Traffic Sign Brightness and Driver Safety

Performance Measures and Requirements: A synopsis
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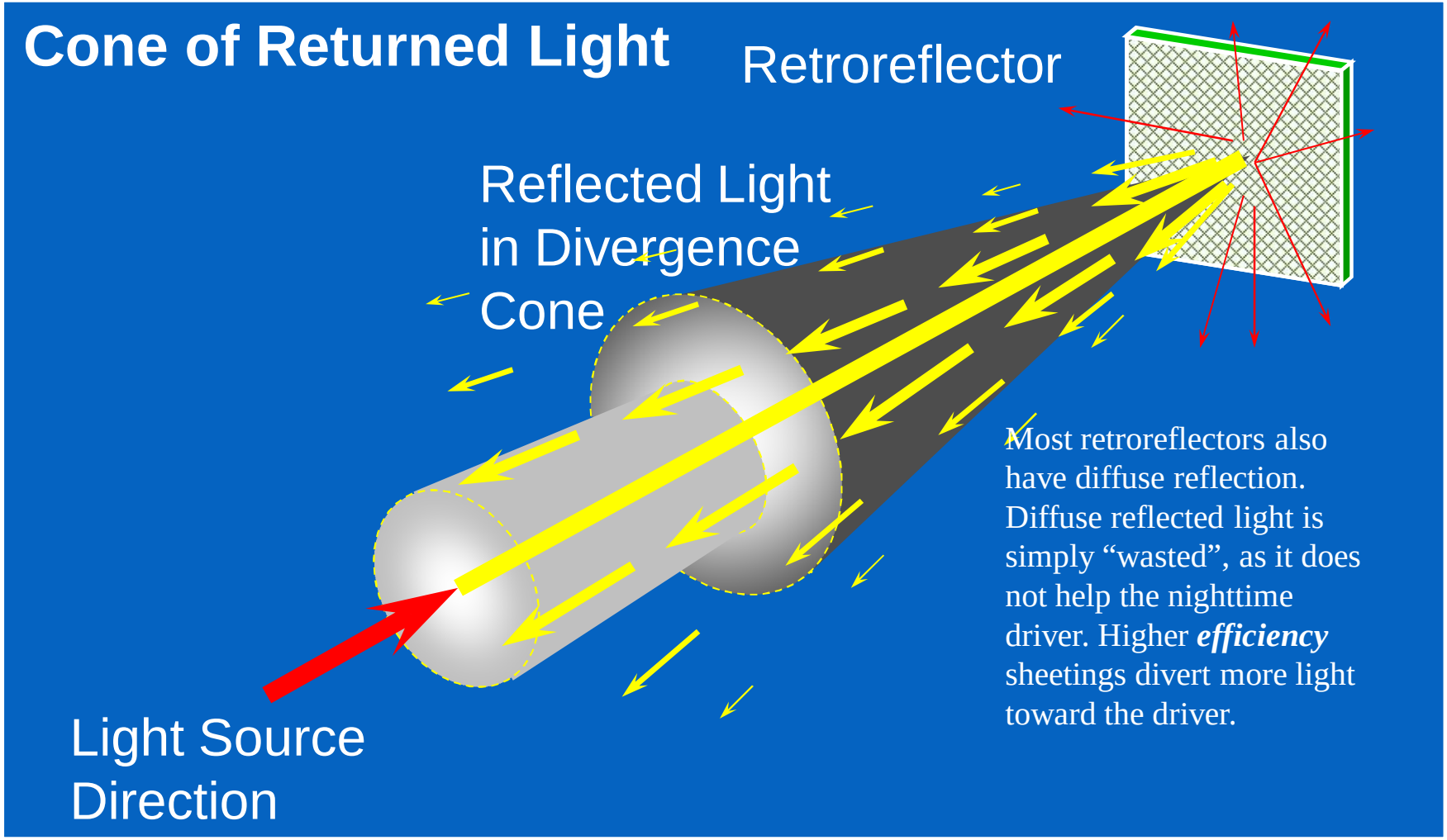
Overview

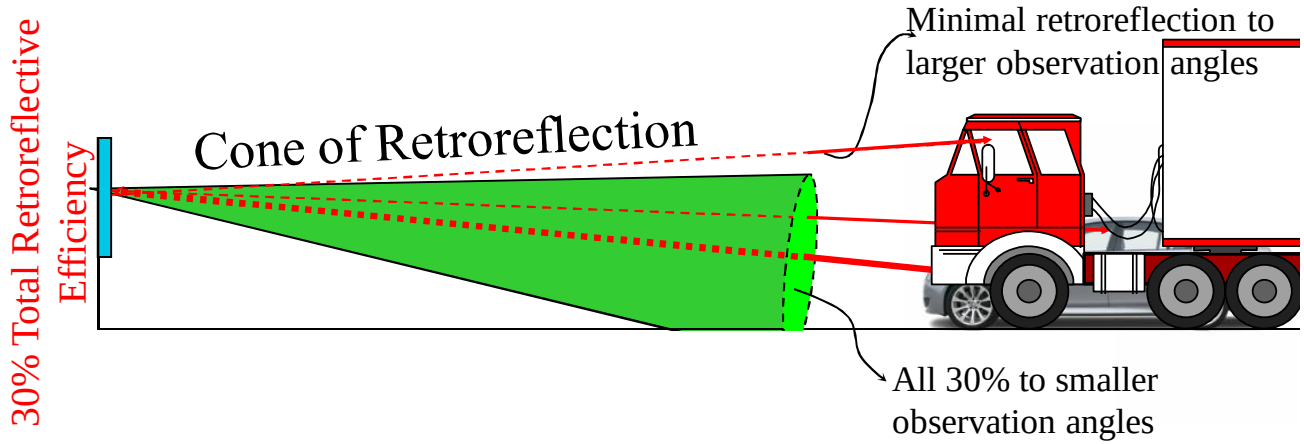
1. Driver needs for traffic sign brightness at night
   - Retroreflection basics
   - How is retroreflective efficiency defined and why does it matter?
   - Luminance needs of drivers
2. How do current retroreflective sheeting perform?
3. Recent studies on safety benefits of high-performance sheeting
4. Questions

