Green Auxiliary Warning Lights on Winter Maintenance Trucks

Green Lights - Background

- At the 2013 North American Association of Transportation Safety and Health Officials (NAATSHO) Conference…
  - Ohio DOT announced use of green/amber/white auxiliary warning lights on winter maintenance trucks (WMTs)
- MDOT ad hoc team piloted green with amber in 2015
- Local agencies/County Road Association of Michigan (CRA) got involved
- Michigan law changed in 2016 to allow the use of green
  - (Note: If the law does not mention the use of a color for an application, it cannot be used.)
- MDOT implemented a phase-in of the use of green and amber on WMTs starting in 2017

Michigan Vehicle Code

Act 300 of 1949, Chapter VI, Equipment

Section 257.698

(5) The use or possession of flashing, oscillating, or rotating lights of any color is prohibited except as otherwise provided by law or under the following circumstances:

(d) Flashing, rotating, or oscillating amber or green lights, placed in a position as to be visible throughout an arc of 360 degrees, must be used by a state, county, or municipal vehicle engaged in the removal of ice, snow, or other material from the highway and in other operations designed to control ice and snow, or engaged in other non-winter operations. This subdivision does not prohibit the use of a flashing, rotating, or oscillating green light by a fire service.

(Note: The reference to “fire service” comes from the use of green lights for identifying incident command posts during an event.)

Michigan Vehicle Code

(Note: The MVC was later amended to add other allowances for the use of green lights.)

(e) A vehicle used for the cleanup of spills or a necessary emergency response action taken under state or federal law or a vehicle operated by an employee of the Department of Natural Resources or the Department of Environment, Great Lakes, and Energy that responds to a spill, emergency response action, complaint, or compliance activity may be equipped with flashing, rotating, or oscillating amber or green lights. The lights described in this subdivision must not be activated unless the vehicle is at the scene of a spill, emergency response action, complaint, or compliance activity. This subdivision does not prohibit the use of a flashing, rotating, or oscillating green light by a fire service.

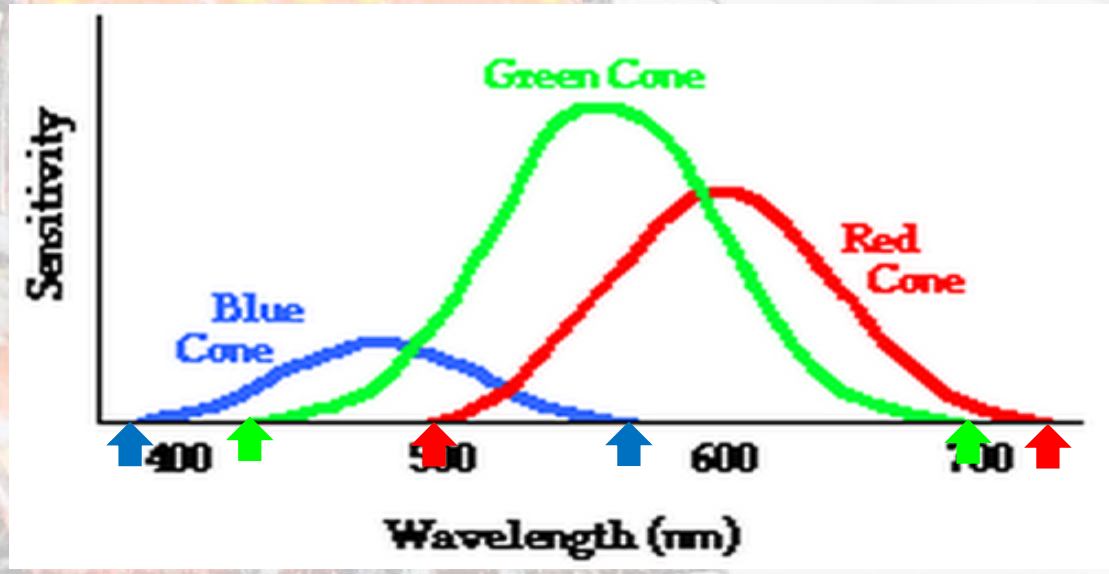
(f)… A vehicle engaged in authorized highway repair or maintenance may be equipped with flashing, rotating, or oscillating amber or green lights. This subdivision does not prohibit the operator of a vehicle utilized for snow or ice removal under section 682c that is equipped with flashing, rotating, or oscillating amber lights from activating the flashing, rotating, or oscillating amber lights when that vehicle is traveling between locations at which it is being utilized for snow or ice removal.

