Research Stage 1 Problem Statement

PROPOSED TITLE: Pavement Marking Durability and Retro Correlation

1. Concisely describe the transportation issue (including problems, improvements, or untested solutions) that Oregon needs to research.

ODOT pavement marking maintenance is seeking a research study on non-durable, waterborne paint material thickness and retroreflectivity. Construction standards apply non-durable paints at a variety of thicknesses given a product, but failure is measured by millicandelas (retroreflectivity), not thickness. There are minimum standards of millicandelas when applying non-durables and it must last for 3 years. ODOT Maintenance has a federal minimum standard of 50 millicandelas, but has found certain thicknesses last longer and work with an annual cycle for staffing purposes. Due to current budget constraints, ODOT Maintenance will be applying thinner lines for the foreseeable future. Experienced crew leads are skeptical thinner lines will provide the lifespan needed/expected and require more staff time. They are unsure of the optimal thickness for best lifespan. ODOT does not have a method of tracking this relationship and relies on the industry knowledge of crew members, leaving this understanding heavily qualitative considering traffic volume and geographic area. The pavement marking group attempted a preliminary research method to view the relationship between thickness and retroreflectivity (documenting failure and life span duration). The discovery was rather inconclusive for either yellow or white pavement marking thickness and its correlation to retroreflectivity due to such few data points to assess. Collection of data for these thinner applications and their lifespan, combined with prior applications' data from past years, will prove valuable for guidance to reach an optimal thickness application as well as help determine life span expectations when thinner applications are needed. There is also a need to understand if there is an optimized use and selection of beads. Depending on selection bead size will vary and may influence life span and retroreflectivity differently

2. What final product or information needs to be produced to enable this research to be implemented?

The research should determine optimal thickness for non-durable markings that maintain federal retroreflectivity standards (≥50 millicandelas) while achieving expected lifespans of 9–18 months. A database combining new and existing ODOT data on thickness, bead application, climate, speed, bead geometry, and pressure will assist maintenance make informed decisions. This dataset will allow analysis of variables influencing retroreflectivity and lifespan. Results should provide predictive models for line failure and durability under varying conditions. These findings will guide asset and material management decisions within ODOT's pavement marking program.

3. (Optional) Are there any individuals in Oregon who will be instrumental to the success of implementing any solution that is identified by this research? If so, please list them below.

Name	Title	Email	Phone
Rebecca Burrow	Maintenance Services Manager	rebecca.burrow@odot.oregon.gov	503.951.9333
Ted Miller	Maintenance Leadership Team rep on Statewide Pavement Marking Committee	theodore.c.miller@odot.oregon.gov	503.731.8559
Gary Copher	Region 1 Pavement Marking Manager	gary.w.copher@odot.oregon.gov	503.668.6715
Shawn Martin	Region 2 Pavement Marking Manager	shawn.martin@odot.oregon.gov	503.373.9420
Steve Silva	Region 3 Pavement Marking Manager	steve.t.silva@odot.oregon.gov	541.957.3651
Rolon Williams	Region 4 Pavement Marking manager	rolon.s.williams@odot.oregon.gov	541.508.9569
Shane Dunham	Region 5 Pavement Marking Manager	kenneth.s.dunham@odot.oregon.gov	541.963.1587
Jeremiah Griffin	Region 3 Transportation Infrastructure Development & Project Manager	jeremiah.m.griffin@odot.oregon.gov	541.774.6352
Nick Fortty	FHWA Regional representative		

4. Other comments:

Preliminary work was done to find related research nationally via a literature review. The results are conflicting and skewed depending on the agency responsible for the research. Ultimately existing research could not determine a direction to follow for ODOT. The literature review was performed by Jon Lazarus (ODOT Research Coordinator) and will be included as an attachment in this document.

The data tables used for the preliminary research performed by ODOT will be provided as a reference for readers to see what was determined important for the study at that time.

5. State of Oregon Decision Making Lenses

State decision making lenses are a part of the state of Oregon's policy structure. State policy and federal policy are not always aligned. The state will prioritize research according to state policy, however ODOT may be required to skip prioritized proposals based on constraints placed on the use of federal funds. If state funds are available ODOT will attempt to fund prioritized research that is deemed ineligible for federal funding.

Please complete the following three sections. Your answers to these questions will be applied on a programmatic basis to support agency decisions. Answering yes to the questions below is not required. Resolving a narrowly focused technical research problem may meet agency needs without answering yes to any of the following questions. The ODOT Research Section will seek a balanced portfolio some

projects will answer yes to one of the three categories below (e.g. climate, equity, and/ or safety) and other projects in a different category.

We are looking for an overall program balance and no one project is expected to balance all categories. Generally, a research problem statement is expected to be able to answer yes with clear and verifiable information in only one of the three categories below, some projects may be able to answer yes in two or even three categories. Some projects (i.e. needs focused on specific elements of infrastructure design), may have no 'yes' answers but may still be a high value research need.

