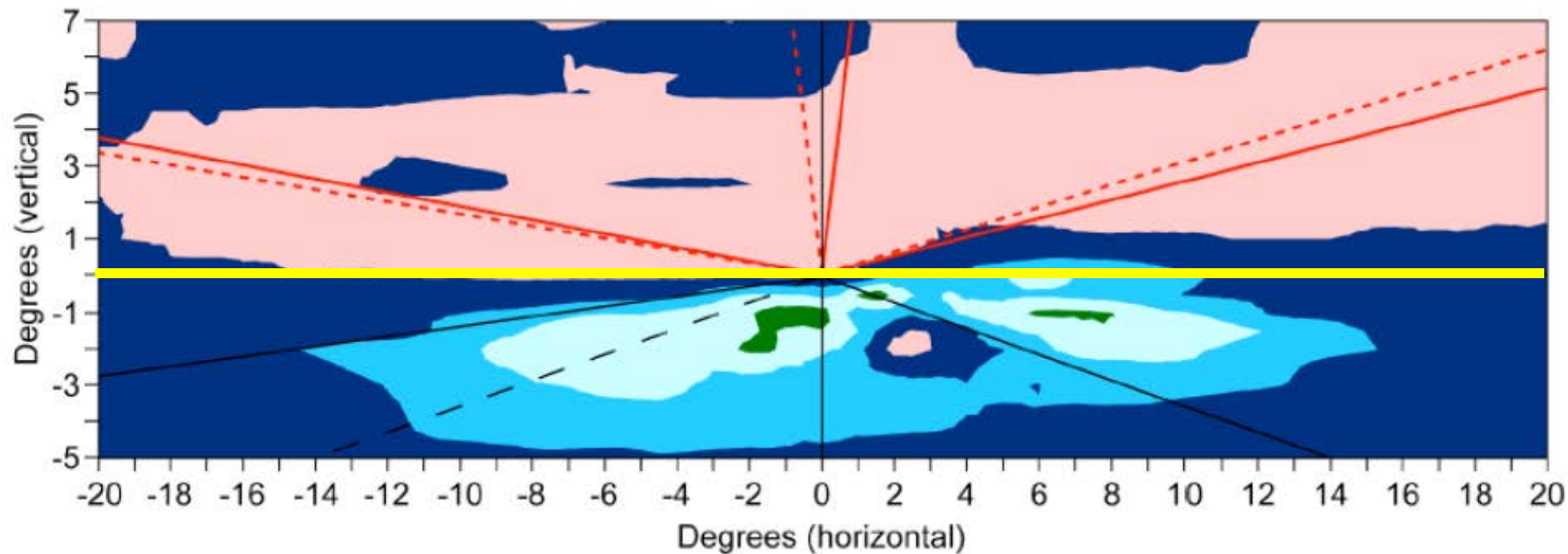
Typical Overhead Guide Sign



State DOT Lighting Practices

- Trend to reduce or eliminate lighting
- Some concerns that lighting may be needed
 - Dew
 - Fog
 - Snow
 - Road geometry
 - Visually Complex areas

Headlamp Trends



Candela differences		
□ -4000 to 0	■ 0 to 4000	□ 4000 to 8000
□ 8000 to 12000	■ 12000 to 16000	

Sign trajectories	
— Left lamp	- - - Right lamp

Sign Sheeting Materials (2014)

2014 Traffic Sign Retroreflective Sheeting Identification Guide



This document is intended to help identify sign sheeting materials for rigid signs and their common specification designations. It is not a qualified product list. FHWA does not endorse or approve sign sheeting materials. Many other sheeting materials not listed here are available for delineation and construction/work zone uses.

Many sign sheeting materials have watermarks and/or patterns that are used to identify the material type and manufacturer. The watermarks shown in this guide have been enhanced. The watermarks will be less visible in practice and may not be present on smaller pieces of sheeting due to the spacing.

Retroreflective Sheeting Materials Made with Glass Beads

Example of Sheeting (Shown to scale)								
ASTM D4956-04	I	II	II	III	III	III	III	III
ASTM D4956-13	I	II	II	III	III	III	III	III
AASHTO M268-13	(1)	(1)	(1)	A	A	A	A	A
Manufacturer	Several companies	Avery Dennison®	Nippon Carbide	3M™	ATSM, Inc.	Avery Dennison®	Nippon Carbide	ORAFOL Americas Inc
Brand Name	Engineer Grade	Super Engr Grade	Super Engr Grade	High Intensity	High Intensity	High Intensity	High Intensity	ORALITE® High Intensity
Series	Several	T-2000	15000	2800 3800	ATSM HI	T-5500	N500	5800
NOTES:	(2) (8)	(3) (4) (9)	(4)	(3) (4) (9)	(4)	(4)	(4)	(4)


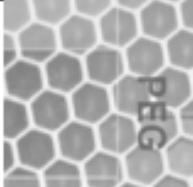
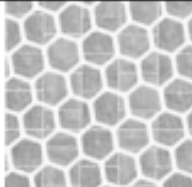


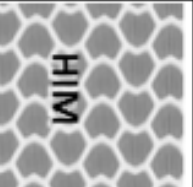
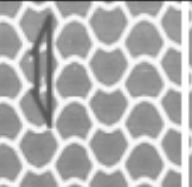

1) Sheeting material does not meet minimum AASHTO classification criteria.

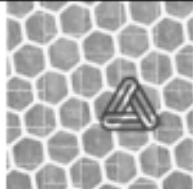
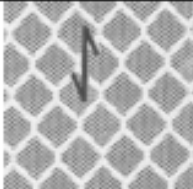
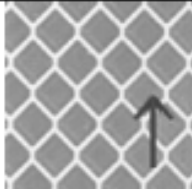
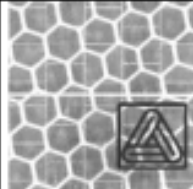
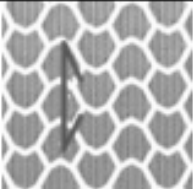
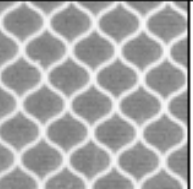
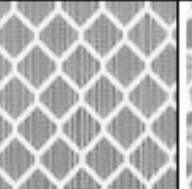
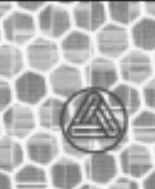
2) Glass Bead Engineer Grade sheeting is uniform without any patterns or identifying marks.

3) Material no longer sold in the United States as of the date of this publication.

4) Section 2A.08 of the 2009 MUTCD (<http://mutcd.fhwa.dot.gov>) does not allow this sheeting type to be used for new legends on green signs.

Retroreflective Sheeting Materials Made with Micro-Prisms

Example of Sheeting (Shown to scale)								
D4956-04	(5)	(5)	III, IV	III, IV, X	(5)	(5)	(5) / X	(5)
D4956-13	I	I	III, IV	III, IV	III, IV	III, IV	VIII	VIII
M268-13	(6)	(6)	B	B	B	B	B	B
Manufacturer	3M™	Avery Dennison®	Avery Dennison®	3M™	ORAFOL Americas Inc	Nippon Carbide	Nippon Carbide	3M™
Brand Name	EGP	PEG	HIP	HIP	ORALITE® HIP	HIM	Crystal Grade	Reflective Sheeting
Series	3430	T-2500	T-6500	3930	5900/5930	CRG 94000	CRG 92000	3940
NOTES:	(8)	(8)						

Example of Sheeting (Shown to scale)								
D4956-04	VIII	VII, VIII, X	IX	IX	(5)	(5)	(5)	(5)
D4956-13	VIII	VIII	IX	IX	IX	IX	XI	XI
M268-13	B	(7)	B	B	B	B	D	D
Manufacturer	Avery Dennison®	3M™	3M™	Avery Dennison®	Nippon Carbide	ORAFOL Americas Inc	3M™	Avery Dennison®
Brand Name	MVP Prismatic	Diamond Grade™ LDP	Diamond Grade™ VIP	OmniView™	Crystal Grade	ORALITE®	Diamond Grade™ DG3	OmniCube™
Series	T-7500	3970	3990	T-9500	95000	7900	4000	T-11500
NOTES:		(9)			(9)			

