Webinar

Marking the Road: Infrastructure to Improve Safety

October 2, 2019

#WeTheStates

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Ethan Peterson, PE, State Pavement Marking & Traffic Device Crashworthy Engineer, MnDOT Office of Traffic Engineering

Adam M. Pike, PE, Associate Research Engineer Program Manager, Texas A&M Transportation Institute

Moderator:
Jake Varn, Policy Analyst, National Governors Association

3M Science. Applied to Life.™

Improving Pavement Marking Visibility at Night in the Rain

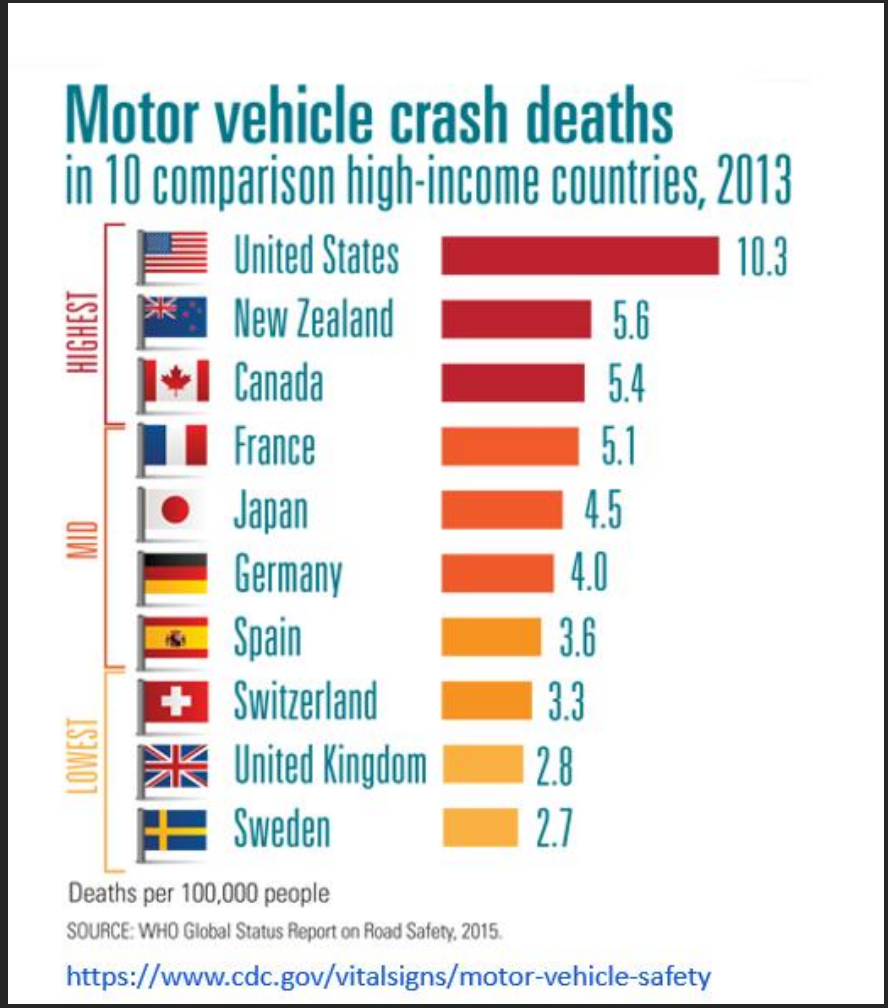
Dan Chen, Division Vice President

Transportation Safety Division

A Global and Local Crisis

In the United States:

- Crashes are the leading cause of death in first three decades of life
- Each year motor-vehicle related injuries send about 3 million people to an emergency department
- 37,800+ deaths on US roads in 2017

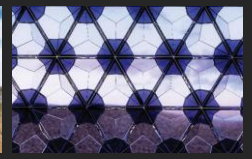
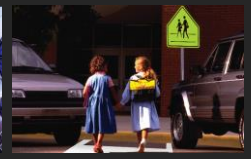


3M Transportation Safety Division History

1930



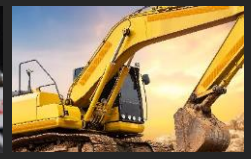
3M invents reflective sheeting and installs the first fully-reflective traffic sign in 1939; reflective technology expands to road markings and license plates.

Microreplication technology improves retro reflectivity and increases day and nighttime sign visibility. Fluorescent technology makes work zone signs and devices and pedestrian crossings more visible during dusk, dawn, and inclement weather.