Climate

Oregon recognizes the climate crisis and makes systemic changes to reduce emissions caused by travel. To that end, we seek research that reduces carbon emissions from construction activities and materials, and from maintenance equipment and operations. Oregon envisions a transportation system that is resilient, this means a system that is durable in the face of seismic events and extreme weather to avoid negative impacts, withstand them or bounce back quickly to resume system function. We seek research that improves the ability of the transportation system to adapt or cope with more frequent and extreme weather events. This may include innovations in data and data sharing, construction materials and project design, communication, emergency planning and response, and more. Similarly, we seek research that avoids negative impacts on key habitats and ecosystems that can buffer or reduce damage to infrastructure and improve environmental conditions for wildlife and native vegetation. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

5a. Will addressing the transportation issue identified as a need in Question 1 develop, or **validate methods for the estimation, measurement, or monitoring** of transportation generated greenhouse gases (GHG)?

☐Yes ☐No ☒Unsure

5b. If climate or GHG is not the focus of this **transportation issue** identified in this problem statement, will the research apply a GHG analysis to transportation infrastructure, planning, operations, maintenance, or materials?

☐Yes ☒No ☐Unsure

5c. Will addressing the **transportation issue** include development or testing of construction practices, methods, or materials to establish potential reductions in greenhouse gas emissions?

☒Yes ☐No ☐Unsure

5d. Will solving the **transportation issue** in question 1 study or support the reduction of vehicle miles traveled and single occupancy vehicle travel or support transition to electric vehicles (or other types of zero emission vehicles) or low-carbon alternative fuels?

☒Yes ☐No ☐Unsure

5e. Will the solving the **transportation issue** in question 1 lead to work that will support, measure, or monitor, transportation system resilience in response to expected climate events, effects, or natural disasters in general?

☒Yes ☐No ☐Unsure

5f. Will solving the **transportation issue** in question 1 lead to work that may result in better environmental conditions for wildlife and native vegetation?

☐Yes ☐No ☒Unsure

5g. If you answered yes to any of the climate questions above or can provide alternative details related to climate, please provide additional information:

ODOT is seeking to optimize use of material and crew utilization resources. If either of these considerations can be optimized to reduce the use of either, then emissions will reduce as well as the risk of contaminants to nature.

5C - If material use is reduced, there is an assumed benefit to the climate (unmeasured) in two main ways:

a) less GHG production to create and apply the non-durable pavement markings, and

b) less staff vehicle use to travel to , work, and return to the office.

5d - If optimized use of equipment and material is found to be less than the current effort, both labor and vehicle miles will be reduced to perform work.

5e - Better optimization of pavement markings increases resilience

Equity

Equity can have many dimensions and impacts relating to communities and transportation. It is important that problem statement proposals clearly explain the equity dimensions or impacts being examined. Oregon commits to social equity in the OTP, specifically to *improve access to safe and affordable transportation for all, recognizing the unmet mobility needs of people who have been systemically excluded and underserved. Create an equitable and transparent engagement and communications decision-making structure that builds public trust*. We seek research that studies elements of this goal or applies analysis to specific transportation topics to ensure the resulting research recommendation is consistent with agency equity goals. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

5h. Is the **transportation issue** identified as a need in Question 1 specifically focused on transportation equity?

☐Yes ☒No ☐Unsure

5i. If the **transportation issue** is not focused on transportation equity, will the primary topic be assessed for equity benefits or impacts within the research project?

☐Yes ☒No ☐Unsure

5j. Is the implementation of potential findings from this research likely to directly involve participation from an identified group that would benefit from an equitable process or outcome?

☐Yes ☐No ☒Unsure

5k. Is the intended final product or information expected to support ODOT's equity efforts (Including but not limited to supporting one of the equity related objectives of the ODOT's Strategic Action Plan or Oregon Transportation Plan) ?

☐Yes ☐No ☒Unsure

5l. If you answered yes to any of the equity questions above or can provide alternative details related to equity, please provide additional information:

Safety

Research outcomes may include interventions and countermeasures to prevent or reduce the frequency of crashes or other causes of transportation-related injury or death; or may include measures to reduce severity of injury (including prevention of death) after a crash or other injurious event. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan, Oregon Transportation Safety Action Plan and Oregon Transportation Plan.

5m. Will solving the **transportation issue** in question 1 support improving **safety culture** for either transportation workers or the traveling public?

☒Yes ☐No ☐Unsure

5n. Will the solving the **transportation issue** support improving safety through **healthy and livable** **mmunities**?

☐Yes ☐No ☒Unsure

5o. Will solving the **transportation issue** support improving safety through using **best available technologies**?

☒Yes ☐No ☐Unsure

5p. Will solving the **transportation issue** support improving safety through **communication and collaboration**?

☒Yes ☐No ☐Unsure

5q. Will solving the **transportation issue** support improving safety through **investing strategically**?

☒Yes ☐No ☐Unsure

5r. If you answered yes to any of the safety questions above or can provide alternative details related to safety, please provide additional information: Safety is a key component of this research proposal. Safety applies to the traveling public as well as ODOT crews. As budgets have declined, it is important to understand which applications still meet minimum safety standards for the traveling public to visibly see the pavement markings. Optimization of the materials means we can evaluate the number of times crews have to apply the pavement markings, as well. This study looks to gain knowledge to still meeting safety standards with optimized material application that allows the product to last for a more predictable lifespan given the variance of the environment it is placed in. This effort will lead to more predictable maintenance schedules, consistent driver expectation, and optimized use of mobile work zones that aims to reduce exposure to ODOT staff and disruptions for the traveling public.