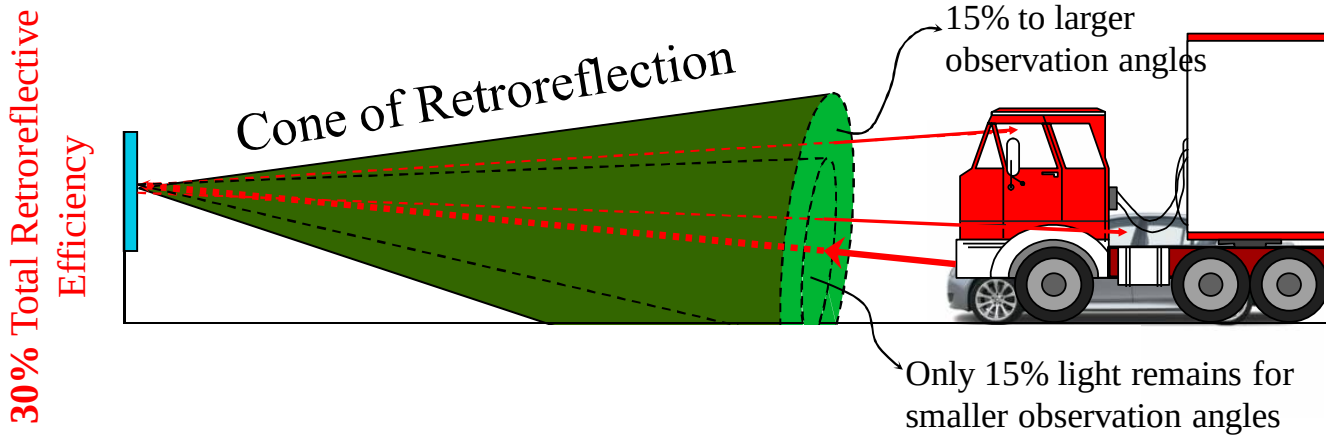
Cone of Returned Light



Most retroreflectors also have diffuse reflection. Diffuse reflected light is simply “wasted”, as it does not help the nighttime driver. Higher ***efficiency*** sheetings divert more light toward the driver.