Wet reflective technology makes road markings visible in the rain; conspicuity markings make trucks and vehicles more visible; digital printing innovations enable enhanced graphics and more efficient traffic sign and license plate production.

2020

3M Technology improves the visibility of roadway infrastructure

Signing

Pavement Markings

Temporary Traffic Control

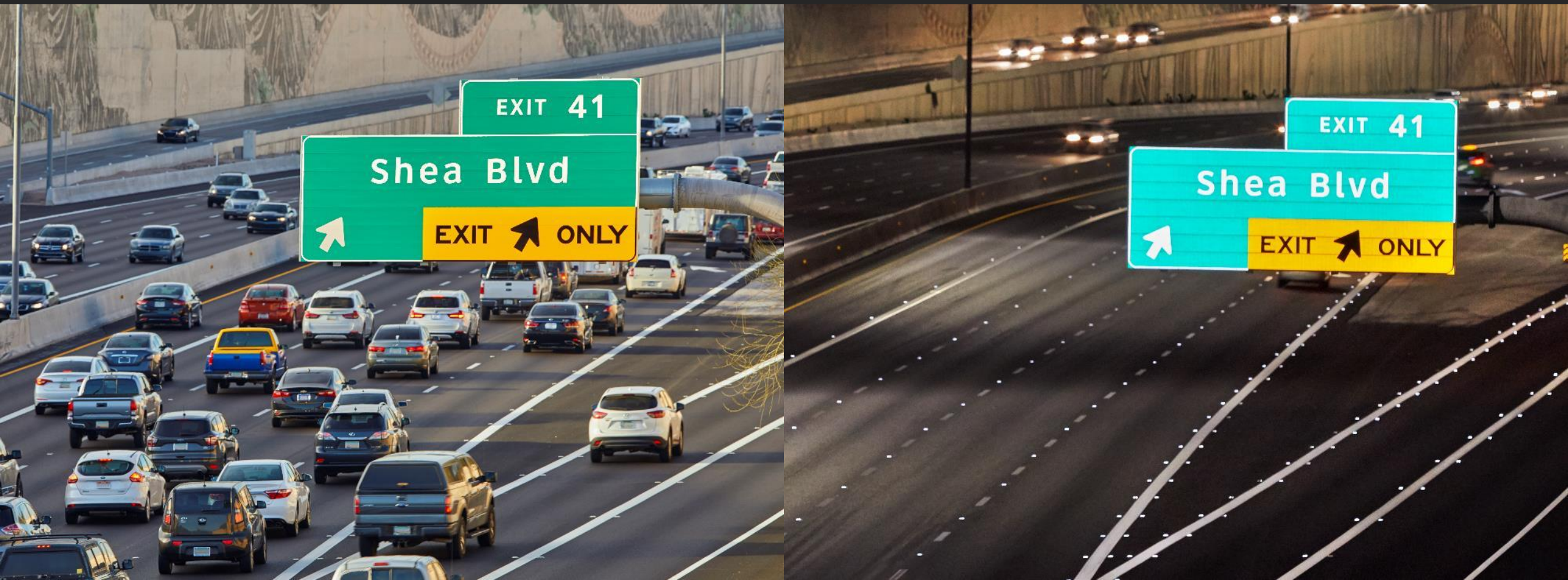
Pavement markings must be visible both day and night

Driving at night in the rain is a big problem

In 2017, 6,952 people died in crashes on U.S. roads when it was raining.

55% (or 3,811) of those deaths occurred at night or in low light conditions.

Only 25% of travel occurs at night.



Why Pavement Marking Visibility Matters

What do drivers see?

Daytime Dry

Night-time Dry

Night-time Rainy

What happens when pavement markings are hard to see?