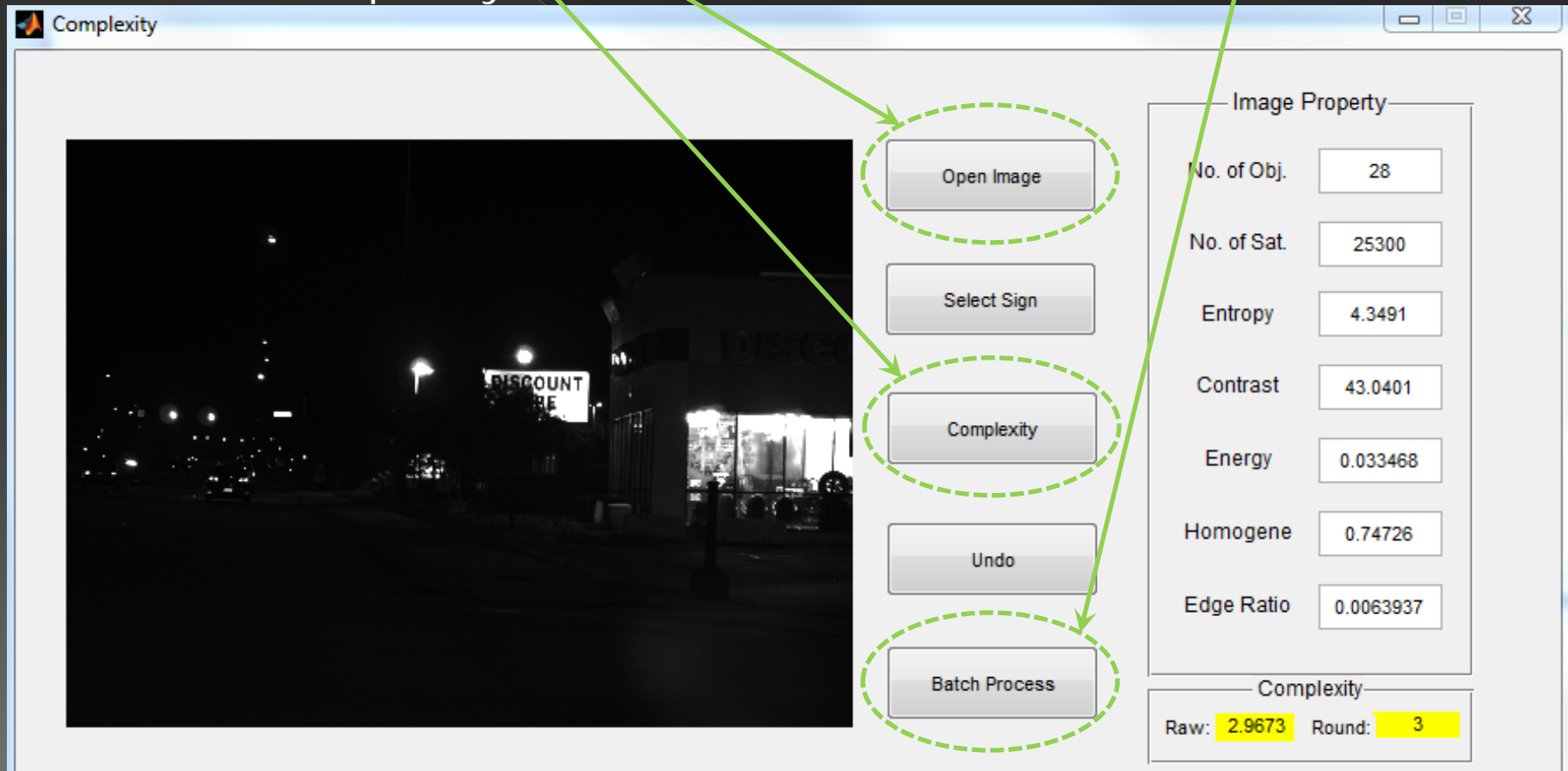
Visual Complexity Software

Published in TRB Journal

Select "Open Image"

Select "Complexity"

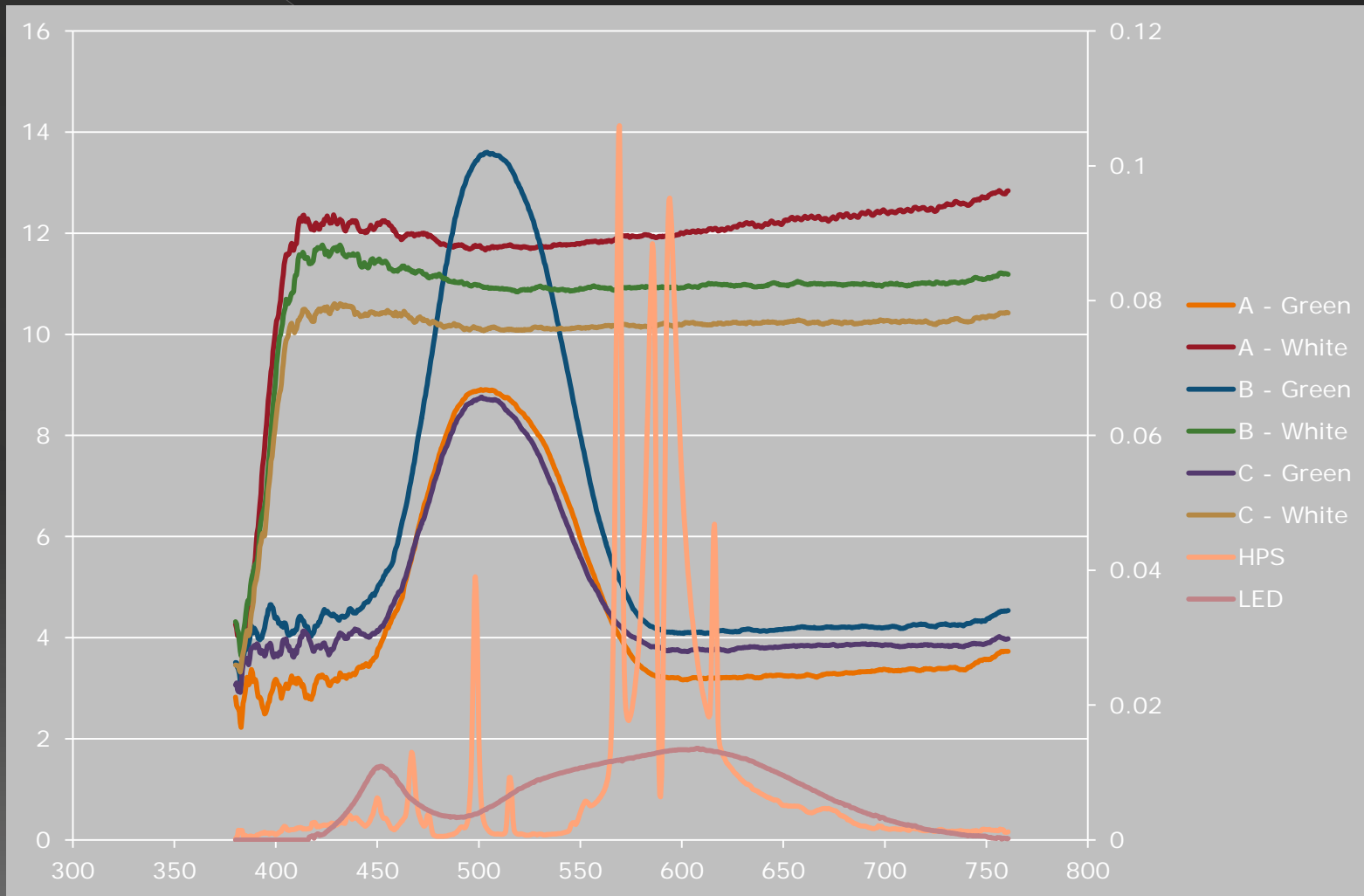
Select "Batch Process" if you have a folder of images.



Sign Lighting Options

- All new lighting installations are using LED light sources
 - Highly energy efficient
 - Full spectrum (White)
 - Provides better color representation
 - Dimmable

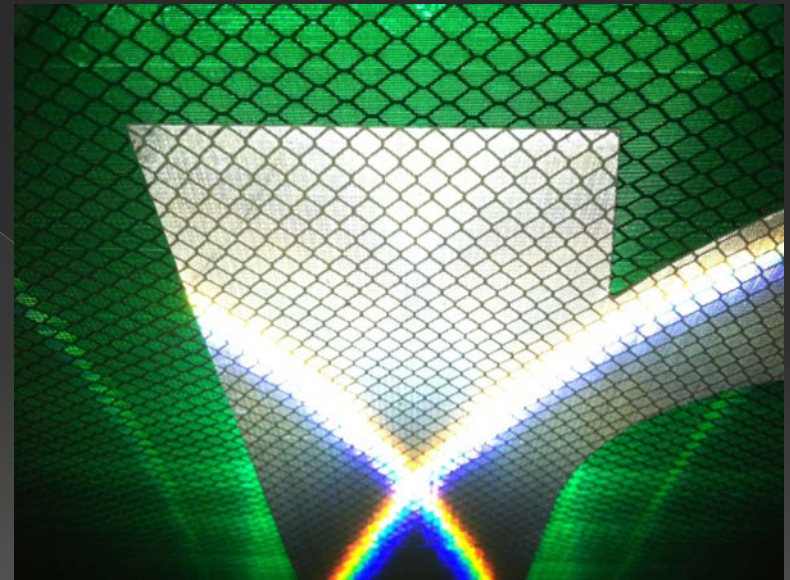
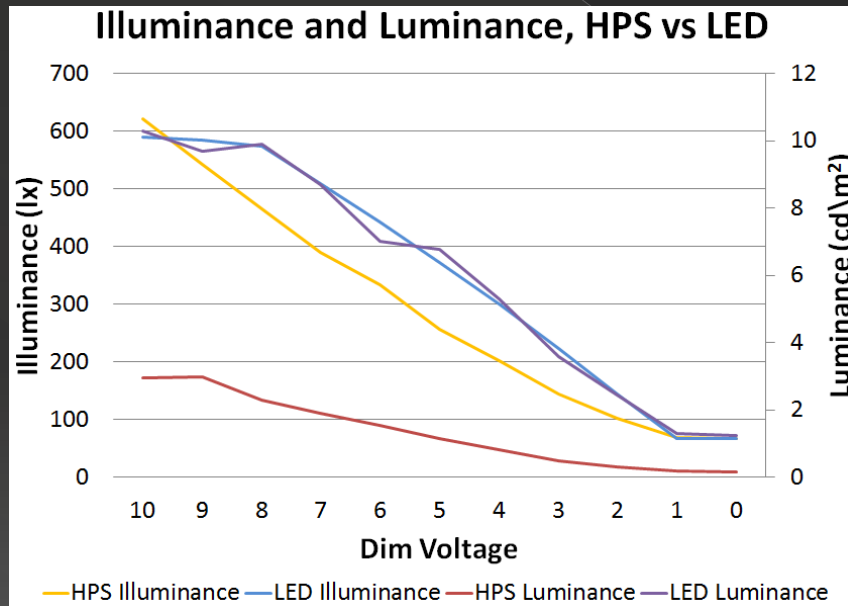
Reflectivity and Output