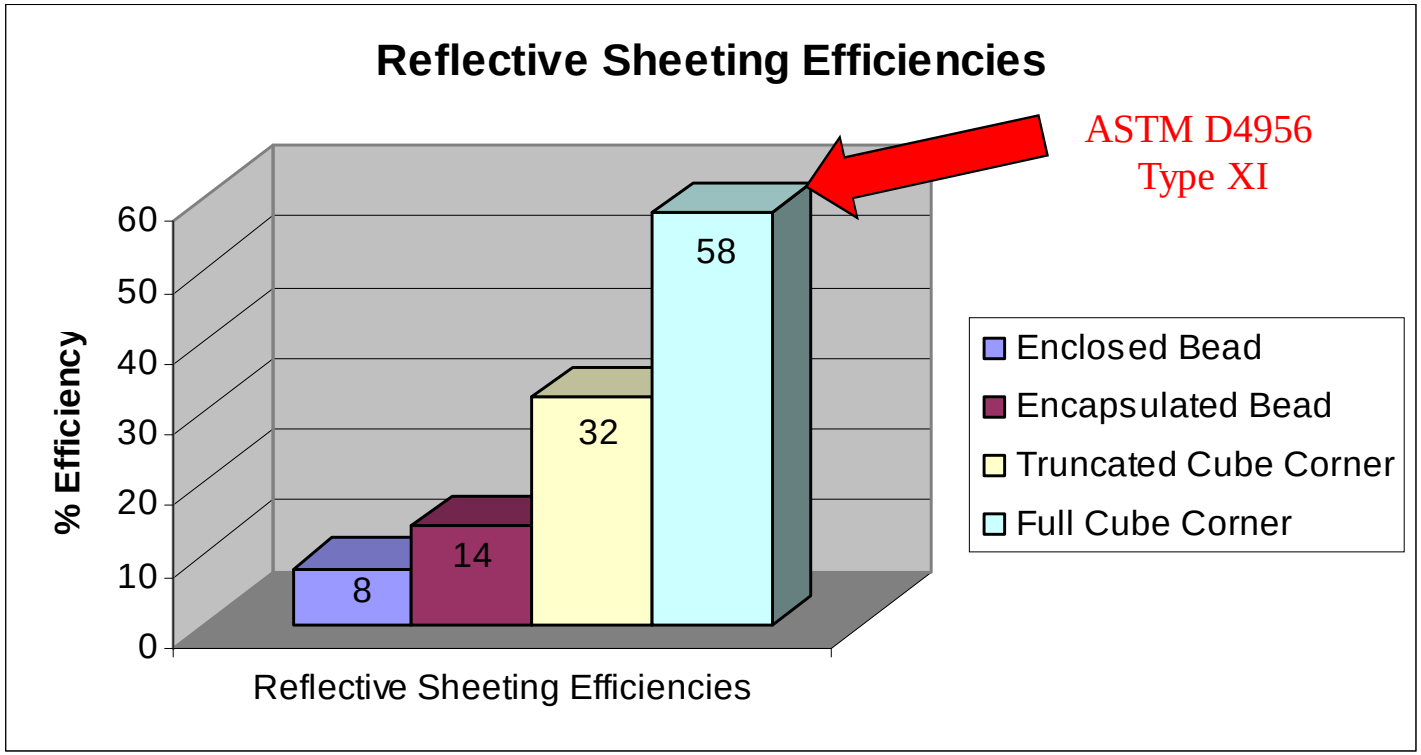
Retroreflective Efficiency



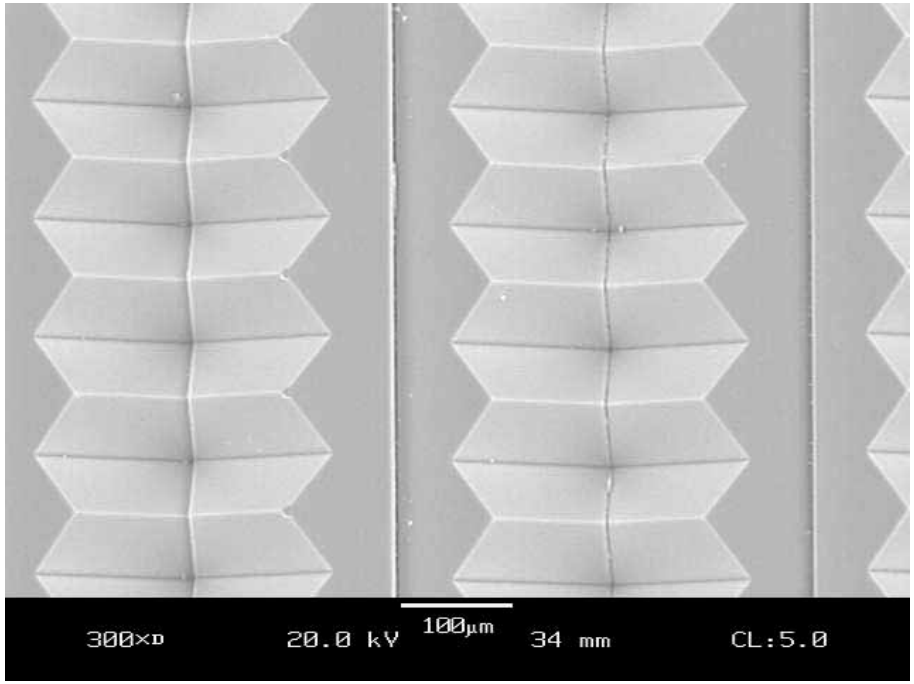


All truncated cube corner sheetings have nearly 30% retroreflective efficiency.

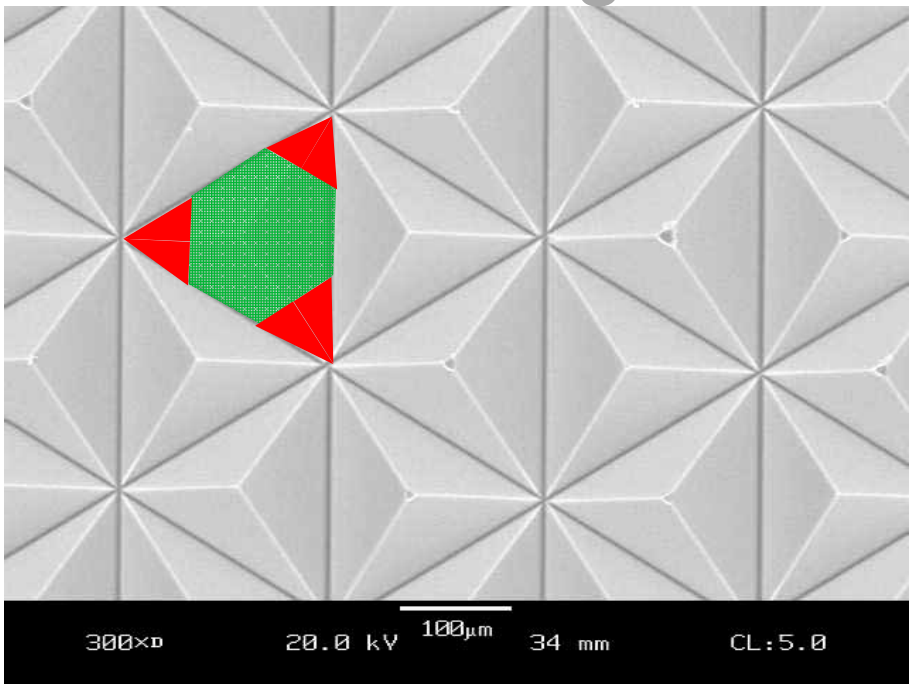
Retroreflective Efficiency of Full-cube Sheeting



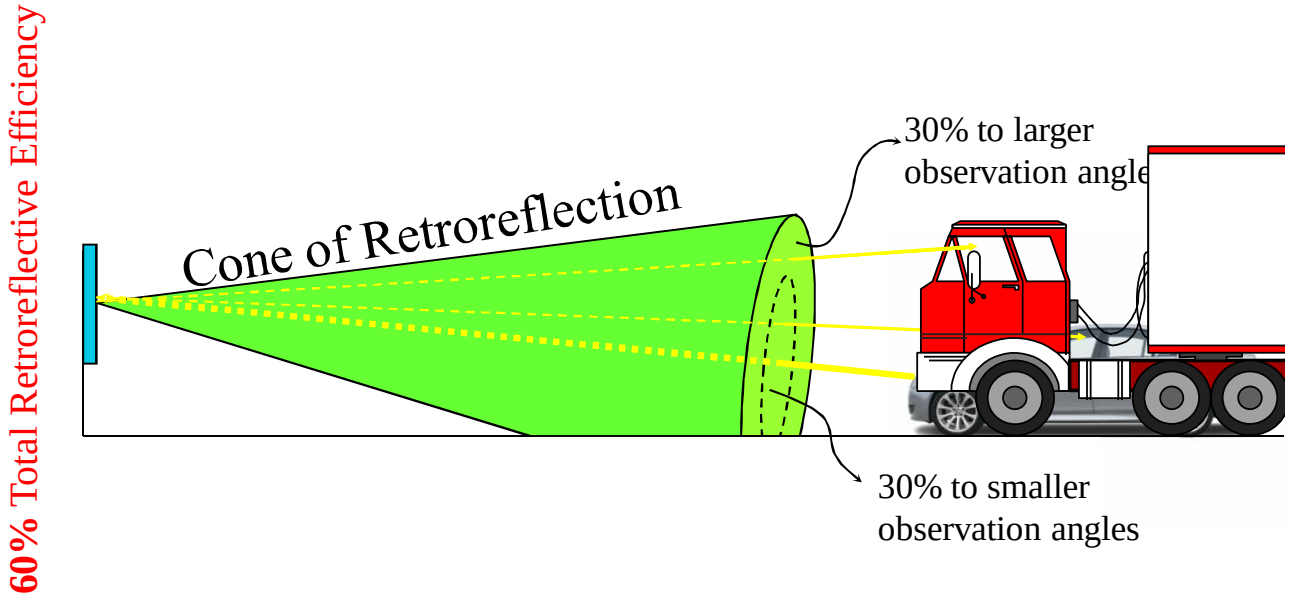
ASTM D4956 Type XI



Other Microprismatic Sheeting



Retroreflective Efficiency



Increasing the overall total retroreflective efficiency helps ensure serving the greatest segment of nighttime vehicle and driver population.