6. Corresponding Submitter's Contact Information:

Name:	Tony Perez
Title:	Field Service Coordinator
Affiliation:	ODOT Maintenance & Operations Branch
Telephone:	503-580-9857
Email:	tony.perez@odot.oregon.gov

7. ODOT Sponsor Contact Information (Required if Submitter is not an ODOT employee)

Name:	Rebecca Burrow
Title:	Maintenance Services Manager
Crew Number:	7863
Telephone:	503.951.9333
Email:	rebecca.burrow@odot.oregon.gov

This form is not a grant application or contract document. Please do not include proprietary information on this form. Once this form is received ODOT may revise and publish the problem statement. If selected, ODOT will assign investigator(s) of the department's choosing to conduct research.

Exhibit 1: Preliminary data assessment of pavement marking thickness and corresponding retroreflectivity.

Route	Yellow Thickness	White Thickness	Retro Right AVG	Retro Left AVG	Two Stripe AVG
HWY 26 210-231	*19.3636363636364*	*10.35*		*85.8728532541451*	*85.8728532541451*
HWY 86 43-71	*19.8795379537954*	*13.46*		*49.1744847192608*	*49.1744847192608*
HWY 20 138-132	*18.4218106995885*	*27.1252032520325*	*113.108678756477*	*115.159132519616*	*115.9377070619*
HWY 70 0-93	*18.0236559139785*	*13.9666666666667*	*62.2741721854305*	*133.29000506928*	*133.415131801284*

Exhibit 2: Draft Preliminary Research Summary.

By Jon Lazarus, ODOT Sr Research Coordinator, ODOT Research Section

Contributions from Frank Belleque, ODOT Traffic Markings & Sign Engineer and Tony Perez, ODOT MOB Field Service Coordinator

Date: 9/9/2025

Requested by: ODOT Office of Maintenance, via Rebecca Burrow

Request description: The request was for a literature review summary of cost-cutting measures regarding pavement markings. This was a discussion item from the July/August 2025 Pavements Markings Committee (PMC) meeting, where the committee wanted to know any other methods to reduce either material's costs or increase efficiencies in operations/equipment. The PMC specifically discussed a review of other states' actions, both successful and unsuccessful, to evaluate their own current options. The PMC has three primary products for longitudinal pavement markings:

- Non-durable (typically water-borne paint with reflective beads),
- Durables (a hot-applied thermoplastic product or Methyl Methacrylate (MMA) product), and
- Other (aka High-Performance Markings).

The PMC believed they could not do much to reduce costs for Durables, therefore, assumed a focus on Non-durables for this literature review would be the most productive.

Search Engine Used: Google Scholar, Google, TRID/TRIS, State DOT Custom Search, No Boundaries Website/database,

Keywords used: [Pavement markings, cost]; [Striping, cost, saving]; [Pavement marking, cost]

Note:

Introduction and Context

The Oregon Department of Transportation (ODOT) services over 18,000 lane miles of pavement markings (Oregon Department of Transportation, 2024). A more precise measure regarding pavement markings was provided in an ODOT Research study, SPR 681 in 2010 (Oregon Department of Transportation, 2010), citing ODOT maintains 26,691 total line miles, denoting a difference between pavement marking lines and a lane (as one lane may have multiple lines).

A 2010 study conducted by the Idaho Transportation Department (ITD) examined various DOTs to identify the most cost-effective markings based on performance, durability, and useful life expectancy (H Sadid, 2010). They concluded that success depended on many factors, including but not limited to: product quality, application process, surface preparation, environmental conditions, annual average daily traffic (AADT), driver's age and visual performance, vehicle type, type of headlights, and pavement type. In addition, the results of field studies conducted by different investigators show that the conclusions were highly dependent upon the method of study, the models used, the type of measurement devices, and the accuracy of their operation. However, there was agreement on certain issues, including: the performance characteristics, life expectancy, and the associate cost. The most cost-effective pavement marking identified and utilized by different transportation departments on low level traffic volume is paint, followed by epoxy. Tape is commonly used on high-volume AADT roadways. Ninety-eight percent of pavement markings used in ITD are paint, with the other two percent consisting of tape or other types, including Methyl Methacrylate (MMA). They determined that ITD's current practice in using pavement markings is the most cost-effective. ITD is in line with many other transportation departments throughout the country that deal with similar climate conditions.

ODOT publishes the Traffic Line Manual (Oregon Department of Transportation, 2025), providing policies, methods, and information to the public. The ODOT also provides pavement marking Design Standards, with the most recent version published in January 2025. The Design Guidelines are also available (Oregon Department of Transportation, 2022). As a comparison reference, Ohio DOT publishes its policy (Ohio Department of Transportation, 2022) for pavement marking within their Traffic Engineering Manual.