Existing Research

- TRB NCHRP Report 624 (2008)
  - Selection and Application of Warning Lights on Roadway Operations Equipment
    - Key takeaways: Placement, concerns with glare, slower flash patterns, more is not better
- Minnesota DOT (2006)
  - Improving the Ability of Drivers to Avoid Collisions with Snowplows in Fog and Snow
    - Key takeaways: Flashing versus steady burn, placement on both sides on rear
- Clear Roads (2015)
  - Use of Equipment Lighting During Snowplow Operations
    - Key takeaways: Flashing for presence, steady burn for estimation of speed

Science Behind Green Lights…

- Your eye's retina is lined with a variety of light-sensing cells known as rods and cones.
- Green is perceived as brighter because the human eye evolved to see it with greater sensitivity.
- While green has the highest sensitivity, it also has the largest range of wavelength.

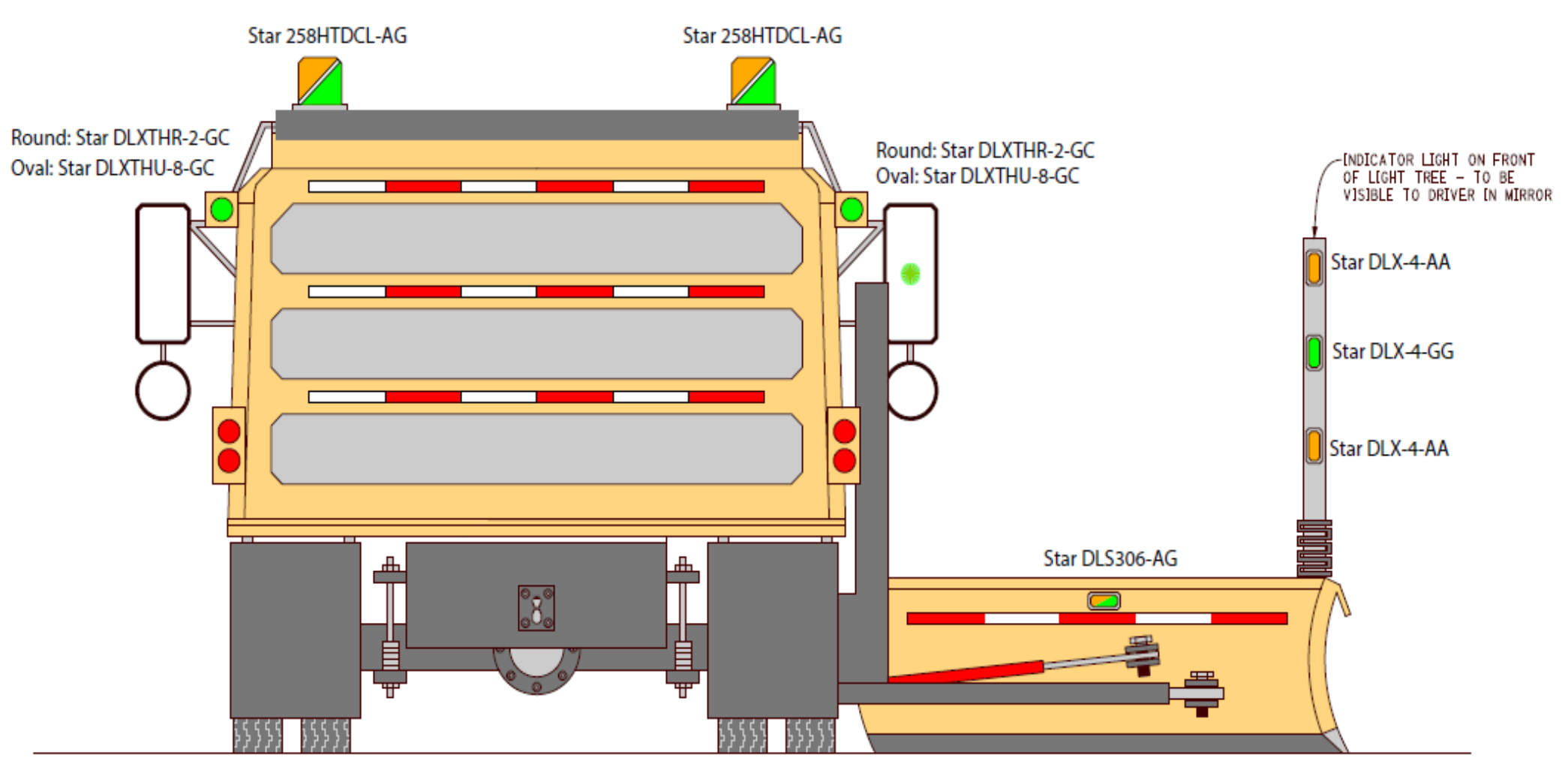


Physicsclassroom.com

MDOT's Implementation Thoughts

- Build on existing MDOT standard for vehicle visibility
  - Standard (formerly policy) prescribes light placement, etc., based on NCHRP 624
- Green only to be used with amber
  - White was not considered as an auxilary warning light due to glare concerns at night and with blowing snow based on the experience with white lights for other applications on WMTs (salt discharge, etc.)
- Green will have a single-flash pattern to aid in depth perception
  - Previous studies mention a steady burn light rather than flash to improve depth perception. Obviously, a steady green was not an option. It was felt that reducing the flash pattern to single for green would help.

WMT Configuration (2017 Implementation)