Lighting Issues

- LEDs are an arrayed source rather than a point source
 - This causes issues with the illuminance and luminance conversion

Luminance Characterization



Legibility Study

- Closed course testing at VTTI
- Sign luminance
 - 3 types of retroreflective material
 - 3 conditions of sign lighting
- Visual complexity (low)
 - 2 levels – roadway lighting on / off
- Driver age
 - 2 levels – young and old

Objective

- This project investigated the relationship of lighting and retroreflective materials for signage
- With high performance materials, the effectiveness of a lighting system may be significantly diminished
 - New materials are designed to reflect light back to the headlamps and may not be effective with fixed lighting

Lighting Design

- The sign lighting was designed to match illuminance on the sign
 - 1 Center mounted HPS
 - 2 Side Mounted LED
 - LED were 6000K
- The sign met the requirements of the IES RP-19 lighting requirements
- The luminance of the sign was characterized at 1000 ft.

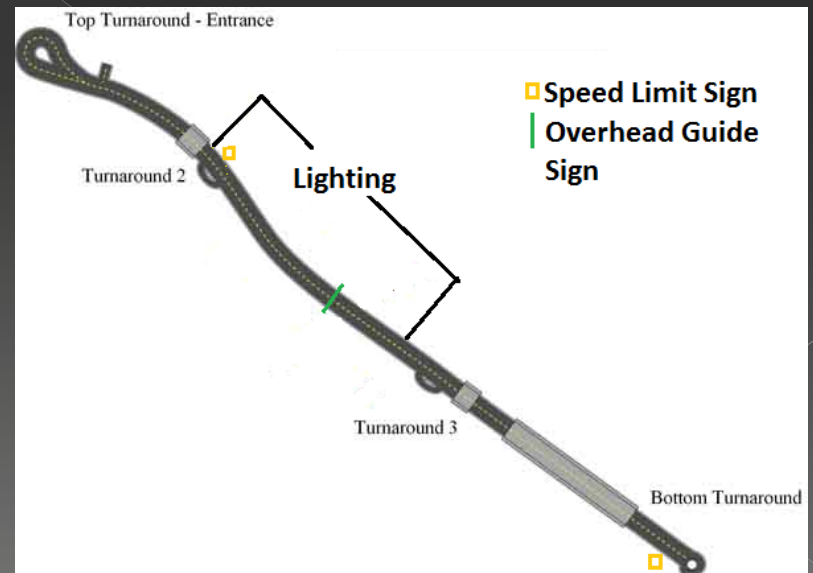
Experimental Design

Variable Type	Variables
Ages	25-35, 65+
Sheeting/Legend Combinations	Type IV on III B, Type XI on IV, Type XI on XI
Sign Lights	HPS, LED
Sign Lighting Levels	100%, 50%, 25%
Overhead light settings	On, Off

Word Pairs	
Lake	Camp
Long	Port
Gray	Cape
Bear	Road
Oven	Park
East	Bend

Method

- The legibility of an overhead sign was measured on the Smart Road.
 - > A sign structure was designed for the sign bridge that allowed for lowering the sign to:
 - Change the legend
 - Change the background sign material
 - > Two lighting system were installed
 - LED
 - HPS
 - Fully Dimmable
- All Legends were 16 inches



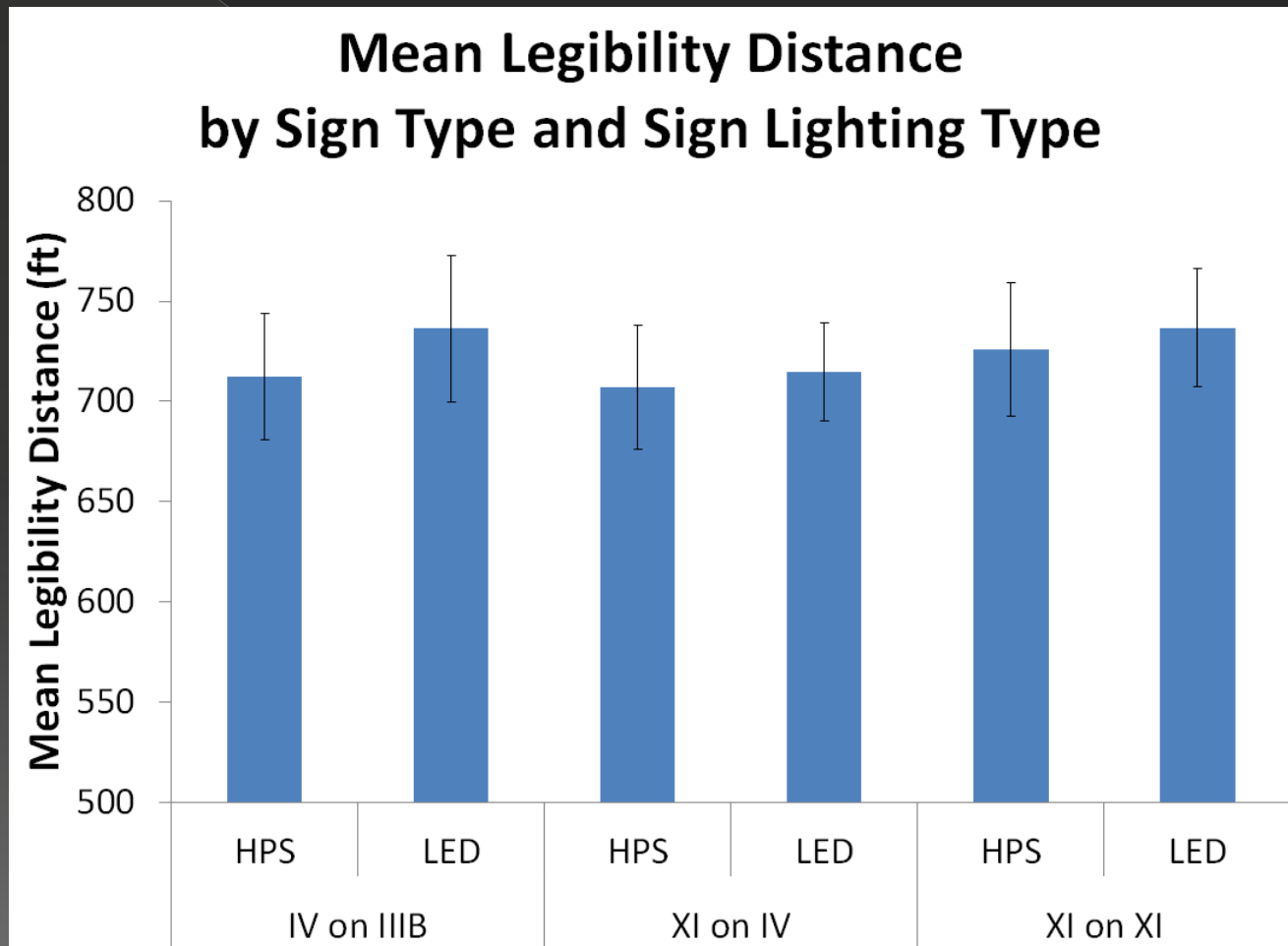
Participants

- Participants drove the Smart Road in an instrumented experimental vehicle
- Participants read the sign and the legibility distance was measured
 - › Legends were changed with each run
- 24 participants
 - › 12 young and 12 older
 - › Gender Balanced
- Background material was a between subjects factor