Immediate ideas for cost-saving measures

A "wide line" is defined in the MUTCD as double the normal line width and a normal line can be 4 to 6 inches. Per ODOT's definitions, a normal-width line (as detailed in the ODOT Traffic Line Manual) is 4 inches wide, and a wide line is 8 inches wide. In a 2024 study, conducted with the Missouri Department of Transportation, they examined the trade-offs of using 4-inch lines versus a wider line (which are lines greater than the minimum MUTCD width, for example, a 6-inch line). Their findings included a nationwide literature review and survey. They found wider lines had larger safety benefits and larger benefit-cost ratios (ranging from 24:1 to 55:1). The recommendations were clear to continue to use wider lines (e.g. 6-inch lines) in high-volume and geographically complex roadways. However, for low-volume roads, the results and benefits were not as prevalent. The study also noted that most states' wider lines are 6 inches, as opposed to a 5-inch line. The study recommends the practice of continued use of wider lines in key areas, and reductions of wider lines in low-volume roads can be a viable cost-reduction strategy. In contrast, during an interview with Frank Belleque, ODOT Traffic Markings & Sign Engineer (Belleque, 2025), Frank agreed that 6-inch lines are a proven safety countermeasure. However, he has concerns about short-term and long-term costs for the agency. Frank points out that there is an increased cost to operate a highway network with varied-width lines. He recalled conversations with Maintenance staff and that they wanted either "all 6-inch lines or no 6-inch lines", to eliminate the extra cost of monitoring, adjusting equipment, increased equipment maintenance due to frequent width changes, etc.

Notably, the literature search did not have any recent findings on cost/benefit findings or life-span data regarding the thickness of the applied materials (specifically searched for non-durables and paint products). During the

ODOT PMC Committee discussion, an idea was generated to reduce the thickness of the applied paint to the minimum acceptable standard, as some prior applications have applied thicker lines, per the contractor's recommendations. The PMC commented that these decisions were experienced-based decisions and the perception was that an optimal thickness (greater than the minimum standard required) produced longer-lasting pavement markings.

In 2021, the Louisiana DOT (LaDOTD) published a paper examining its practice of painting on a 2-year cycle. The literature review showed substantial variability in the paint service life throughout the United States, ranging between 0.25 and 6.2 years. Data was gathered from the National Transportation Product Evaluation Program (NTPEP) database and, specifically, focused data from the Southern states. ODOT refers to this data for reference and product submittals, but does not use it for any official decision making (Belleque, 2025). Degradation models were developed given climate, traffic volumes, and product type(s). It was found that some degradation models had R2 values as low as 0.1, and these models were used to plan restriping efforts. The study:

(i) develop new cost-effective restriping strategies using 4-inch and 6-inch wide waterborne paints when applied on asphalt pavements in hot and humid climates; and
(ii) employed an advanced machine learning algorithm to develop performance prediction models for waterborne paints, considering the variables that are believed to affect their performance.

The findings were that a 4-inch wide standard paint line exhibited service life up to four years, depending on the line color, traffic volume, and initial retroreflectivity, while a 4-inch wide high-build paint line had a service life of at least three years. Based on a life-cycle cost analysis, it was concluded that LaDOTD could restripe its district roads every three years instead of the current two-year period using the same product (4-inch or 6-inch wide), saving about $20 [JON TO CHECK NUMBER HERE] or $2 million, respectively, every year when restriping a 5,000-mile network. Additionally, two machine-learning models were developed with an acceptable level of accuracy, which can predict the retroreflectivity of waterborne paints for up to three years (degradation models) using only the initial measured retroreflectivity values. The predictability was accurate enough to eliminate the need to conduct annual retroreflectivity sampling, and thus, saved staff time and cost.

Currently, ODOT conducts checks on their longitudinal lines to meet MUTCD requirements with each region's striping crews. In addition to these checks, ODOT conducts data collection on new-product pavement markings from the ODOT Testdeck evaluation. The ODOT Testdeck is a location on an ODOT maintained road in which product vendors are invited to place transverse lines of new products on the roadway for a set period of evaluation time. The roadway location has stayed at a similar location (OR 22) for approximately 20 years. The location was selected because the traffic volume is a typical low-to-medium volume road and because the roadway has sections of Portland Cement Concrete and Asphalt Concrete. Typically, the ODOT Testdeck conducts evaluations every two to three years, but has been at irregular intervals for the last decade. ODOT Testdeck is not used to predict longevity of long-line applications (note these are transverse lines), however, ODOT Office of Maintenance has expressed a desire to develop a predictive model from this data source.

In February 2023, New Jersey Department of Transportation (NJDOT) published a paper focusing on the performance of pavement marking lines with respect to sensing capabilities of autonomous vehicles for operational purposes. The study acknowledged the loss of line performance (using vehicle sensing) in certain cases, despite the pavement marking being recently applied. The study provides guidance and recommendations to improve efficiencies for new marking installation specifications, new techniques, and improve existing marking maintenance practices. Specifically, NJDOT evaluated drying time issues, alternative testing protocols, durability issues, cost benefits, temporary markings, and developed an alternative specification for quick application of paints when supply chain issues arise. [JON TO EXPLORE MORE DETAILS OF THIS STUDY – what actions were the most cost-beneficial? The use of paint when supply chain issues, matches ODOT use because of budget issues, what did they learn?]