Reduced Visibility

Increased Discomfort

Less Effective Lane Guidance

Increased Crash Risk

FHWA Report: Safety Evaluation of Wet Reflective Pavement Markings

46%

Reduction in
Run-off-road crashes on
multi-lane roads

41%

Reduction in
crashes with injury on
multi-lane roads

12%

Reduction in
crashes with injury on
freeways

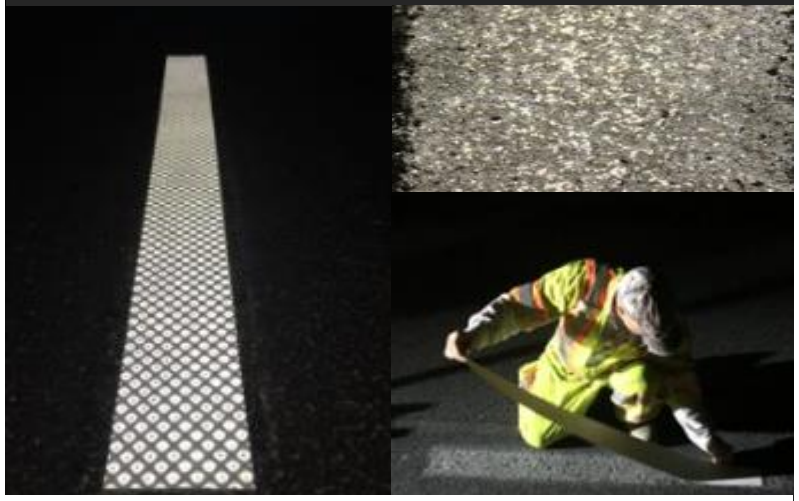
U.S. Department of Transportation
Federal Highway Administration

All weather pavement marking activity

GDOT specifies all weather tape to counteract wet night crashes

- 2014-2016: 30% increase in fatalities, many happening at night in rain
- Move to all weather tape on concrete expressway centerline, skip line, and edge line

MassDot RPM and other markings to all weather solutions



- Replacement of raised pavement markers with all weather tape and elements
- Move to 4”x2ft tape skips and all weather elements for edge lines
- Initial cost increase while life cycle cost of markings decreasing

MnDOT/TTI Wet Visibility Research

DEPARTMENT OF TRANSPORTATION

Texas A&M Transportation Institute

- Currently no minimum wet visibility wet retroreflectivity standards
- Research project to determine driver needs, recommended visibility requirements

Pavement Markings in Minnesota

Ethan Peterson| State Pavement Marking and Traffic Device Crashworthy Engineer

Office of Traffic Engineering

10/2/19

DEPARTMENT OF TRANSPORTATION

mndot.gov

Importance

- Single vehicle road departures are nearly 30% of all Minnesota fatalities
  - These crashes were widely distributed across the entire state and local network, with horizontal curves making up a disproportionate amount.
  - When looking at how low the crash density (~0.01 severe road departure/mile/year) is, pavement markings are extremely cost effective to cover an entire system.
  - Road departures are especially prevalent on rural county highways, which is why MnDOT has been an advocate for local safety planning and providing HSIP money for locals.
  - It's not the road departure that's the main concern, it's what happens afterwards!

Fatal and serious injury crashes
3,199 severe crashes
640 severe crashes per year
45.5% of all severe crashes

Crashes of all severities
86,902 crashes
17,380 crashes per year
24.0% of all crashes

On Minnesota roadways, there were 3,199 severe lane departure crashes (including run-off-road, head-on, and sideswipe opposing crashes) between 2008 and 2012. This is an average of 640 severe crashes per year and accounted for 45.5% of all severe crashes during the five-year period.

MnDOT's PM Goal

- "Provide an appropriate pavement marking on all highways, 365 days per year."

- An appropriate pavement marking is one that meets or exceeds the standards defined in the MN MUTCD. During winter weather events, pavement markings should provide presence after pavement is clear of snow and ice.