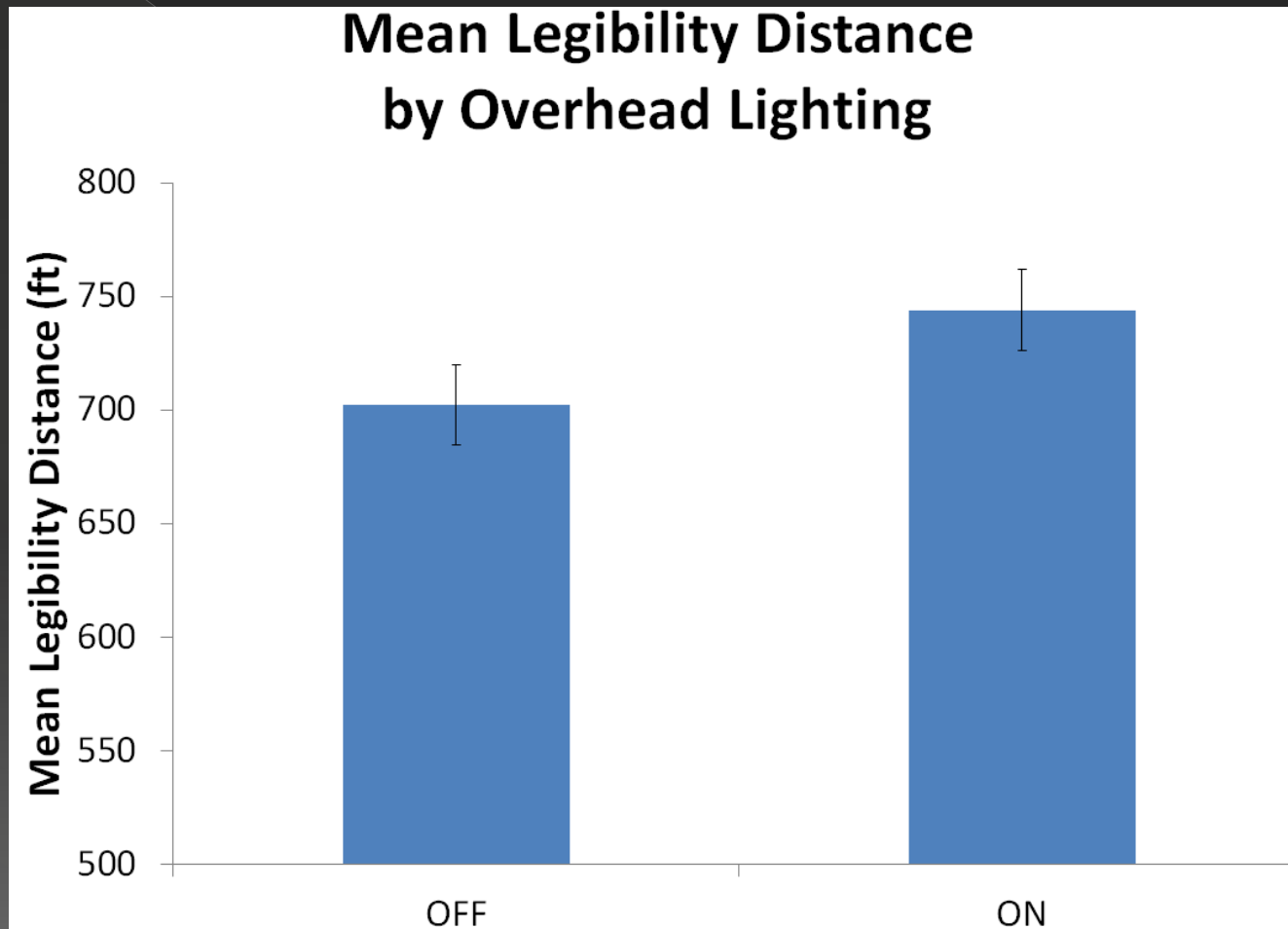
Example Orders

Lap No.	Age	Sign Material	Sign Lights	Overhead Lights	Sign Lighting Levels	Legend Combo
1	28	IV on III B	HPS	ON	100%	Lake Camp
2	28	IV on III B	HPS	ON	50%	Long Port
3	28	IV on III B	HPS	ON	25%	Gray Cape
4	28	IV on III B	HPS	OFF	100%	Bear Road
5	28	IV on III B	HPS	OFF	50%	Oven Park
6	28	IV on III B	HPS	OFF	25%	East Bend
7	28	IV on III B	LED	OFF	25%	Cape Lake
8	28	IV on III B	LED	OFF	50%	Road Long
9	28	IV on III B	LED	OFF	100%	Park Gray
10	28	IV on III B	LED	ON	25%	Bend Bear
11	28	IV on III B	LED	ON	50%	Camp Oven
12	28	IV on III B	LED	ON	100%	Port East