Wyoming DOT (WyDOT) developed degradation models for all their pavement marking material products in 2023. They utilized several other State DOT's data to create their own models. These models provided more accurate life spans for the given location, traffic volume and product. This gave WyDOT planners more advanced warnings of end-of-life pavement markings and the ability to project funding needs. Per Tony Perez, ODOT's Office of Maintenance, Field Service Coordinator (Perez, 2025) ODOT does not conduct a similar life-span analysis or modeling. Perez acknowledges that this could be possible with ODOT Testdeck data if past data was recovered and if there was a future commitment from ODOT to continue to collect Testdeck data. Perez acknowledges that there is a desire to evaluate ODOT's pavement marking degradation data and determine future needs, similarly to WyDOT's analysis.

In 2024, North Carolina DOT (Gallo, 2024) investigated life cycle costs for multiple products in an effort to find longer-lasting products and cost savings. Their data included new markings installed in 2000 with subsequent readings of cost & performance data (presumably over 20 years), 14 divisions (ODOT calls similar areas "districts"), 4 ADT ranges, and 5 products (Paint, Spray Thermo, Extruded (standard) Thermo, Polyurea, and Cold Applied Plastic (Tape)). They found that both extruded thermo and spray thermo outperformed paint in cost and had better life spans. They noted:

- Spray Thermoplastic is not considered a long-life pavement marking, but acknowledged better performance than paint
- NCDOT has 4 divisions that have moderate-to-heavy snowplowing. The districts were averaged and not adjusted to reflect this variable in their data. NCDOT realizes this will affect the analysis and make paint pavement markings not show as to last as long, however, they estimated the effect was not significant;
- An assumption that all lines should be replaced at 100 mcd/lux/m^2 ;
- Data and assessment were only for 4 inch lines;
- Extruded Thermoplastic costs are 4" X 90 Mil - $0.65 (Std); and
- Paint costs are $0.20 installed per coat, and permanent paint markings require 2 coats ($0.40).

They concluded that NCDOT will adjust policy to use long-life markings on all TIP and resurfacing projects. They acknowledged that there are additional savings in less staff time to reapply pavement markings and additional safety benefits not calculated within the study.

In May 2024, a Brazilian study (L Mazzoni, 2024) focused on paint and bead combinations for optimized pavement marking efficiency. The study investigated the characterization of glass bead size distribution by the coefficient of uniformity and curvature. Three field test sites on a Brazilian highway with various paint and glass bead combinations were evaluated. A statistical model, GAMLSS (Generalized Additive Model for Location, Scale, and Shape), was adjusted to evaluate the performance of the markings' retroreflectivity as a function of paint and glass bead characteristics. The model revealed that well-graded glass beads increased retroreflectivity by around 10%, while paints with a higher volume of solids improved service life by around 65%. The results show that acrylic water-based paints with higher volumes of solids and well-graded glass beads with better shape characteristics should be preferred to achieve enhanced durability.

Additional ideas for longer-term cost savings

In 2023, Kansas DOT examined upgrading its current fleet of paint trucks, which were 5 years old at the time. The upgrades included automation of some functions. Specifically, these upgraded vehicles are expected to:

a) speed up the marking layout process, and
b) eliminate the need for one of the crew members in the striping truck.

Phase one reported against the adoption of the automated pavement restriping system on a purely economic basis. Phase 2 data collection focused on the accuracy and quality of the automated work performed compared to

an experienced KDOT maintenance employee. [JON TO EXPLORE MORE DETAILS OF THIS STUDY – was accuracy and quality better?]

An innovative method that could lead to cost savings would be the inclusion of photoluminescent elements into the waterborne paints (non-durables) at a reduction of retroreflectivity beads (which are more expensive). A June 2023 study had findings that suggest photoluminescent road markings could strengthen the visual guidance of drivers on the road with traffic by increasing the visibility distance beyond the headlamp beams during the first few hours of the night, but the performance varies based on the nighttime illumination level.

In another 2023 study, they concluded that persistent phosphorescent road markings (PPRMs), and electric luminous road markings (ELRMs), as next-generation road markings, will exhibit the unique advantages of traffic safety improvement, smart traffic control, and an intelligent transportation system.

Works Cited

Belleque, F. (2025, September 8). ODOT Traffic Markings & Sign Engineer. Salem, Oregon: none. Retrieved September 8, 2025

Gallo, S. R. (2024, February 5). *Pavement Marking Life Cycle Cost Analysis.* (N. C. DOT, Ed.) Retrieved August 28, 2025, from Connect NCDOT Signing and Delineation: https://connect.ncdot.gov/resources/safety/Signing%20and%20Delineation%20Library/Pavement%20Marking%20Life%20Cycle%20Cost%20Analysis.pdf

H Sadid, R. W. (2010). *Material Acceptance Risk Analysis: Pavement Markings.* Idaho Transportation Department. Bosie: Idaho Transportation Department, Research Program. Retrieved September 7, 2025, from https://apps.itd.idaho.gov/apps/research/Completed/RP182A.pdf