MnDOT Provisions for Pavement Marking Operations

Expected Life of Surface Applied Markings

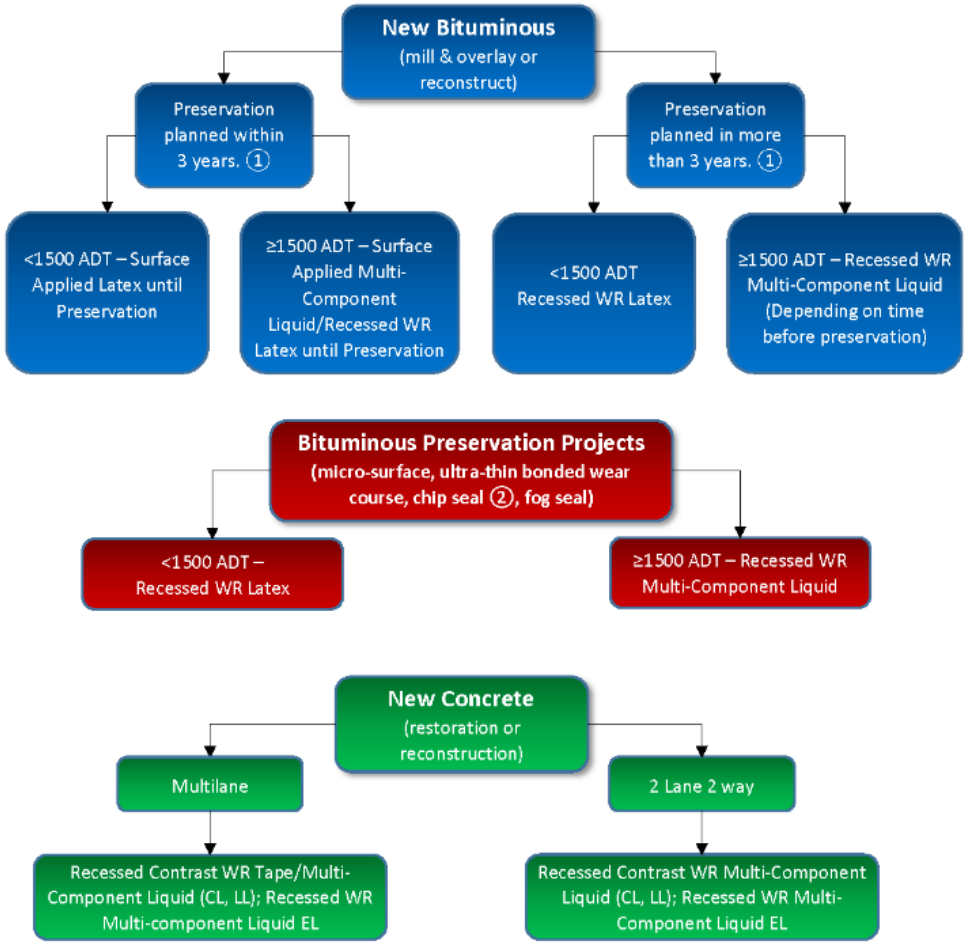
Material	ADT	
	<1,500	>1,500
Latex Paint	>1 yr.	1 yr.
Multi-Component Liquid	>5 yr.	3-5 yr.
Preformed Polymer Tape or Thermoplastic	>5 yr	>5 yr

Expected Life of Recessed Markings

Material	ADT	
	<1,500	>1,500
Latex Paint	>3 yr.	3 yr.
Multi-Component Liquid	>6 yr.	5-7 yr.
Preformed Polymer Tape or Thermoplastic	>7 yr	>7 yr