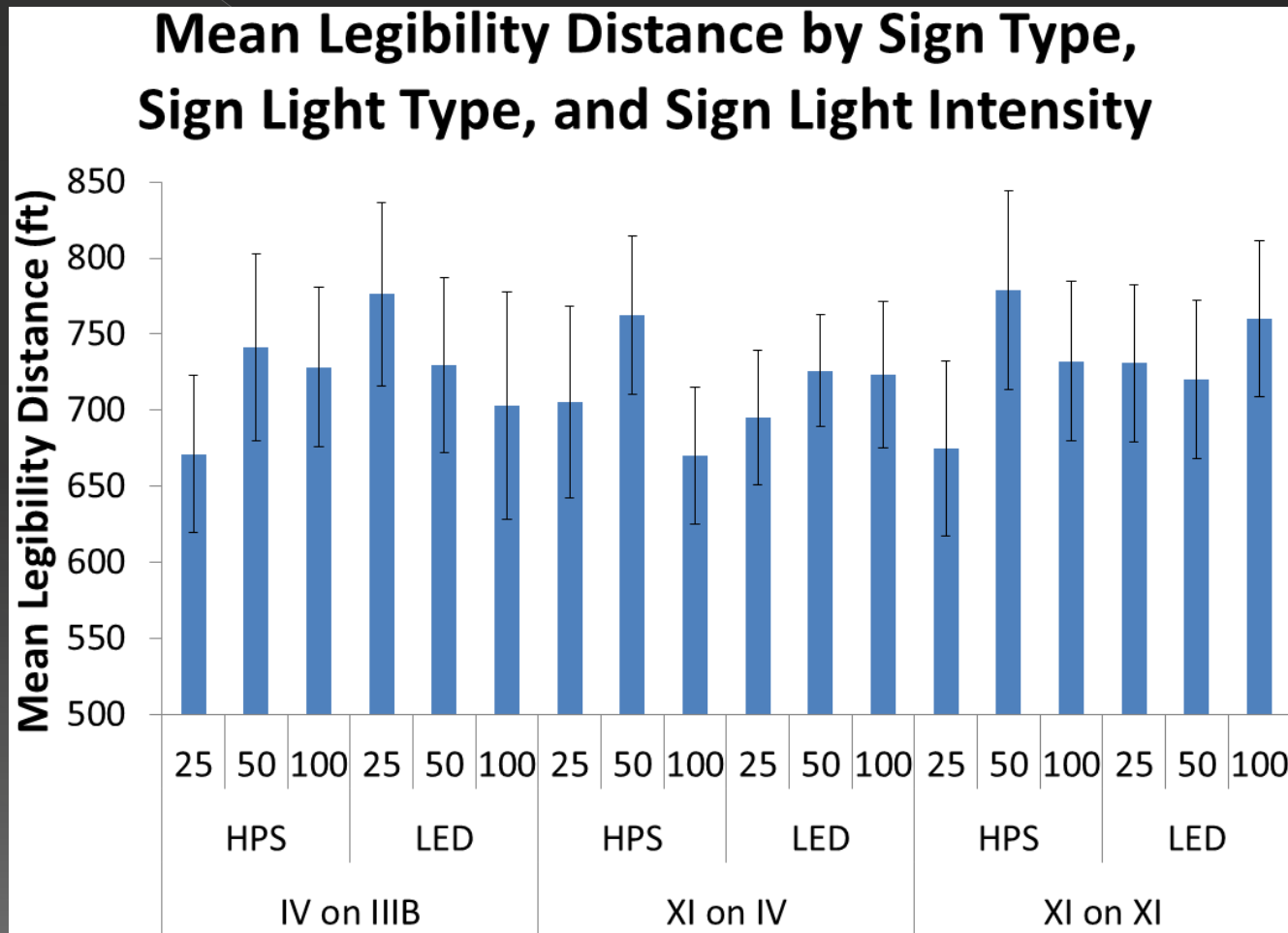
Results – Light Source Type



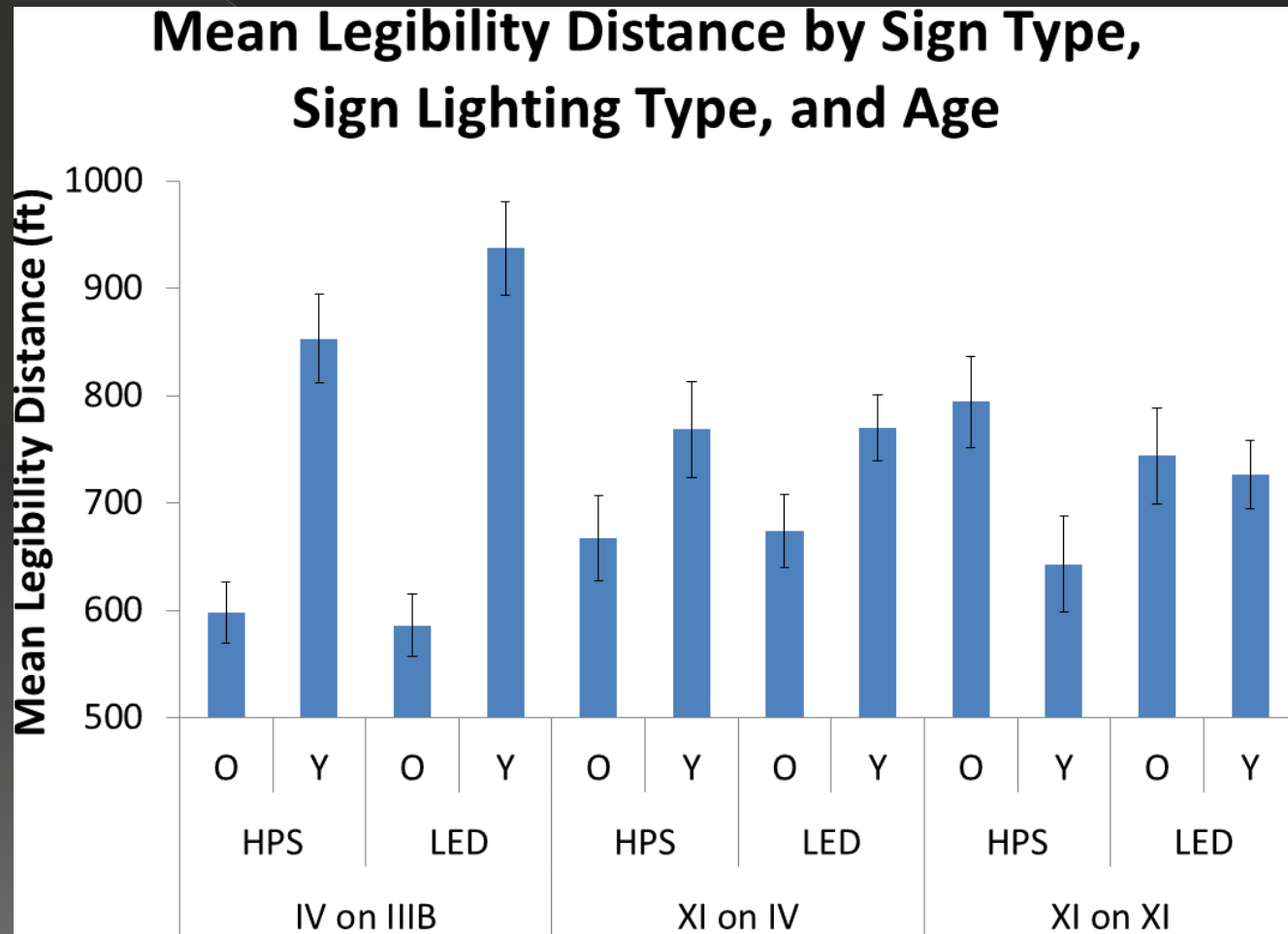
Results – Impact of Lighting



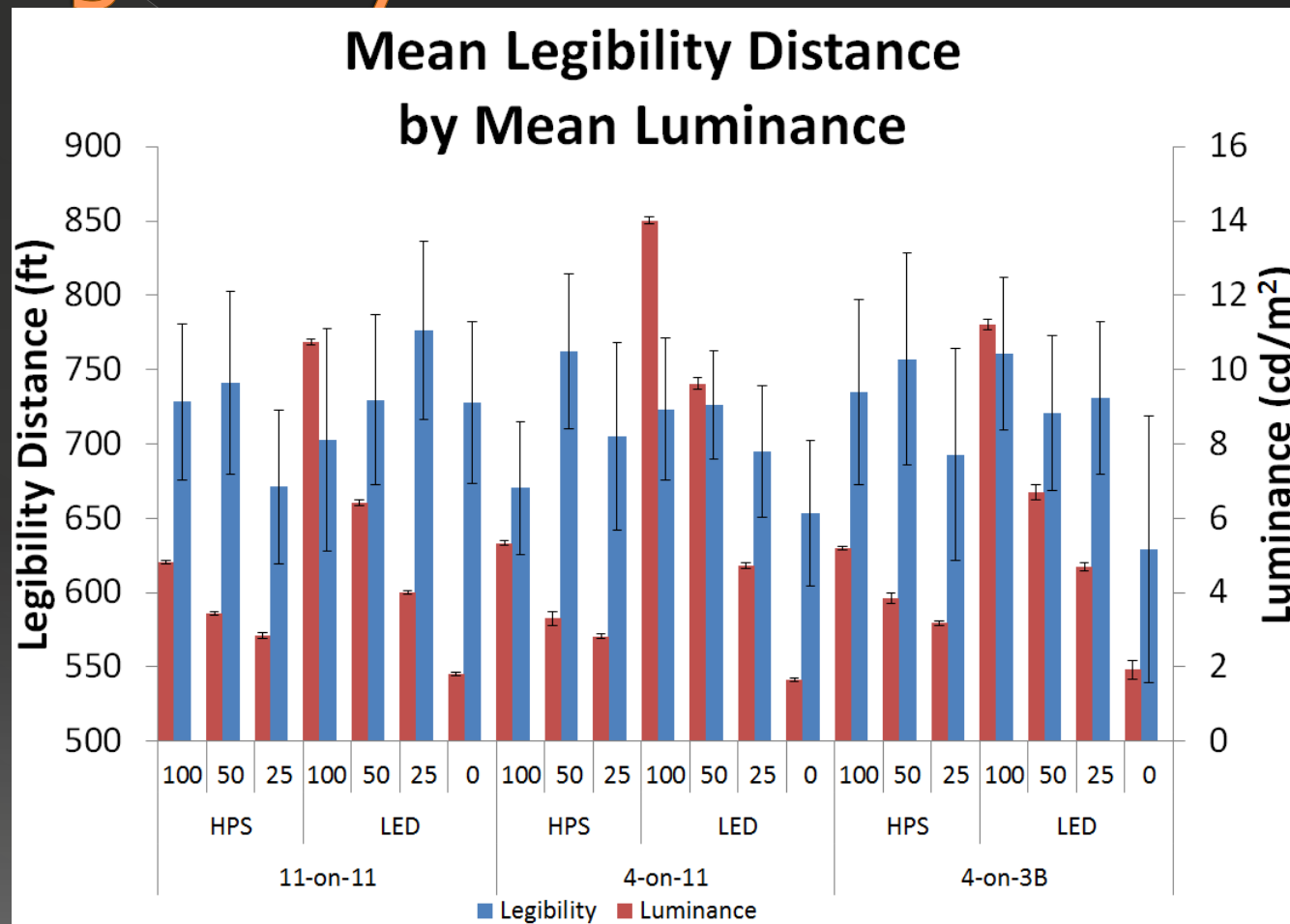
Results - Dimming



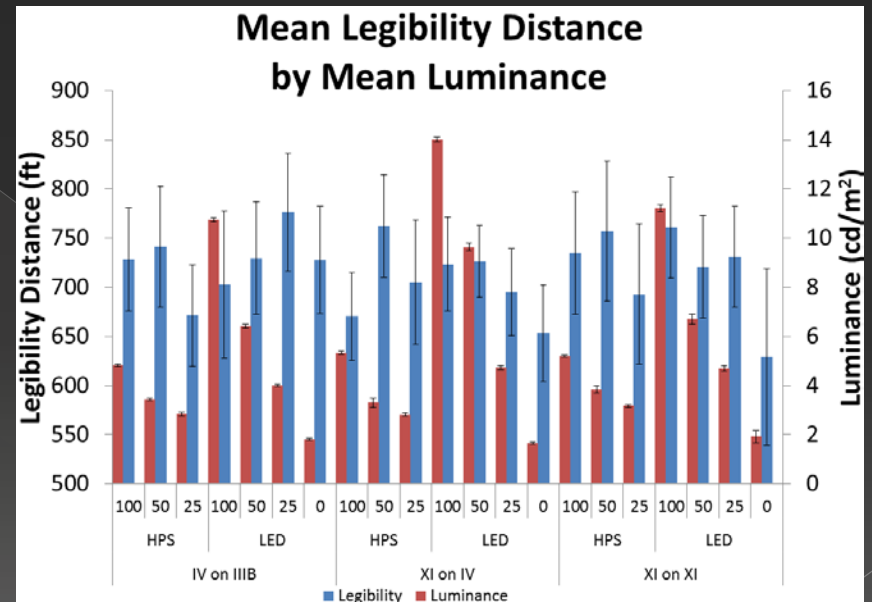
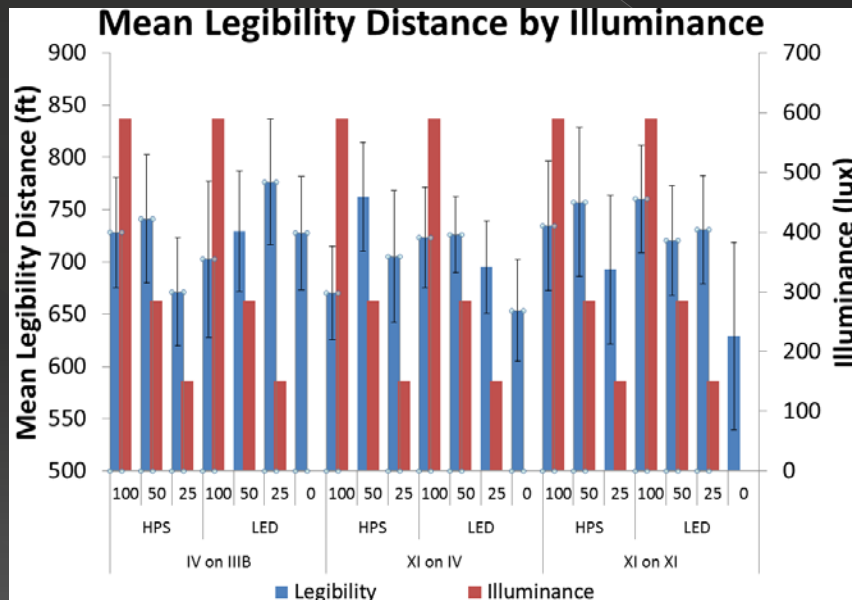
Results - Age



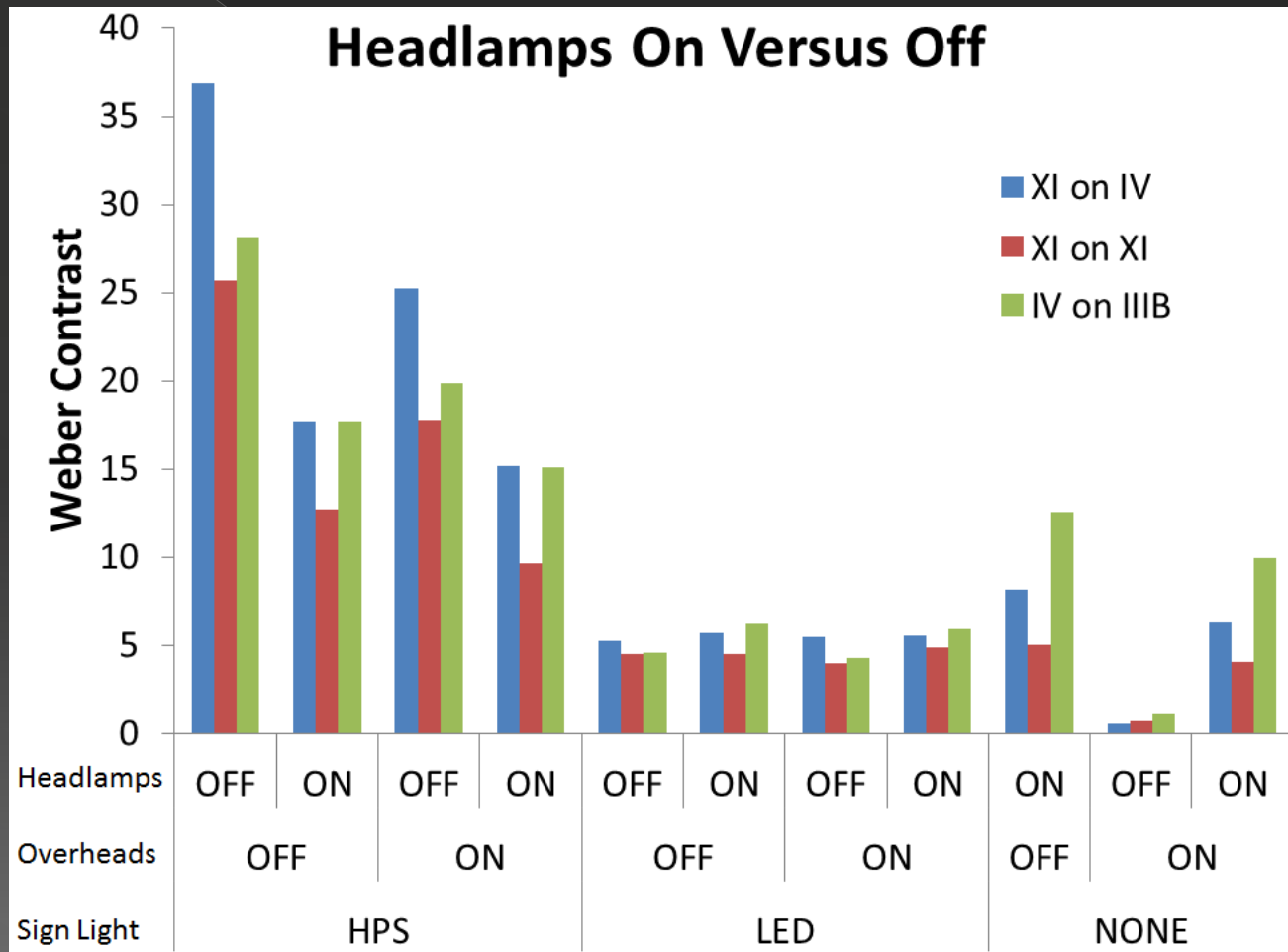
Results – Lighting Level vs. Legibility Distance



Luminance and Illuminance by Legibility Distance



Contrast



Comparison to Visual Acuity

- Visual Acuity is: $VA = \frac{m}{M} = \frac{\text{viewing distance (in meters)}}{\text{letter size (in M-units)}}$
- > Our young participants measured at 20/28.5 Vision (Younger) and 20/37.5 (older)

Distance (ft)	Letter height for 20/20 Vision (in)	Distance (ft) for 20/28.5 Vision	Distance (ft) for 20/37.3 Vision
1100	19.20	771.93	589.81
1000	17.45	701.75	536.19
900	15.71	631.58	482.57
800	13.96	561.40	428.95
700	12.22	491.23	375.34
600	10.47	421.05	321.72
500	8.73	350.88	268.10

Conclusions

- ◉ Addition of lighting has a minimal impact on legibility of sign with high performance sheeting
 - We are at the maximum of predication with Visual Acuity
 - Broad Spectrum LED Light Source improve legibility slightly (Greens are Greens)
- ◉ Installation of Lighting should be evaluated in terms of limited headlamp distance
 - Curves, Hills, Overpasses were headlamps don't reach the sign

Recognition Study



Locations



Participants

- Volunteer with monetary compensation (\$50)
- Recruited through
 - › Craig's List
 - › Local Groups (i.e., softball leagues, retirement facilities, colleges)
 - › Personal Contacts
- Age Groups
 - › Younger: 21-35
 - › Older: 55+ (emphasis on 65+)
- Gender (emphasis on even split)

Procedure

- Participant Arrival
 - All participants met TTI staff at safe/monitored facility (TTI or hotel).
 - Completed paperwork and vision testing.
- Data Collection
 - Participant escorted to data collection vehicle and familiarized with vehicle controls (i.e., seat adjustment, mirror adjustment, lights, climate controls).
 - Escorting staff member sat in front and provided route guidance and served as safety observer.
 - Second staff member monitored data collection equipment and geocoded responses in back seat.
- Participant Exit
 - Debriefing discussion / questions.
 - Compensation.