(Note: This configuration has been updated based on field use and durability, research, and vendor/product availability.)

Implementation for WMTs

- Number of trucks converted: approximately 300
- Average cost per unit: $600
  - Does not include labor
  - Note: Additional cost of $205 to convert wing sticks, but unknown as to how many were converted
- Total cost to convert WMTs: only approximately $180,000
- Time to convert all WMTs: started in fall 2017, finished in fall 2018

Concerns leading up to the research project

- Existing research does not really address green as one of the colors for WMTs
- Insufficient data to determine effectiveness
- Impact is currently subjective
  - WMT driver feedback (very positive)
  - Motorist feedback (only one negative call over two seasons)
- What are the right flash patterns?
- Is green and amber together the best color combination, or is one or the other color alone better?

MDOT Research Project

- Confirm or refute the effectiveness of green auxiliary warning lights, with or without amber, on winter maintenance equipment, including review of flash patterns
- Michigan State University (MSU) was selected by the team based on their proposal
- Request to include recommendations for use beyond WMTs
- Final report issued August 2020

Process

- Survey other states (all 50 responded!)
- Assemble human subjects and an MDOT WMT
- Static Experiment:
  - 450 feet away
  - Day and night
    - Visibility (attention/conspicuity)
    - Reaction (driving action)
    - Peripheral detection – static day only
  - 37 different configurations
  - 150 feet for Glare Rating Test (discomfort) – night only
  - Completed at our Paw Paw facility on Nov. 12, 2019

Process (continued)