MnDOT Provisions for Pavement Marking Operations

Longitudinal Striping

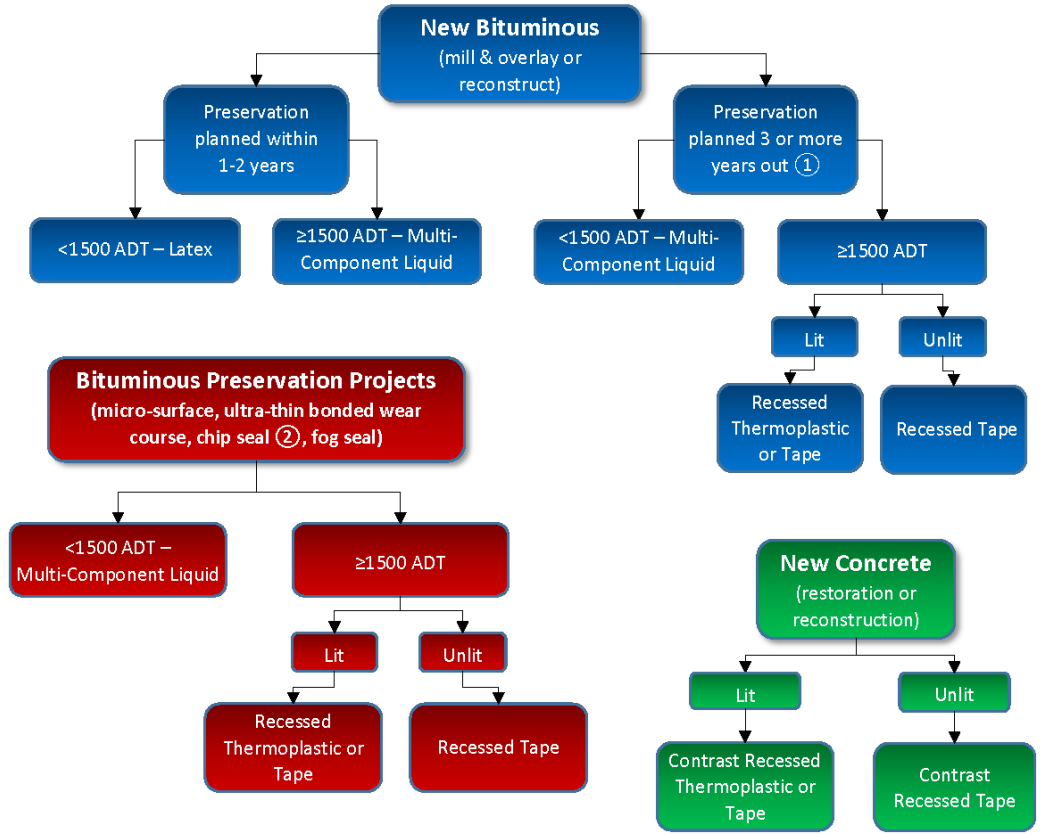


WR = Wet Reflective
CL = Center Line
LL = Lane Line
EL = Edge Line

(1) Based on life of material and suggested optimum time to initial preservation project.
(2) Methods for recessing markings on chip seals are still being developed.

Pavement Messages

(Transverse, gore markings, cat tracks, and roundabouts)



(1) Based on life of material and suggested optimum time to initial preservation project.
(2) Methods for recessing markings on chip seals are still being developed.
3. Enhanced skid resistant materials are recommended for roundabouts and crosswalk blocks.

Retroreflectivity

- Research has shown that the threshold between an acceptable and an unacceptable pavement marking based on nighttime driver visibility needs is between 80 and 120 MCD/m2 /lux.
- MnDOT is adopting a minimum performance of 100 MCD/m^2/lux for both white and yellow. As markings approach this threshold they will be replaced.
- Minimum initials have been set to get the desired longevity of the pavement markings. These are tested via mobile retroreflectometer.