L Mazzoni, K. V. (2024). *Field Data Analysis of Pavement Marking Retroreflectivity and Its Relationship with Paint and Glass Bead Characteristics.* University of Sao Paulo. Applied Sciences. doi:10.3390/app14104205

Ohio Department of Transportation. (2022, January 21). *Ohio DOT Material Selection for Pavement Marking and Expected Marking Life in Years.* Retrieved August 25, 2025, from https://www.dot.state.oh.us/roadway/TEM/Tables/0397-01.pdf

Oregon Department of Transportation. (2010, August). *ODOT Research Publications.* Retrieved August 11, 2025, from https://www.oregon.gov/ODOT/Programs/ResearchDocuments/Pavement_Marking_Testing.pdf

Oregon Department of Transportation. (2022, January). *ODOT Traffic Standards.* Retrieved August 14, 2025, from Pavement Marking Design Guide: https://www.oregon.gov/odot/Engineering/Documents_TrafficStandards/Pavement-Marking-Design-Guide.pdf

Oregon Department of Transportation. (2022). *Pavement Marking Design Standards.* Retrieved from https://www.oregon.gov/odot/Engineering/Pages/Striping.aspx

Oregon Department of Transportation. (2024). *Oregon Department of Transportation Pavement Condition Report 2024.* Salem: Oregon Department of Transportation. Retrieved September 8, 2025, from https://www.oregon.gov/odot/Construction/Pages/Pavement-Condition.aspx

Oregon Department of Transportation. (2025, January 1). *ODOT Traffic Standards.* Retrieved August 14, 2025, from Traffic Line Manual: https://www.oregon.gov/odot/engineering/documents_trafficstandards/traffic-line-manual.pdf

Perez, T. (2025, September 9). Oregon Department of Transportation, Maintenance Branch, Field Services Coordinator. (J. Lazarus, Interviewer) Retrieved September 9, 2025

***** - List of Abstracts - *****

Direct Studies Related to Request

Striping Program [June 2024] Link

The use of wider (greater than 4 in) edge line pavement markings is recognized as a proven safety countermeasure by the Federal Highway Administration (FHWA). However, providing wider edge lines can pose challenges due to

budget and striping capacity constraints. One strategy that could be used to address the capacity constraints involves reducing the amount of striping performed on low volume roads. The objective of this research study is to synthesize existing research and Department of Transportation (DOT) practices regarding the use of wider edge line markings on all roads and the use of pavement markings of any width on low volume roads to facilitate the evaluation of tradeoffs between different pavement marking strategies. The research methodology to meet these objectives includes a literature review (e.g., research studies and DOT guidance and standards) and DOT interviews. Results from the literature review indicate crash reductions for wider pavement markings ranging from 7 percent to 30 percent (total crashes) and from 14 percent to 51 percent (fatal and injury crashes) and benefit-cost ratios ranging from 24:1 to 55:1. Regarding prevalence of wider pavement markings, most state DOTs use 6-in markings (or, in some cases, 5-in markings) to some extent. Previous research studies on the use of pavement markings on low volume or narrow roads have shown mixed results. The literature review identified 12 state DOTs with state-specific warrants for center line or edge line markings on low volume roads. Implementation challenges noted by DOTs during the interviews include communication, budget and capacity constraints, and equipment needs. Overall, the research findings indicate that increased use of wider pavement markings and reductions in the use of pavement markings on lower volume roads is a viable strategy that can be explored further for implementation.

Evaluation of NJDOT Hardened Traffic Paint Markings and Stripes Performance [February 2023] Link

Summary

Pavement markings are the primary means for an agency to provide longitudinal guidance to drivers. Effective pavement markings can improve safety, improve driver comfort, and increase functionality/reliability of automated driving systems or Advanced Driver Assistance Systems (ADAS). To be effective, markings must be visible during all driving conditions, and be observable during both day and night. Markings are typically characterized by their retroreflectivity, which is a surrogate measure for how visible the marking is at night. However, retroreflectivity does not consider other factors that will impact the actual visibility of the marking, such as the color or retroreflectivity of the pavement that the marking is applied to, the color or width of the marking, or the viewing conditions (i.e., observation vehicle, observer characteristics, weather conditions). Retroreflectivity is also a metric for nighttime visibility, which may not relate to the marking visibility during the day. The combined impact of the factors, such as: adverse weather conditions, drying time, inadequate thickness of marking, excess traffic volume, and poor surface coating, contribute to deterioration of the quality of pavement markings. Therefore, it is highly needed to periodically evaluate the performance of pavement markings, since some markings and stripes are not performing satisfactorily, despite only being shortly applied on roadways. This project aims to obtain and analyze relevant technical and performance data of various pavement marking materials, and to determine which product(s) can be used to stripe various roadway surfaces to withstand the NJ weather and traffic conditions. In addition, this project will evaluate: drying time issues, alternative testing protocols, durability issues, cost benefits, temporary markings, and to develop an alternative specification for quick application of paints when supply chain issues arise. This study will provide guidance and recommendations to improve new marking installation specifications and techniques, improve marking maintenance practices, and evaluate the current specifications and requirements for road markings and stripes paint with respect to sensing capabilities of autonomous vehicles for operational purpose.