Instructions

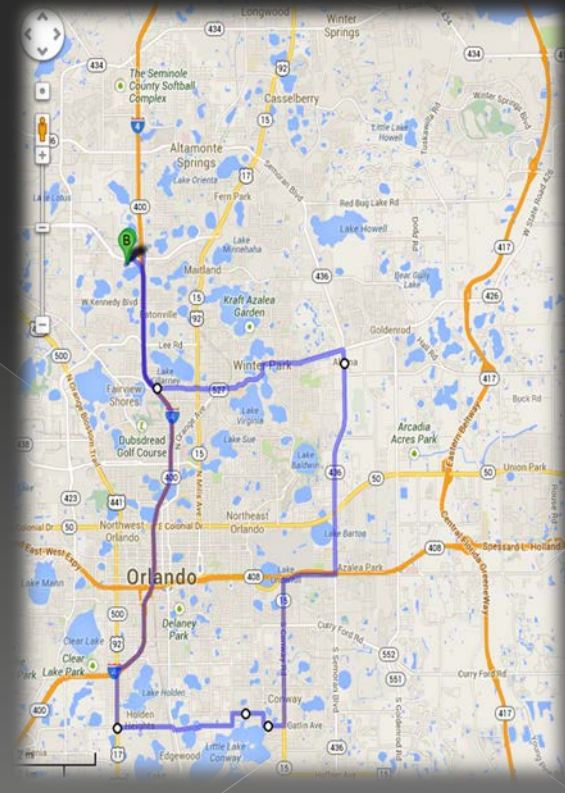
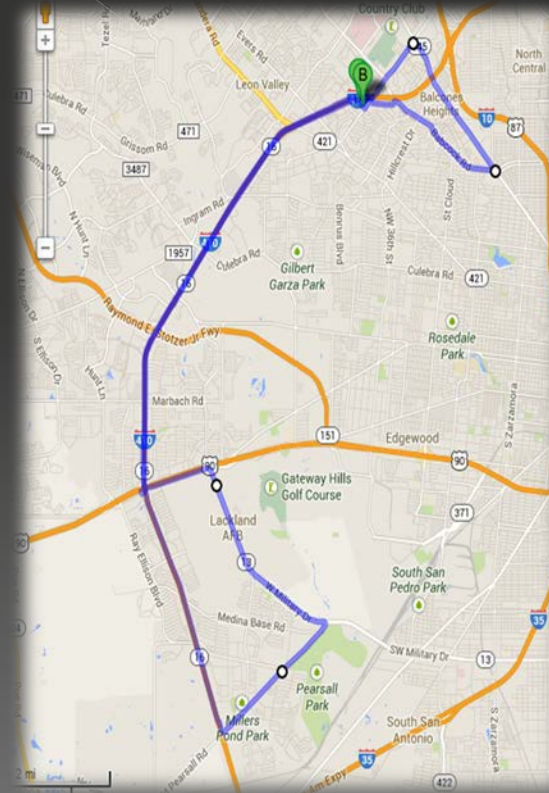
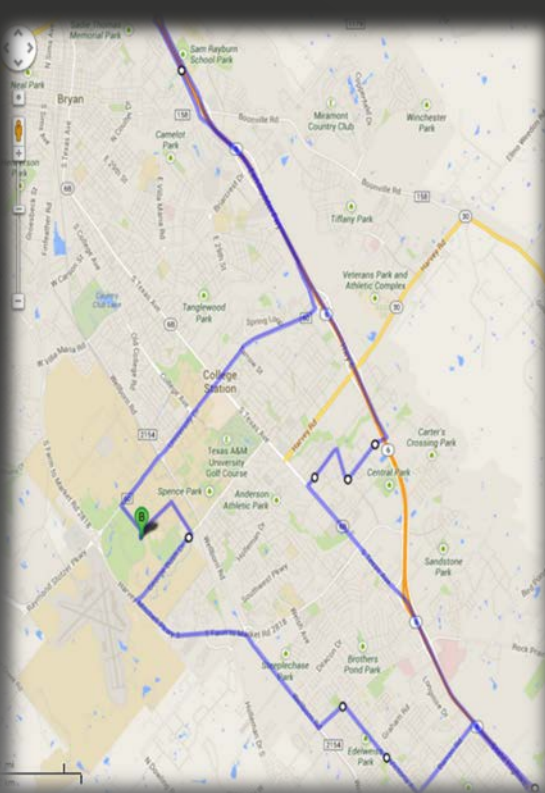
- Participants were told:
 - To follow route guidance from staff.
 - Staff would let them know words of interest.
 - Participants asked ***not to guess***.
 - Only identify signs when they could ***clearly be identified***.
 - Signs could be located on either side of the road, or directly overhead.
 - There may be more than one sign.
 - The staff member providing route guidance will also serve as a second set of eyes on the road to alert the driver of potential dangers on the road, such as someone in their blind spot, debris in the road, turning traffic, or stopping traffic.

Routes

College Station, TX	
Number of Signs	27
Mean Complexity	1.4
Standard Deviation	0.5007
Maximum	2
Minimum	1

San Antonio, TX	
Number of Signs	36
Mean Complexity	1.8
Standard Deviation	0.8319
Maximum	3
Minimum	1

Orlando, FL	
Number of Signs	36
Mean Complexity	2.5
Standard Deviation	1.0857
Maximum	4
Minimum	1



Participants

College Station		18 to 35		55+	
		Female	Male	Female	Male
		3	4	8	8
Number of Participants		79	107	215	199
Sample Size (n)		79	107	215	199
Recognition Index (ft/in)	Mean	52.3	45.9	39.1	38.2
	Standard Deviation	21.0661	19.7024	21.6906	18.5598
	Maximum	111	108	117	90
	Minimum	22	14	7	7

San Antonio		18 to 35		55+	
		Female	Male	Female	Male
		4	5	8	8
Number of Participants		131	162	274	271
Sample Size (n)		131	162	274	271
Recognition Index (ft/in)	Mean	52.3	59.3	45.3	50.1
	Standard Deviation	15.6321	22.5160	20.5927	21.9210
	Maximum	102	136	124	113
	Minimum	12	9	6	6

Orlando		18 to 35		55+	
		Female	Male	Female	Male
		4	4	8	9
Number of Participants		149	148	283	304
Sample Size (n)		149	148	283	304
Recognition Index (ft/in)	Mean	40.3	36.5	33.8	32.9
	Standard Deviation	16.6237	18.9347	14.3449	14.3240
	Maximum	93	105	81	81
	Minimum	7	6	6	4