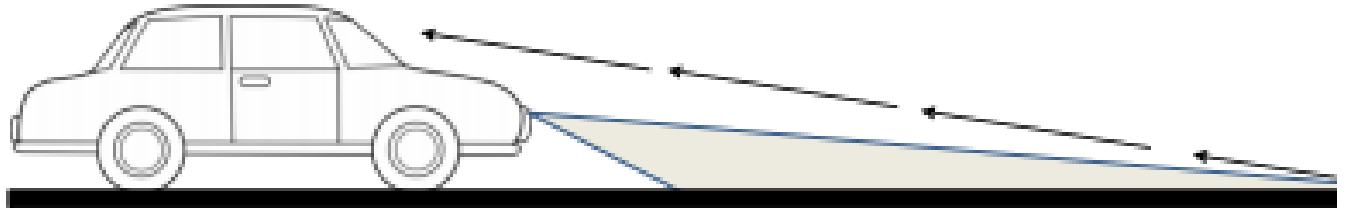


Table 2582.3-3
Minimum Initial Pavement Marking Retroreflectivity

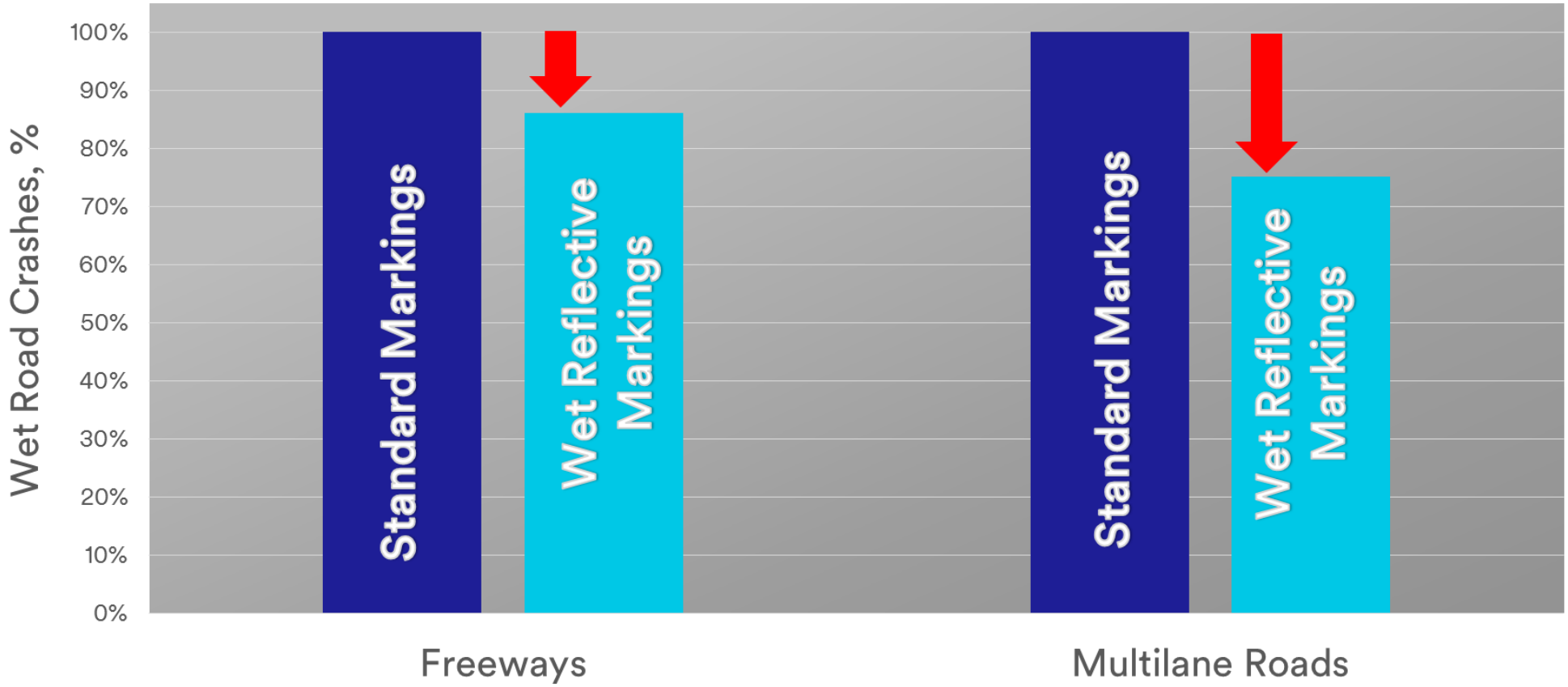
	White	Yellow
PREF TAPE	600 mcd/ m^2/lux	500 mcd/m^2/lux
PREF THERMO	300 mcd/ m^2/lux	200 mcd/ m^2/lux
PREF THERMO, ESR (Enhanced Skid Resistance)	250 mcd/ m^2/lux	150 mcd/ m^2/lux
MULTI COMP	300 mcd/ m^2/lux	200 mcd/ m^2/lux
PAINT	275 mcd/ m^2/lux	180 mcd/ m^2/lux

Wet Retroreflectivity Benefits

Safety Evaluation of Wet Reflective Pavement Markings

Craig Lyon, Bhagwant Persaud, and Kimberly Eccles. Vanasse Hangen Brustlin, Inc. (VHB) and Persaud Lyon, Inc. 2015

U.S. DoT, FHWA Sponsored Study



Wet Retroreflectivity Benefits

Wet Retroreflectivity Study

- A Technical Advisory Panel with Texas A&M Transportation Institute has been on going to establish minimums (initial and maintained) of measured wet retroreflectivity (wet continuous) for MnDOT.
- The study has included a comprehensive review of past research, analysis of available data sources, and a human factors study at the 3M test facility.
- There have been discussions with manufacturers of wet retroreflective media and they believe our desired initial install of 200 MCD/m^2/lux for yellow and white is attainable.
- A small amount of 2020 projects will include the initial wet retroreflectivity special provision.
- Adam Pike with Texas A&M Transportation Institute will present study specifics.

Other PM Topics

- 6” edgelines
- Rumble and Mumble Strips
- Connected and Autonomous Vehicles asks for pavement markings
- Enhanced Skid Resistance for pavement marking messages

Thank you again!

Ethan Peterson

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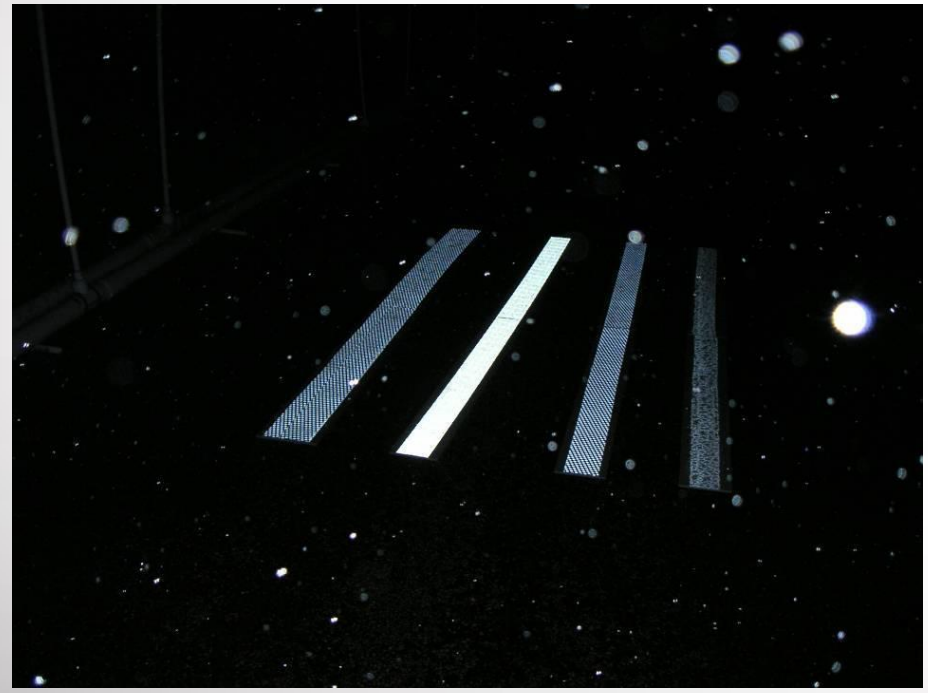
Texas A&M Transportation Institute