Key Takeaways

1. Higher retroreflective efficiency overall helps provide higher luminance signs and serve across a wide range of drivers of various vehicle types.
2. High efficiency is achieved by a different reflective cube design (fully-reflective cube corners)
   - ASTM D4956 and AASHTO M268 industry standards classify sheeting by retroreflectivity
   - Sheeting that meet ASTM D4956 Type XI (India IRC: 67-2012 Type XI) are currently of full-cube design
   - ASTM Type XI standard does not require a certain design or efficiency. However, the higher efficiency of these sheetings allow them to easily meet the Type XI requirements.
3. Many government transportation agencies around the world specify and rely on ASTM Type XI sheeting performance
4. Multiple manufacturers provide sheeting that meet Type XI

Driver Needs
Field Performance
Safety Benefits

Minimum vs Optimum Luminance

- Minimum required brightness is around 3.2 cd/m^2 for median driver above the age of 65[1] (at 40 ft/in or 4.8 m/cm).
- 80 cd/m^2 is recommended as optimal for maximizing legibility range[2]
- Literature varies in recommendation of luminances from 3.2 cd/m^2 to 120 cd/m^2, based on the adaptation level, age, legend, letter size, font, contrast, etc.
- If a sign at 3.2 cd/m^2 luminance can be read, why increase its luminance?

1. Eugene R. Russell, M.R., Andrew Rys, and Merle Keck, *Characteristics and Needs for Overhead Guide Sign Illumination from Vehicular Headlamps, Dept of Civil Engineering,* Kansas State University. 1999, FHWA Office of Safety and Traffic Operations Research and Development, FHWA-RD-98-135.
2. Schnell, T., Aktan, F., Li, C., 2004, *Traffic Sign Luminance Requirements of Nightime Drivers for Symbolic Signs. Transportation Research Record No. 1862: Journal of the* Transportation Research Board, 2004: p. 24-35.

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Hypotheses

- A study conducted at the University of Iowa[1], Operator Performance Laboratory offers great insight on the aforementioned problem statement

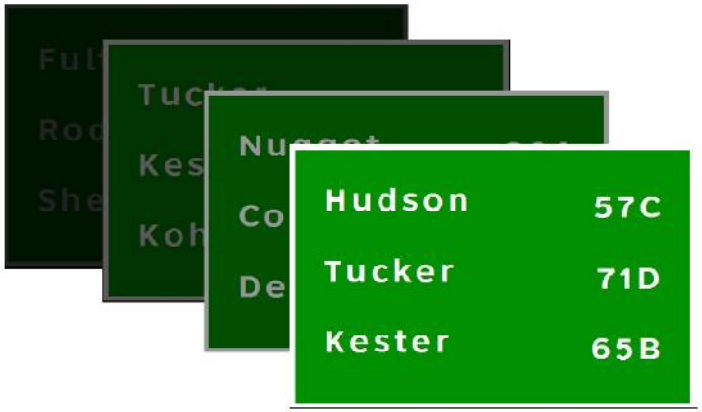
- Brighter signs “communicate” with the drivers much more effectively
  - Increasing luminance above legibility threshold yields faster information acquisition
  - When exposure is limited, brighter signs provide more accurate information transfer
  - These hypotheses are valid within the legibility range

1. Schnell, T., Yekhshatyan, L., Daiker, R., Konz, J., Effect of Luminance on Information Acquisition Time and Accuracy from Traffic Signs. Paper accepted for presentation and publication, Transportation Research Record, Journal of the Transportation Research Board, 2008.

Method

Independent Variables:

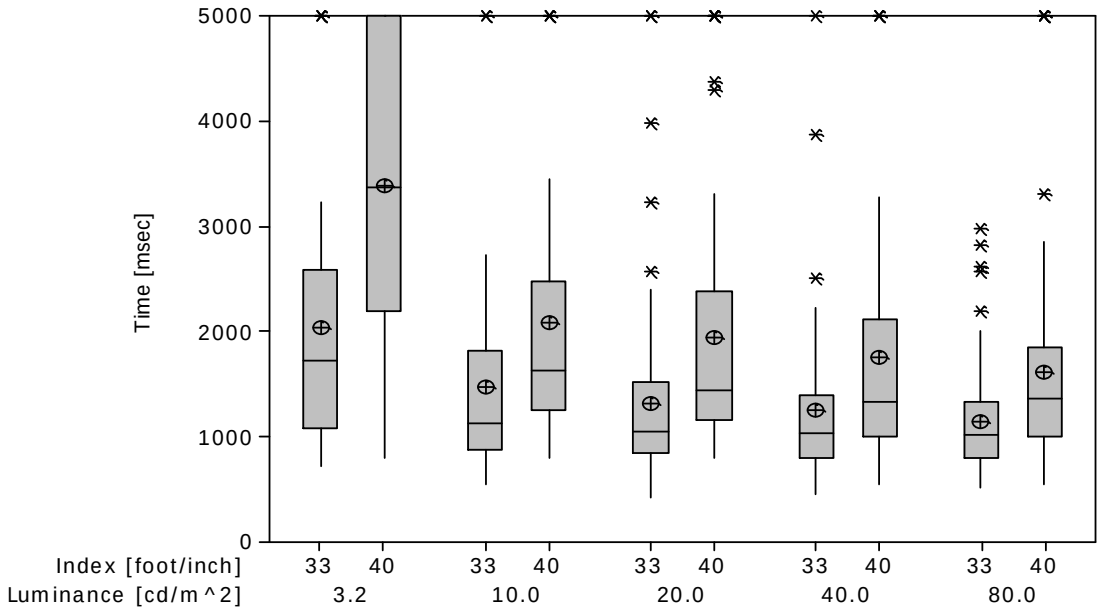
- Luminance of legend:
  - 3.2 cd/m^2 (6:1 Contrast)
  - 10 cd/m^2 (6:1 Contrast)
  - 20 cd/m^2 (6:1 Contrast, 10:1 Contrast)
  - 40 cd/m^2 (6:1 Contrast)
  - 80 cd/m^2 (6:1 Contrast, 10:1 Contrast)
- Text Size/Distance (Legibility Index)
  - 33 foot/inch
  - 40 foot/inch
- Percentile Accuracy
  - 50th Percentile Accuracy
  - 84th Percentile Accuracy