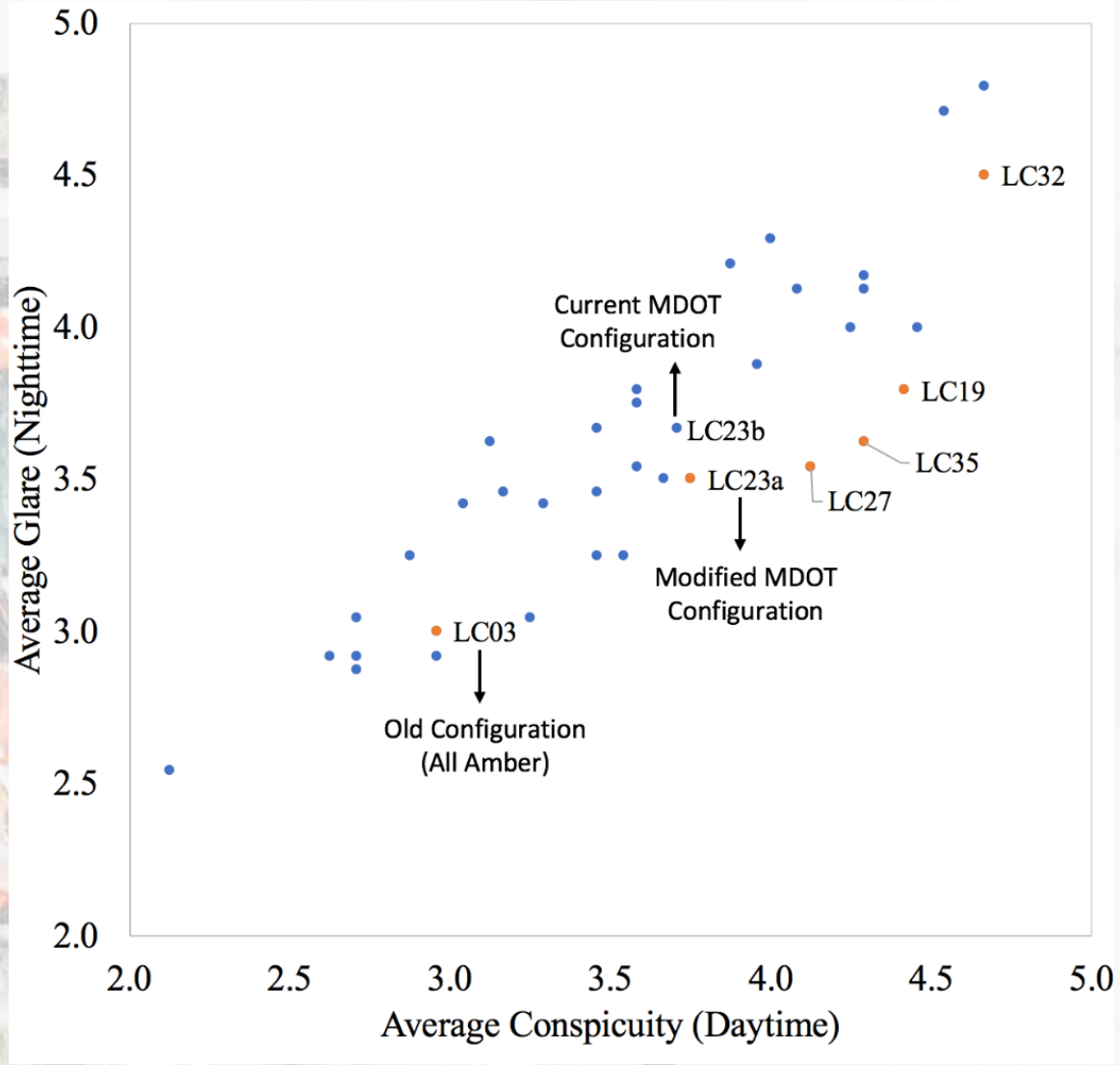
- Dynamic Experiment:
  - Human subjects riding as passengers
  - Conducted at the American Center for Mobility
  - Day – Nov. 26, 2019
  - Night – Dec. 5, 2019
  - Six representative configurations based on the static experiment
    - Visibility (conspicuity)
    - Reaction
    - Glare (night only)

Process (continued)

- Snowy Weather Experiment
  - Day and night
  - Had to take place at a moment's notice based on winter events in the area
  - Safety concerns for test subjects, so limited number used
  - Completed – Feb. 26, 2020 (just a couple weeks before the state's COVID-19 shutdown)
  - (Note the difference between the two lower photographs with the amber versus green lights)

Results

- Conspicuity Test (visibility)
  - All amber had the lowest
  - Amber and green had the highest
  - Single-flash had the lowest
  - Quad-flash had the highest
- Glare Test (discomfort)
  - All amber had the lowest
  - Amber and green had the highest
  - Single-flash had the lowest
  - Quad-flash had the highest



Interpretation of Results

- Correlation between conspicuity and glare
- Selecting the proper light configuration is a tradeoff between these two factors
- Amber single-flash was the lowest
- Amber quad-flash with green quad-flash had the highest
- Four patterns were found to offer improved visibility while resulting in a “bearable glare discomfort to travelers”
  - All four had varying configurations of amber (quad) and green (single)