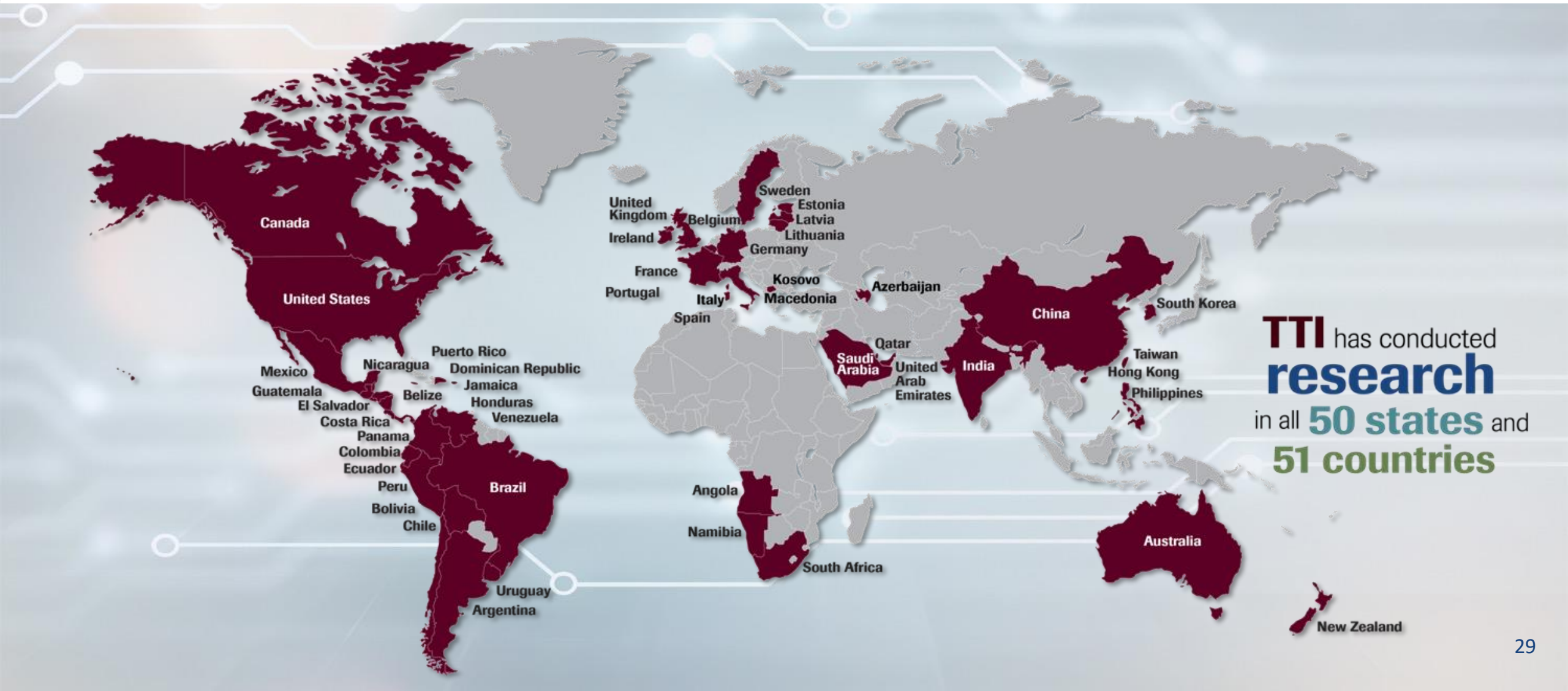


Driver Needs: Wet-Night Pavement Marking Visibility

Adam Pike, Manager
Signs and Markings Program

Global Presence

Texas A&M Transportation Institute



TTI Research Portfolio

MnDOT Study – Wet Retroreflectivity Standards

- What retroreflectivity levels are needed by drivers in wet-night conditions?
- Utilized rain tunnel at 3M Test Track in Cottage Grove, MN to simulate active rain conditions
- Evaluated participant detection distance of marking samples
  - 43 participants
  - Average age 58.5 (over half were 65 or older)
- Over 1200 total observations