Dependent Variable

Information Acquisition Time (Limited to 200-5,000ms)

Results



- **Main effects: Luminance, size, accuracy level all significant in affecting information acquisition time**
- **Each luminance level is statistically different from one another others**

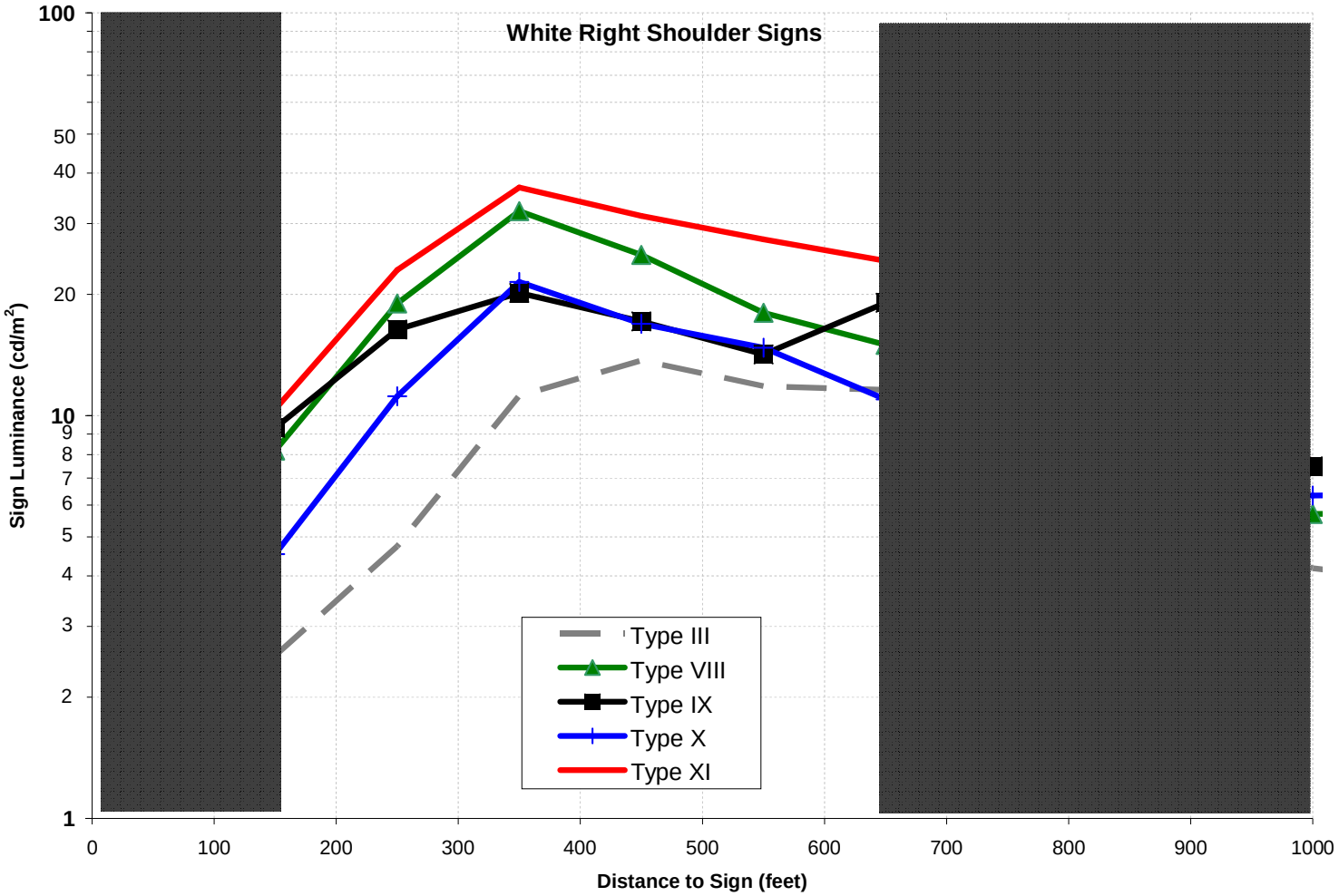
Key Conclusions

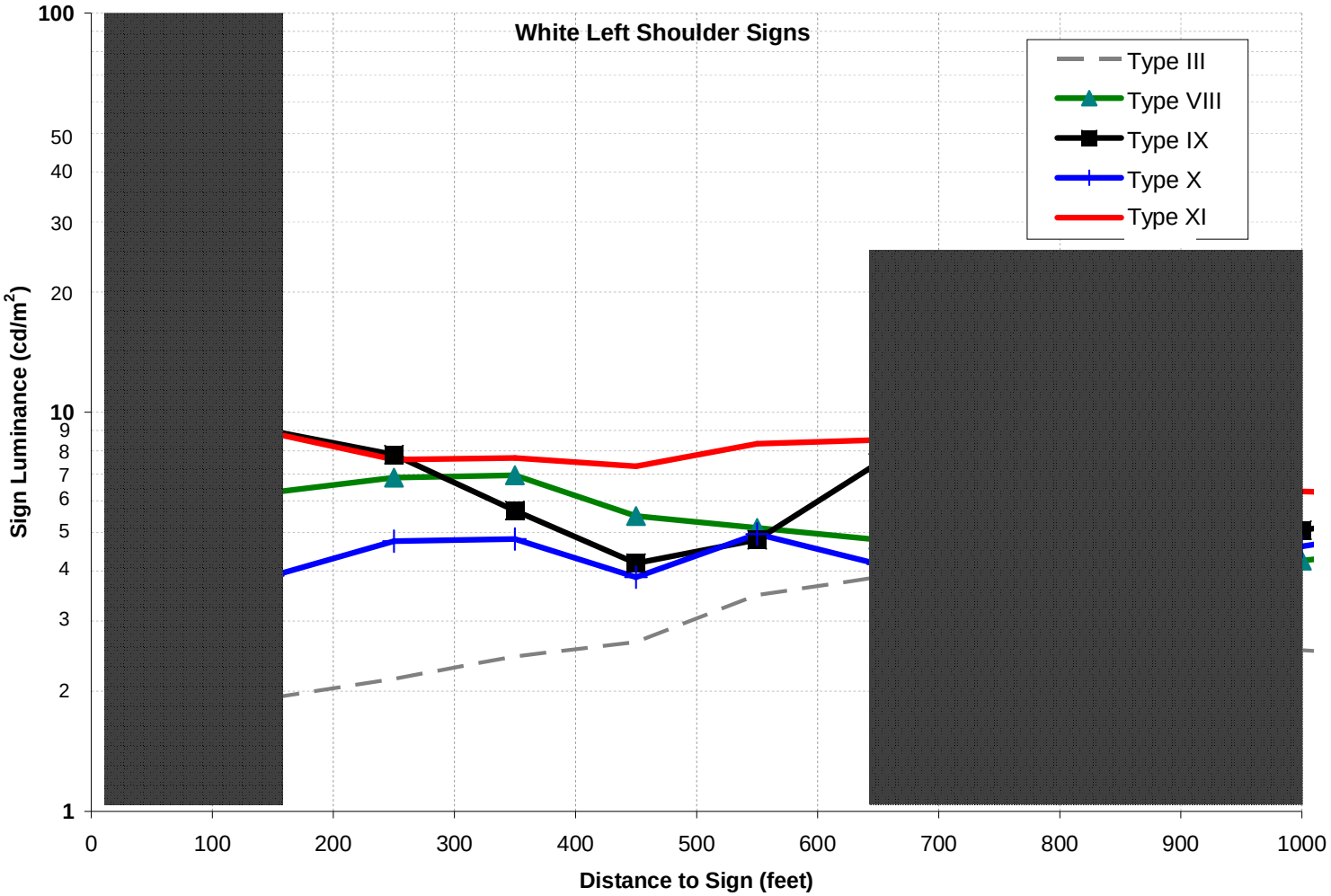
- Highest tested luminance, 80 cd/m^2, provided fastest information acquisition thereby shorter time is required to reach a certain reading accuracy.
- If viewing time is limited, higher sign luminance and/or larger letter sizes provide more accurate sign reading
- Larger signs increase information acquisition speed.
- Information acquisition times are less affected by distance (or letter size) if the sign luminance is maintained at a high level
- Information transfer accuracy improves with increasing exposure time.

80 cd/m^2 provided great results

What are the real luminances from signs?[1]

1. Aktan, F., Burns, D. M. (2008). In-The-Field and Modeled Luminance of Retroreflective Sign Sheetings. 87th Annual Meeting of the Transportation Research Board, Washington, D.C., TRB.





J. Bullough et al*, NY Expressway (Guide Signs)