Equipment Setup

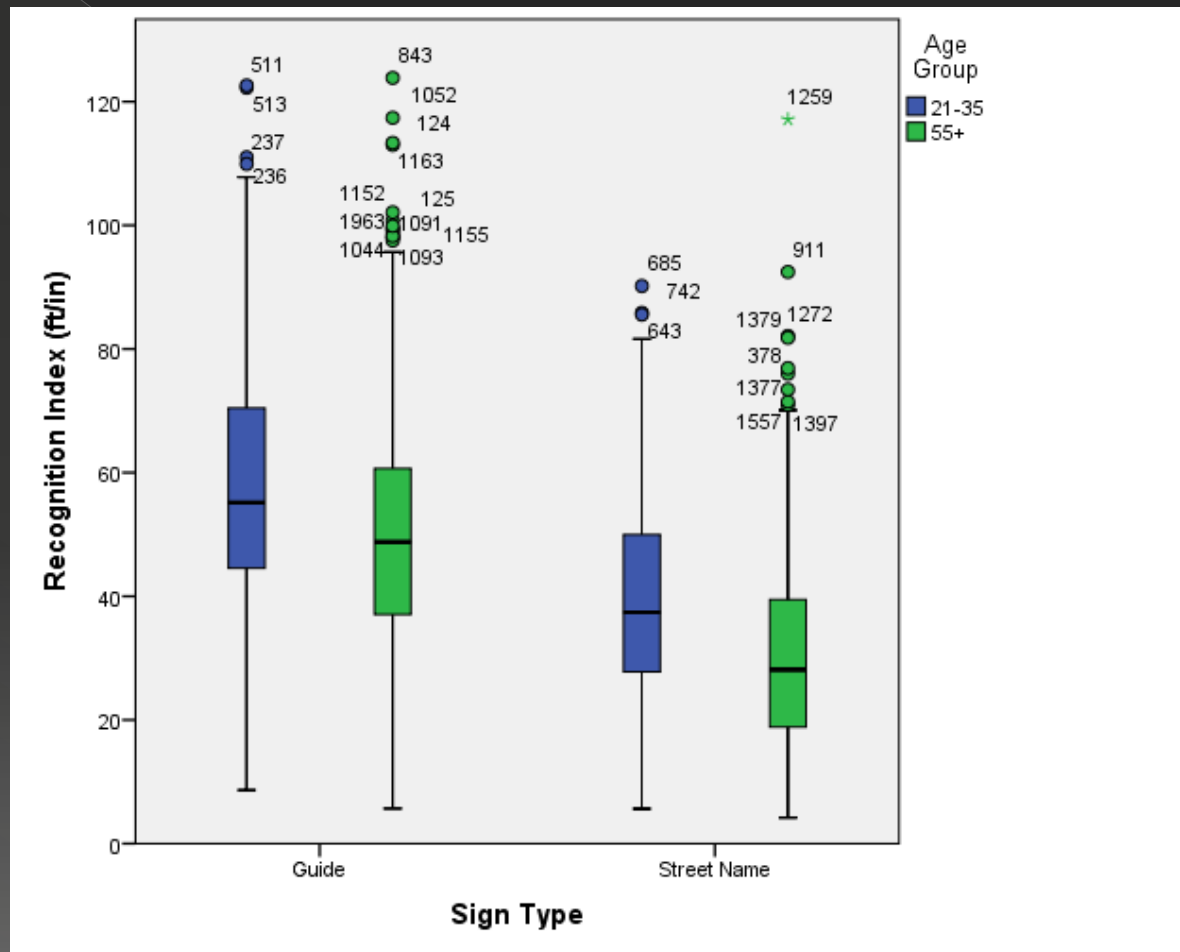
Data Collector Control Center



Mobile Luminance with GPS



Overall RI

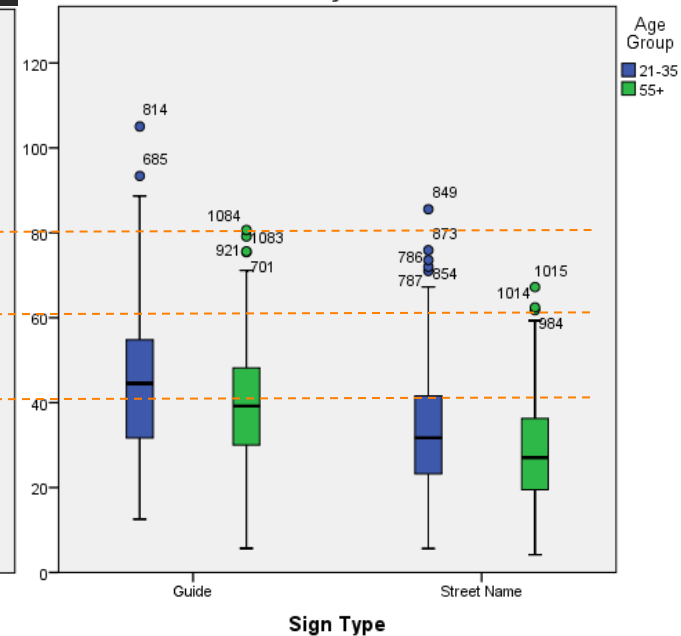
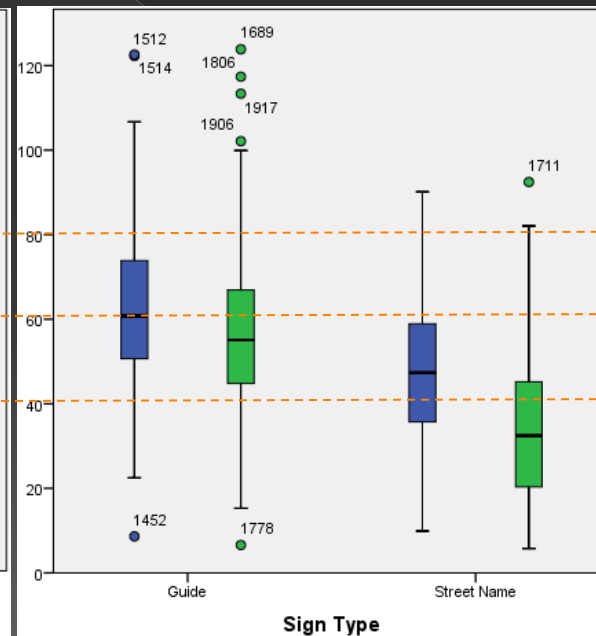
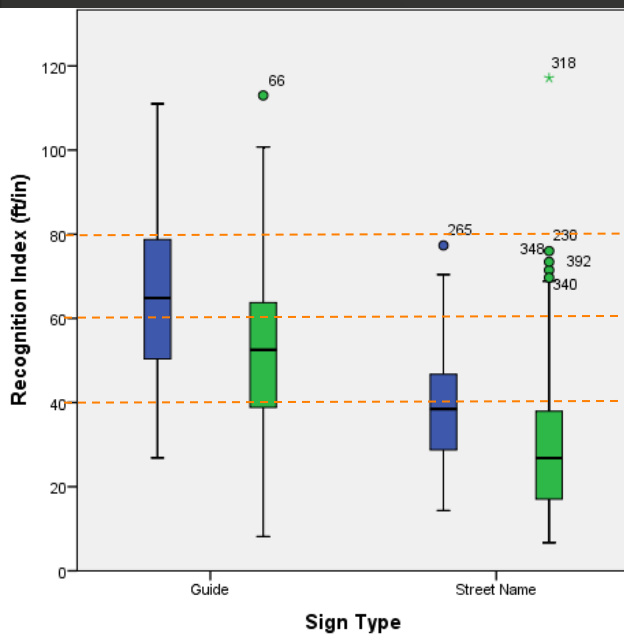


RI by Location

College Station, TX
Mean complexity = 1.4

San Antonio, TX
Mean complexity = 1.8

Orlando, FL
Mean complexity = 2.5



Complexity for Guide Signs

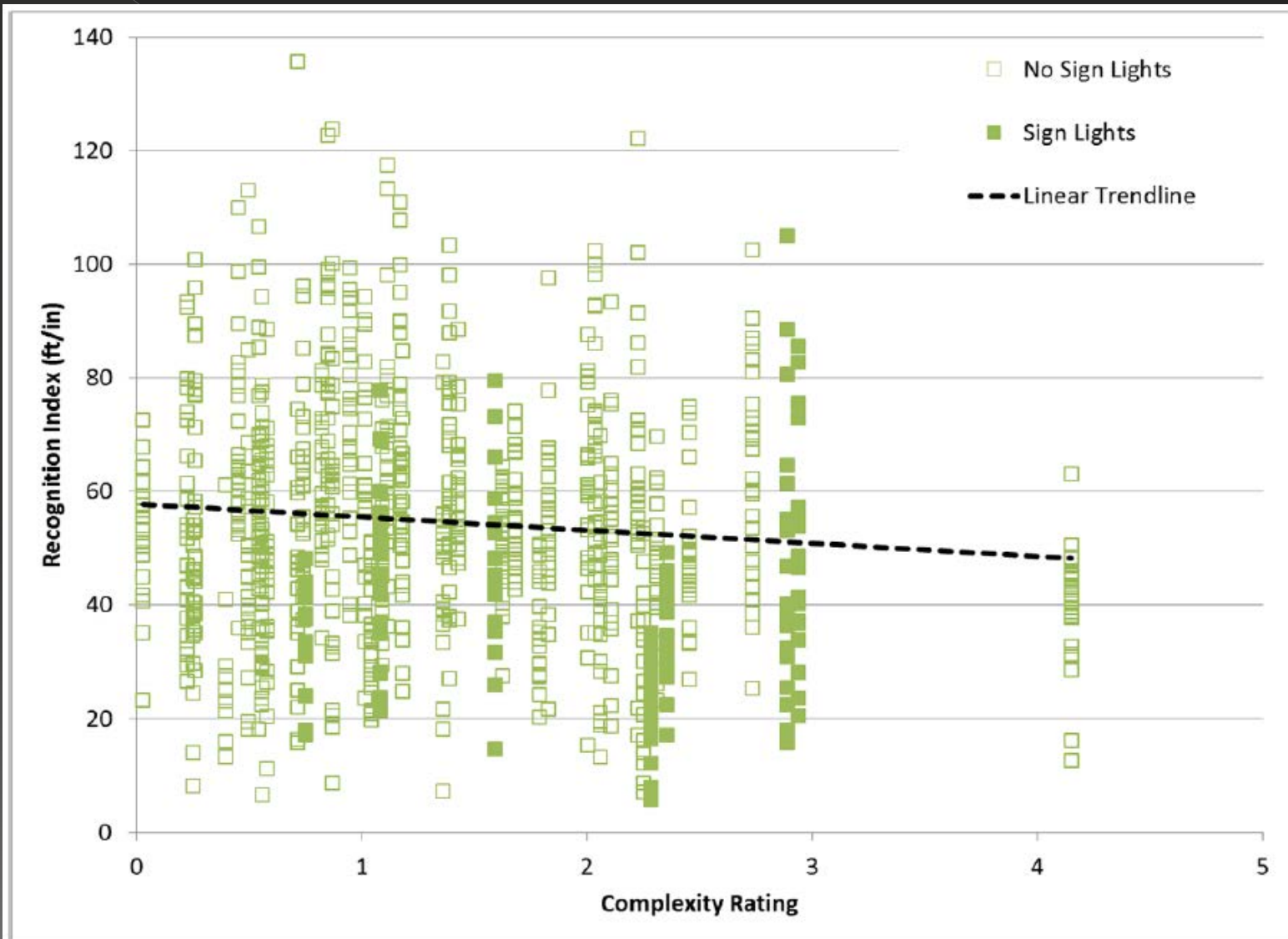












Figure 27. Recognition Distance of Guide Signs by Complexity Rating

Findings

- Research results were used to develop recommendations based on the needs of nighttime drivers while considering:
 - Visual complexity,
 - Sign sheeting materials,
 - Lighting technologies, and
 - Roadway geometry.
- Research recommendations are being adopted in the American Association of State Highway and Transportation Officials (AASHTO) *Roadway Lighting Design Guide*.

Recommendations

Visual Complexity Level	1	2	3	4	5
Guide Signs					
Street Name Signs					
Minimum Luminance (cd/m ²)	2.5	8	14	20	25
What this means → Providing Adequate Nighttime Visibility					
Sign Lighting	Optional if	Optional if	Optional if	Optional if	Needed
ASTM D4956 Legend	IV, VIII, IX, XI	IV, VIII, IX, XI	VIII, IX, XI	XI	

More Info

- ◎ ***NCHRP Report 828***
 - › ***Published and available on-line***
- ◎ ***TRB Annual Meeting***
 - › ***Paper Number 17-04786***
 - › ***Accepted for Publication***