Luminance Images of Markings

Values indicate continuous wet retroreflectivity (mcd/m^2/lux)

Retroreflectivity Requirements by Preview Time and Speed

	1.5 in/hr Rainfall Rate						
Retroreflectivity (mcd/m²/lx)	45 mph	50 mph	55 mph	60 mph	65 mph	70 mph	75 mph
1	1.0	0.9	0.8	0.8	0.7	0.7	0.6
2.5	1.3	1.2	1.1	1.0	0.9	0.9	0.8
5	1.6	1.4	1.3	1.2	1.1	1.0	0.9
10	1.8	1.6	1.5	1.4	1.3	1.2	1.1
12.5	1.9	1.7	1.5	1.4	1.3	1.2	1.1
15	2.0	1.8	1.6	1.5	1.4	1.3	1.2
20	2.0	1.8	1.7	1.5	1.4	1.3	1.2
25	2.1	1.9	1.7	1.6	1.5	1.4	1.3
30	2.2	2.0	1.8	1.6	1.5	1.4	1.3
50	2.4	2.1	1.9	1.8	1.6	1.5	1.4
60	2.4	2.2	2.0	1.8	1.7	1.6	1.5
90	2.6	2.3	2.1	1.9	1.8	1.6	1.5
110	2.6	2.4	2.2	2.0	1.8	1.7	1.6
150	2.7	2.5	2.2	2.1	1.9	1.8	1.6
200	2.8	2.6	2.3	2.1	2.0	1.8	1.7
250	2.9	2.6	2.4	2.2	2.0	1.9	1.7
400	3.1	2.8	2.5	2.3	2.1	2.0	1.8
425	3.1	2.8	2.5	2.3	2.1	2.0	1.9
800	3.3	3.0	2.7	2.5	2.3	2.1	2.0

Recommendations

- Minimum maintained continuous wet retroreflectivity level (ASTM E2832), **50 mcd/m²/lux**
  - Minimum driver needs at 60 mph
  - Considers older driver population
  - Heavy rain conditions
- Initial continuous wet retroreflectivity, **200 mcd/m²/lux**
  - Based on expected service life of 4 years
  - Considered actual MnDOT continuous wet retroreflectivity degradation
  - Achievable initial level

Safety Evaluation of Wet-Weather Pavement Markings

- Study location: TxDOT Atlanta District
- Considered specific crash types
- Considered time of day
- Included wet weather exposure levels
- Evaluated segments with wet-weather marking implementation

Finley, M., A. Pike, E.S. Park, L. Wu, L. Theiss, M. Brewer, K. Fitzpatrick, R. Avelar, and T. Barrette. *Traffic Control Device Analysis, Testing, and Evaluation Program: FY 2018 Alternatives.* Report 0-6969-R1. Texas A&M Transportation Institute, College Station, TX. August 2018.

http://tti.tamu.edu/documents/0-6969-R1.pdf

Safety Evaluation of Wet-Weather Pavement Markings

- 196 total segments evaluated
- 1052 center line miles
- 2011 to 2017 crash period
- Empirical Bayes Before-After and Full Bayes Before-After

	Percent Crash Reduction (Uncertainty Estimate)					
Approach	Wet-Night	Dry-Night	Wet-Night Fatal Injury	Dry-Night Fatal Injury	Wet-Night Run-Off-Road	Dry-Night Run-Off-Road
EB	**33%** (10%)	10% (7%)	**58%** (10%)	**21%** (9%)	*25%* (13%)	5% (9%)
FB	**47%** (10%)	4% (10%)	**60%** (9%)	7% (14%)	**35%** (11%)	-6% (12%)

On-going Pavement Marking Projects

- Pavement Marking Patterns and Widths – Human Factors Study
- Reference Machine Vision for ADAS Functions
- A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions

Pike, A., S. Clear, T. Barrette, T. Hedblom, and J. Whitney. *Effects of the Wet Retroreflectivity and Luminance of Pavement Markings on Lane Departure Warning in Nighttime Continuous Rain with and without Glare Sources.* SAE Paper 2019-01-1014.

Q&A

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Thank You!

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