Measurement session	Sign and type	Background luminance, cd/m² (std. dev.)	Character luminance cd/m² (std. dev.)
Nighttime 1	#1 – IX	3.4 (0.7)	19.7 (3.1)
Nighttime 1	#2 – IX	1.4 (0.1)	7.4 (0.4)
Nighttime 1	#3 – IX	1.6 (0.2)	9.6 (3.3)
Nighttime 1	#4 – IX	0.9 (0.1)	5.0 (1.4)
Nighttime 1	#5 – $VIII_a$	6.0 (0.1)	27.0 (1.1)
Nighttime 1	#6 – $VIII_a$	6.9 (2.3)	26.9 (5.1)
Nighttime 1	#7– proposed XI	6.9 (0.6)	37.4 (6.4)
Nighttime 1	#8 – $VIII_b$	2.5 (0.8)	9.6 (0.4)
Nighttime 1	#9 – $VIII_b$	4.9 (1.6)	15.9 (1.2)
Nighttime 2	#1 – IX	2.5 (0.7)	12.1 (3.6)
Nighttime 2	#2 – IX	0.8 (0.2)	4.3 (0.4)
Nighttime 2	#3 – IX	0.8 (0.1)	5.1 (1.4)
Nighttime 2	#4 – IX	0.5 (0.1)	3.4 (0.8)
Nighttime 2	#5 – $VIII_a$	2.1 (0.4)	9.4 (0.7)
Nighttime 2	#6 – $VIII_a$	1.9 (0.1)	10.1 (0.3)
Nighttime 2	#7 – proposed XI	2.3 (0.7)	10.9 (2.4)
Nighttime 2	#8 – $VIII_b$	3.6 (0.7)	14.3 (3.2)
Nighttime 2	#9 – $VIII_b$	3.4 (0.5)	15.7 (2.9)
Nighttime 2	#10 – III	1.3 (0.3)	6.7 (3.7)
Nighttime 2	#11 – III	0.5 (0.1)	2.8 (0.4)

* Bullough, J. D., Skinner, N. P., O'Rourke, C. P. (2010). Legibility of Urban Highway Traffic Signs Using New Retroreflective Materials. Transport, 2010, 25(3): 229-236

LED Billboard Luminances at Night

A study conducted by RPI shows that LED billboards' luminance measured between 150-277 cd/m^2 with an average of 210 cd/m^2.