Light Configuration	Beacon Color (Flash Pattern)	LED Color (Flash Pattern)
LC03	Amber (Quad)	Amber (Single)
LC19	Amber (Quad) + Green (Single)	Amber (Quad)
LC23a	Amber (Quad) + Green (Single)	Green (Single)
LC27	Amber (Quad)	Amber (Quad) + Green (Single)
LC32	Green (Quad)	Amber (Quad) + Green (Quad)
LC35	Amber (Quad) + Green (Single)	Amber (Quad) + Green (Single)

The four patterns are: LC19, LC23a, LC27, and LC35

Final Recommendations

- Amber lights with single-flash pattern does not provide sufficient conspicuity
- Quad-flashing green is not recommended due to nighttime discomfort/glare
- Continued use of green is recommended
- Quad-flashing amber and single-flashing green was deemed the most effective.
  - Trade-off between conspicuity and glare
- Minor impact on current use of green lights on MDOT's WMTs
  - Slight improvement with synchronization
- Improved conspicuity should allow for use beyond WMTs

MDOT Research Spotlight Video

https://www.youtube.com/watch?v=jke5bYpwPGo

MDOT's Implementation Plan

- Synchronize top/front lights on new WMT build-ups
  - Continue investigation for technological options to synchronize all lights
- Used amber/green combination lights on rear on new WMTs and if replacing existing WMT's green only
  - Vendors now have options available
- Expand use of green (with amber) lights on other vehicles and equipment
  - Risk-based approach
    - First (initial) responder pickups first (aka: responders to highway incidents and closures).
    - Attrition basis for all others as new vehicles and equipment are leased and/or purchased.
      - Developing a configuration/pattern for each type of equipment for consistency in deployment throughout department, building on existing standard for placement.
      - Update the MDOT standard/policy.
- Share the information/research report with others
  - Below is a link to the Research Spotlight. On the second page, right blue box, contains a link to download the final report.
  - Green warning lights make winter maintenance trucks more visible (Michigan.gov)

Final thoughts

- The intent of adding green to WMTs was to improve the safety of the motoring public and the workers.
- MDOT made the best decision we could based on what we knew at the time as to the proper configuration.
- The MSU research provided excellent information to confirm that we made the right decisions.
- Improvements and expanded use of green lights on MDOT equipment will continue.

Questions?

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Wing Plow Lights

Addendum Presentation (If time allows)

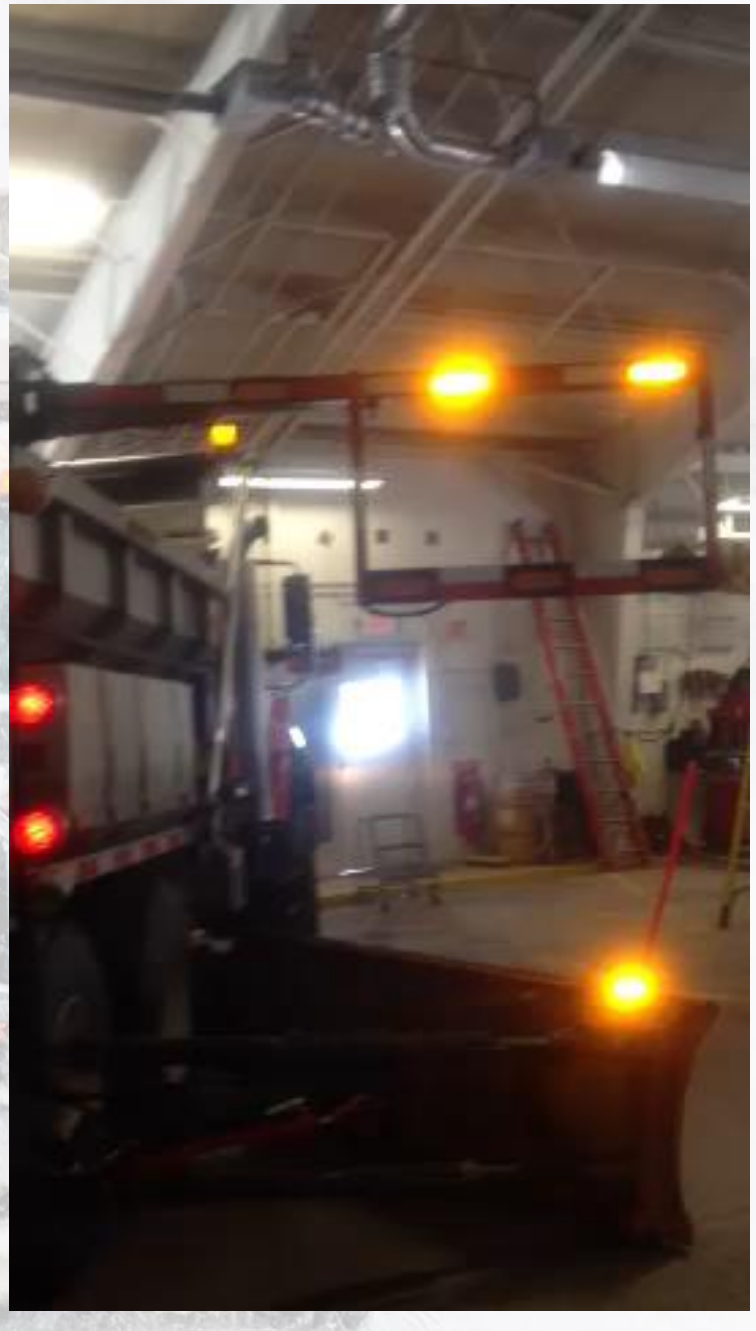
Michigan Department of Transportation (MDOT)