Tajnin, Mst Rahanuma; Farid, Ahmed; Albatayneh, Omar; Roy, Uttara; Ksaibati, Khaled. **Enhancing Pavement Marking Management Practices in Wyoming**. Wyoming Technology Transfer Center; Wyoming Department of Transportation, 2023, 211p
https://trid.trb.org/view/2499196

Abstract: Pavement markings safeguard road users, and maintaining adequate retroreflectivity is crucial for ensuring road safety. As the Wyoming Department of Transportation (WYDOT) performs routine application of pavement markings, there is a pressing need for a comprehensive management program to ensure their cost-effective management. So, this report focuses on enhancing pavement marking management in Wyoming by investigating factors influencing retroreflectivity, developing predictive models for degradation over time, and establishing a comprehensive Pavement Marking Management Plan (PMMP) template that incorporates the principles of the Transportation Asset Management Plan. Binary Logistic Regression models were developed to determine the contributing factors affecting pavement marking retroreflectivity. The findings of this study indicate that factors, such as the degree of curvature of horizontal curves, location (rural or urban), material type, pavement marking color, and line position significantly affect pavement marking retroreflectivity. The degradation models provide valuable insights into the deterioration process of pavement markings over time and can assist highway agencies in prioritizing maintenance efforts. The proposed PMMP template also integrates Pavement Marking Management Systems of several state departments of transportation (DOTs) and Transportation Asset Management principles, providing project selection, budgeting, procurement, and contracting strategies.

Effectiveness of Automated Pavement Restriping Systems - Phase 2. [Project]. Kansas Department of Transportation. Start date: 15 Jun. 2023.
https://trid.trb.org/view/2255814

Description: The Kansas Department of Transportation (KDOT) is responsible for maintaining the pavement markings on its 10,291-mile roadway network. The centerline markings, lane markings, and edge line markings are applied annually using waterborne paint from six restriping trucks, one for each KDOT district. These vehicles are durable pieces of equipment and are expected to last 20+ years; currently these vehicles are each less than 5 years old. While having newer vehicles is generally a good thing, as new technologies become standard equipment on newer models it can be a challenge to justify upgrading existing vehicles until the next replacement cycle, meaning new innovations might not be implemented until the next equipment replacement cycle. One paint crew (District 5) has been selected to receive two upgraded vehicles (layout truck and striping truck) in 2023 to increase the productivity of the pavement restriping process. Specifically, these upgraded vehicles are expected to a) speed up the marking layout process, and b) eliminate the need for one of the crew members in the striping truck.
After the finding of the phase one report against adoption of the automated pavement restriping system on a purely economic basis, the second phase of this project is being proposed to run during CY 2023. The automated painting system has been delivered to District 5's paint crew since the conclusion of phase one, so this phase will aim to evaluate that system to determine the accuracy and effectiveness of the work produced by it. This evaluation would use field data collection to determine if the system results in a similar result as if an experienced KDOT field employee were doing the restriping. Together, this will serve to improve KDOT's understanding of automated paint restriping systems to determine if wider implementation is warranted systemwide and create a more accurate cost savings recommendation.

Maintenance and Restriping Strategies for Pavement Markings on Asphalt Pavements in Louisiana

In Louisiana, most districts restripe their roadways using waterborne paints every other year; this strategy is questionable in terms of efficiency and economy. Meanwhile, previous studies showed substantial variability in the paint service life throughout the United States ranging between 0.25 and 6.2 years. Shortcomings in modeling the retroreflectivity of waterborne paints appear to significantly contribute to these variations as several studies predicted these values using degradation curves with a coefficient of determination (R2) as low as 0.1. Therefore, the objective of this study was to (i) develop new cost-effective restriping strategies using 4-inch (15-mil thickness)

and 6-inch (25-mil thickness) wide waterborne paints when applied on asphalt pavements in hot and humid climates, and (ii) employ an advanced machine learning algorithm to develop performance prediction models for waterborne paints considering the variables that are believed to affect their performance. To achieve these objectives, National Transportation Product Evaluation Program (NTPEP) data were collected and analyzed to evaluate the field performance of waterborne paints commonly used in Southern United States. Results indicated that 4-inch wide standard paints exhibited service life up to four years depending on the line color, traffic and initial retroreflectivity, while 4-inch wide high-build paints had a service life of at least three years. Based on a life-cycle cost analysis, it was concluded that LaDOTD could restripe their district roads every three years instead of the current two-year period using the same product (4-inch or 6-inch wide) saving about $20 or $2 million, respectively, every year when restriping a 5,000-mile network. Additionally two machine-learning models were developed with an acceptable level of accuracy, and that can predict the skip and wheel retroreflectivity of waterborne paints for up to three years using only the initial measured retroreflectivity and the anticipated project conditions over the intended prediction horizon, such as line color, traffic, air temperature, etc. These models could be used by transportation agencies throughout the United States to (1) compare between different products and select the best product for a specific project, and (2) determine the expected service life of a specific product based on a specified threshold retroreflectivity to plan for future restriping activities.