* Bullough, J. D., Skinner, (2011). Luminance Criteria and Measurement Considerations for Light-Emitting Diode Billboards. *Transportation Research Board 90th Annual Meeting, Washington, DC, January 23-27. Washington, DC: Transportation Research Board*

Safety Benefits of Better Signage – Field Studies

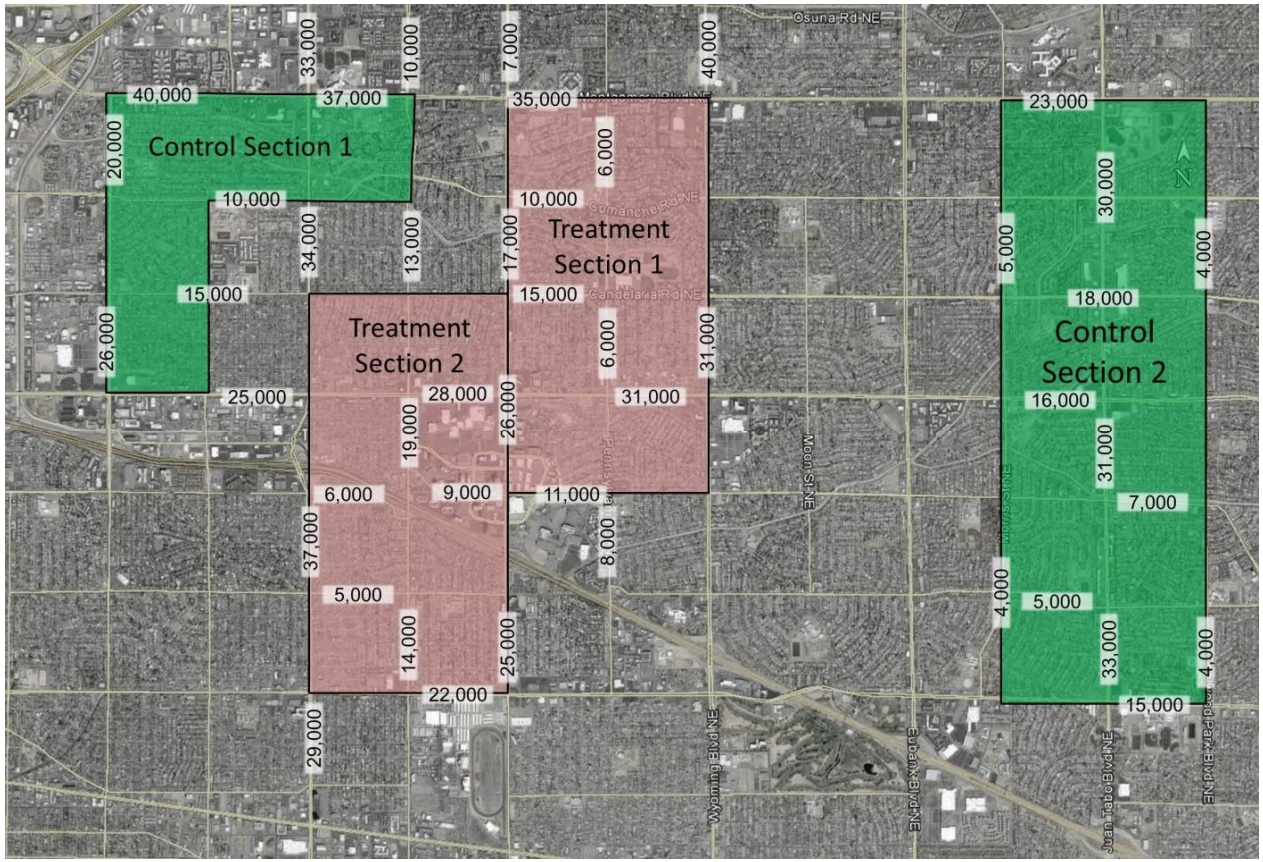
Do Sign Upgrades Improve Traffic Safety?

- Sioux City, IA, reduced crashes by ~30% in the 3 years after upgrades*
- Benefit to cost ratio of 34:1
- Insurance Council of British Columbia (ICBC) concluded a Benefit-Cost Ratio for sign upgrades at greater than 10:1*
- Mendocino County (California) showed a 46% crash reduction over a 6-year period*
- And a benefit to cost ratio of 159:1 to 299:1
- Putnam County (New York) showed a 25% crash reduction in the three years after the upgrades*

*Ripley, D. A., Howard R. Green Company, ITE AB04H313, Quantifying the Safety Benefits of Traffic Control Devices— Benefit-Cost Analysis of Traffic Sign Upgrades, 2005 Mid-Continent Transportation Research Symposium Proceedings

Sign Upgrades in Albuquerque, NM*

- Challenges exist in isolating the “effect” of traffic signage on “crashes”
  - It is difficult to isolate the variable of interest in “before and after” studies
- City of Albuquerque, NM upgrades traffic signage in installments by sections
  - Systemic upgrades allows for control sites



* Brimley, B., Seyedeh, M. M., Carlson, P., Dixon, K., “Safety Effects of Traffic Sign Upgrades in Albuquerque, New Mexico”. *Transportation Research Board 96th Annual Meeting, Washington, DC, January 8-12. Washington, DC: Transportation Research Board*