Wing Plow Markers/Lights

- Issue: Use of wing plows in live lanes. Initially allowed for shoulders only. Expanded for use in passing relief lanes, etc.
- Concerned that motorists may pass WMTs on side wing plow is deployed.
- Need for improved visibility of wing plow, especially with blowing snow.
  - “Fill the lane”
  - Needs to be high enough to improve visibility
- Various configurations of lights/pilots tried:
  - North configuration
  - Superior wing stick
  - Whip
- Cost differences.
- Maintenance differences.

North Configuration

- Pro: High and low lights
- Con: Moving parts resulting in maintenance issues

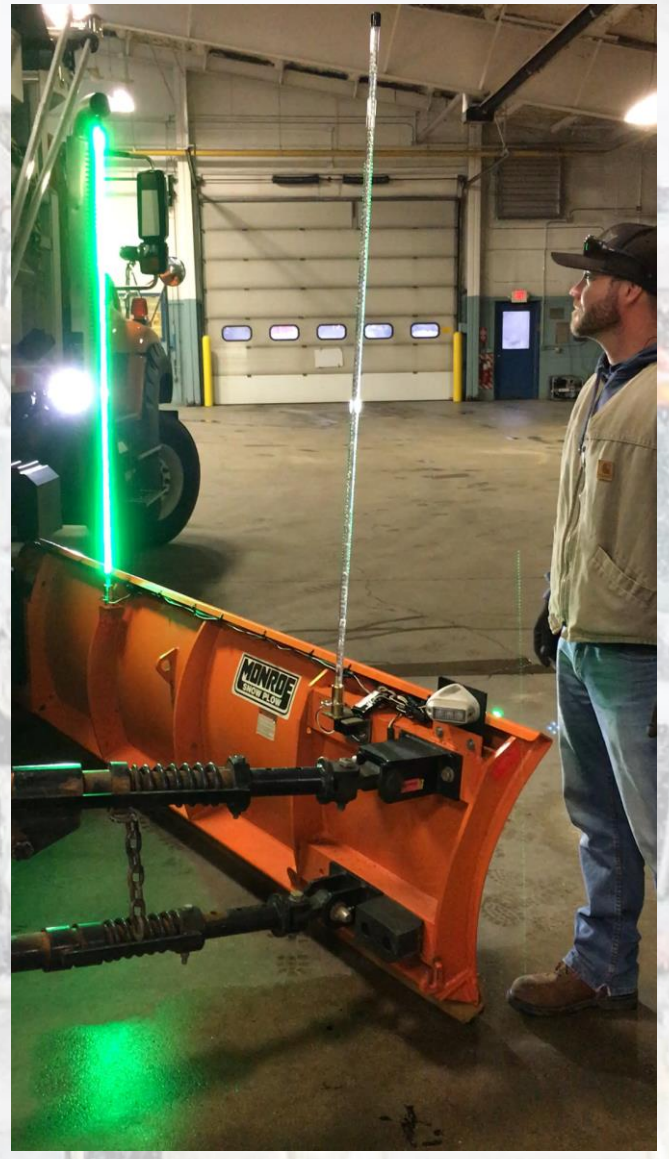


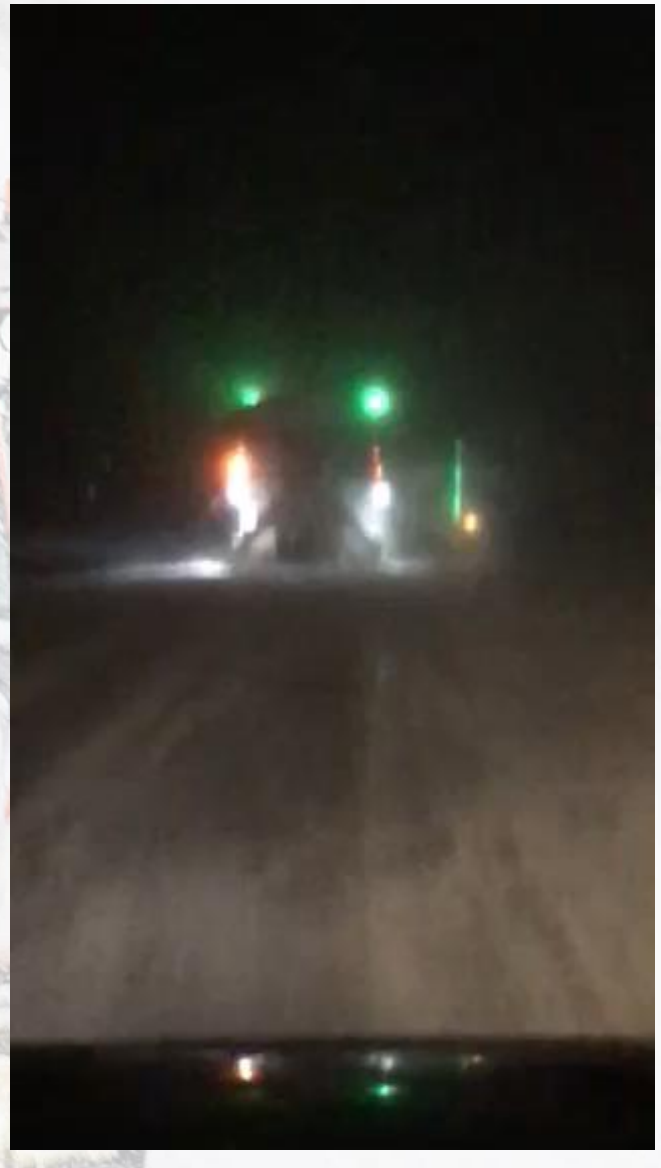
Superior Wing "Stick"

- Pro: Deemed as effective in warning motorists of wing plow
- Con: Durability
- Con: Stick is in the way if loading salt on same side
- Configuration formalized as shown on slide 8 of earlier presentation and updated to include green with amber

Wing “Whip”

- Pro: Lower cost
  - $140 versus $315
- Pro: Flexible
- Pro: Ease of replacement
- Con: May not be as bright as traditional warning lights
- Con: Not able to synchronize with other lights
  - Note: Pilot went with green only as an amber/green model was not yet available
- Con: Durability
  - Exploring/working with multiple vendors
    - Tribal Whips
    - Buggy Whip
    - Others?





MDOT's Status

- Continue to have lights on wing plows to improve visibility to the motorists.
- Configuration:
  - Use a "whip" with amber and green at the end of each wing used.
  - Use amber/green strobe on mid-point of moldboard.
- Implement on new build-ups and transfer out old (Superior style) wing sticks as needed rather than converting all to control cost and labor.