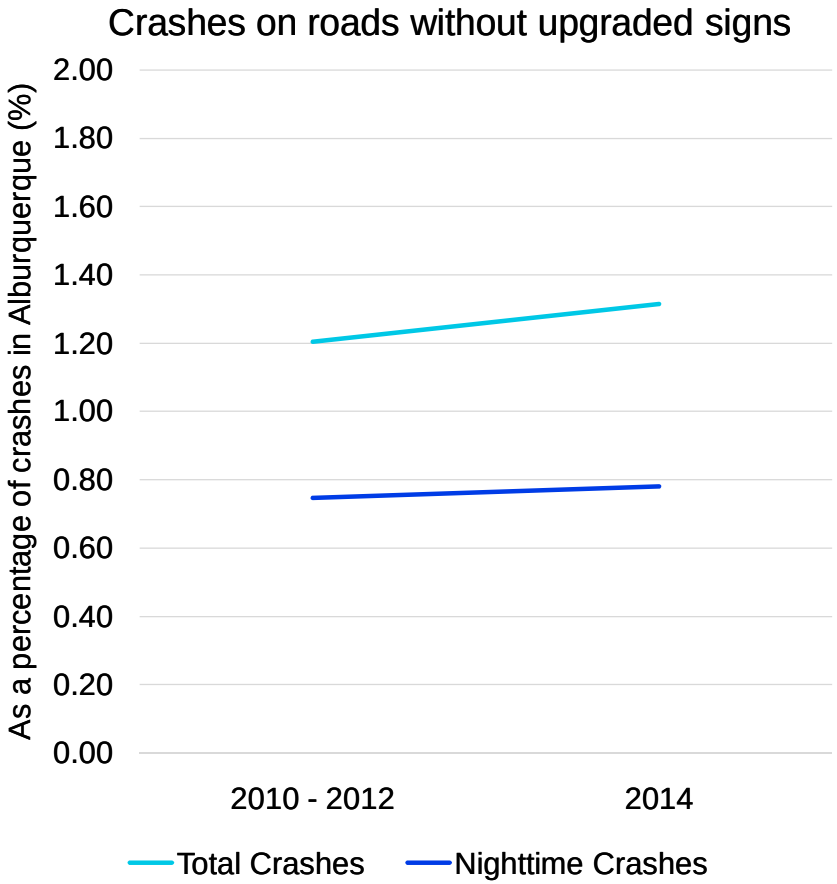
Results

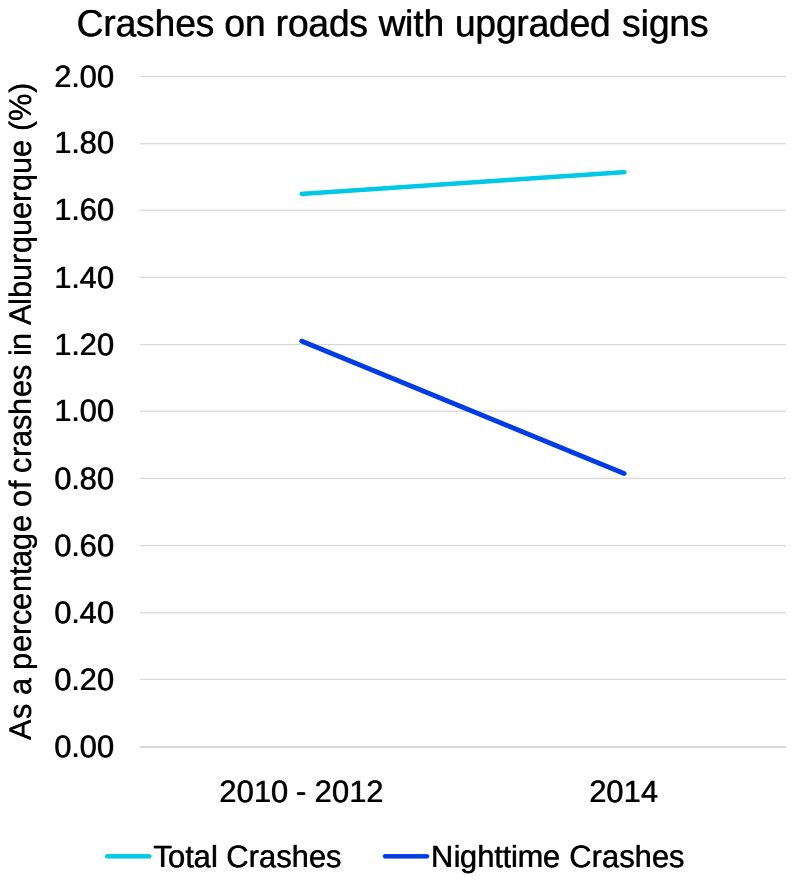
	2011	2012	2013*	2014
City of Albuquerque				
Total Crashes	16,546	16,070	16,292	17,728
Fatal and Injury Crashes	4,798	4,190	4,614	4,959
Nighttime Crashes	2,529	2,462	2,612	2,943
Nighttime Fatal and Injury Crashes	678	581	685	732
Control Segments				
Total Crashes	193	209	191	233
Fatal and Injury Crashes	59	51	52	66
Nighttime Crashes	22	20	17	23
Nighttime Fatal and Injury Crashes	3	8	10	10
Treatment Segments				
Total Crashes	293	256	242	304
Fatal and Injury Crashes	88	67	87	78
Nighttime Crashes	33	33	23	24
Nighttime Fatal and Injury Crashes	8	8	11	7

***Treatment occurred in 2013**

Effect	DF	F Ratio	p-Value
ANOVA for Total Crashes			
Study Area (Treatment or Control)	1	58.5	0.001
Total Crashes in Albuquerque	1	17.7	0.008
Signs (Old or New)	1	0.019	0.896
ANOVA for Fatal and Injury Crashes			
Study Area (Treatment or Control)	1	41.72	0.001
Fatal and Injury Crashes in Albuquerque	1	8.84	0.031
Signs (Old or New)	1	2.94	0.147
ANOVA for Nighttime Crashes			
Study Area (Treatment or Control)	1	268.9	0.008
Nighttime Crashes in Albuquerque	1	4.05	0.100
Signs (Old or New)	1	5.29	0.070

Nighttime Fatal and Injury Crashes





Recommended Guidelines for Nighttime Overhead Sign Visibility*

Complexity Level 5: Use of external light recommended

Complexity Level 4 and below: ASTM D4956 Type XI only

Complexity Level 3 and below: Type VIII, IX, XI

Complexity Levels 1 and 2: Type IV, VIII, IX or XI

* Carlson, P. J., Brimley, B., Chrysler, S. T., Gibbons, R., Terry, T. (2017). Recommended Guidelines for Nighttime Overhead Sign Visibility. *Transportation Research Record, No: 2617, Journal of the Transportation Research Board, Washington, DC, 2017. pp. 27-34*

Conclusions: Traffic Signs and Safety

- Signs with higher luminance provide better service to drivers
- Retroreflective signs are generally below the optimal luminance levels
- Signs with higher luminance yield faster information transfer to drivers, allowing more eyes-on-the-road time, which is strongly linked to safety
- Higher brightness also helps improve motorist safety
  - An actionable safety improvement
- Drivers will likely continue to visually acquire information from signage
  - Redundancy, vehicle diversity
- Vehicles are increasingly likely to acquire information from signs as well
  - Visual spectrum or by other means
  - Human factors → other sensor fusion

Thank You