Record URL: https://doi.org/10.5281/zenodo.6468972

Dataset URL: https://doi.org/10.5281/zenodo.6468974

Dataset URL: https://digitalcommons.lsu.edu/transet_data/128/

Record URL: https://digitalcommons.lsu.edu/transet_pubs/128/

Record URL: https://rosap.ntl.bts.gov/view/dot/61835

Dataset URL: https://rosap.ntl.bts.gov/view/dot/62246

Supplemental Notes: Supporting datasets available at: https://digitalcommons.lsu.edu/transet_data/128/; https://doi.org/10.5281/zenodo.6468974; https://rosap.ntl.bts.gov/view/dot/62246 This document was sponsored by the U.S. Department of Transportation, University Transportation Centers Program.

Corporate Authors:

Transportation Consortium of South-Central States (Tran-SET)

Louisiana State University
Baton Rouge, LA United States 70803

Office of the Assistant Secretary for Research and Technology

University Transportation Centers Program
Department of Transportation
Washington, DC United States 20590

Authors: Mousa, Momen R 0000-0002-1723-364X; Hassan, Marwa 0000-0001-8087-8232

Publication Date: 2021-8

***

Field Data Analysis of Pavement Marking Retroreflectivity and Its Relationship with Paint and Glass Bead Characteristics

Applied Sciences

May 2024

DOI:10.3390/app14104205

Authors: Laura Nascimento Mazzoni; Kamilla Vasconcelos; Orlando Yesid Esparza Albarracin;

Liedi Bernucci;

Download full-text PDFRead full-text

Abstract and Figures

Featured Application White water-based paints with high-volume solids and well-graded glass beads, characterized by uniformity and curvature coefficients, improve pavement marking service life. Abstract Pavement marking retroreflectivity, a critical factor for safe driving, depends on the characteristics of both the paint and the embedded glass beads. However, traditional methods for predicting pavement marking service life often overlook these materials properties. This study investigates the influence of paint and glass bead characteristics on pavement marking retroreflectivity performance and addresses the characterization of glass bead size distribution by the coefficient of uniformity and curvature. Three field test sites on a Brazilian highway with various paint and glass bead combinations were evaluated. A statistical model, GAMLSS (Generalized Additive Model for Location, Scale, and Shape), was adjusted to evaluate the performance of the markings' retroreflectivity as a function of paint and glass bead characteristics. The model revealed that well-graded glass beads increased retroreflectivity by around 10%, while paints with a higher volume of solids improved service life around 65%. Therefore, the results show that acrylic water-based paints with higher volumes of solids and well-graded glass beads with better shape characteristics should be preferred to improve pavement markings' retroreflectivity and service life. The statistical model identified the key characteristics with the greatest impact on pavement marking retroreflectivity, offering valuable insights for real-world applications, which will assist pavement marking practitioners and road authorities in selecting appropriate materials to achieve enhanced durability.

Other Studies which Provide Framework and Best Practices

Contrast Striper [October 2013] Link

Summary

The MoDOT developed a 3-sprayer device that paints a yellow/white line and two black lines next to it. This provides a high-contrast, visible line during daytime driving. The staff reported better results in quality and time to apply contrast lines for daytime pavement marking visibility compared to other methods.

Applying Machine Vision Algorithm on Pavement Marking Retroreflectivity Measurement [December 2023] Link

Summary

This preliminary study presents the development of integrating a real-time mobile device with a machine vision algorithm to assess the retroreflectivity of the broken lane lines of in-service road marking. A stereo camera was used as the photometer, and the measuring vehicle's headlights were used as the illumination system. The machine vision algorithm includes marking centroid determination, standard measuring condition control, illumination condition calculation, and luminance measurement. The test results show that the average absolute error percentage of 47 marking samples is 6.1%, with the highest and lowest accuracies of 99.9% and 85.7%, respectively. The left and right lane line (broken line) markings can be evaluated simultaneously in a single pass up to 100 kph. The hardware package, including a stereo camera, a camera support beam, cables, and a laptop

computer, costs approximately USD 3,500, which is much lower than the cost of conventional and advanced fully automatic retroreflectometers. Moreover, the developed method is for general usage and can be easily modified and applied to camera sets and vehicle carriers of different specifications. Although the results are promising, the proposed method has some limitations. First, the accuracy decreases when the test section is rough with bumps and dips. Second, this algorithm is not ready for surveying solid lines. Furthermore, the current version can only be implemented under vehicle headlights. Future work can focus on improving the hardware and machine vision algorithm to overcome the challenges.

Characterization of luminescent road markings [June 2023] Link

Summary

Photoluminescent paints for road marking application have been evaluated through laboratory measurements and visibility computations. The luminance decay in the dark was measured after constant excitation during at least 6?hours. To study the effect of night-time lighting conditions, luminance was measured under a constant low illumination (simulating moon and light pollution), and a periodic lighting, simulating automotive traffic. Measurements were also carried out on luminescent road marking applied on real pavement in a full-scale mock-up. Then, possible uses and limits of photoluminescent road markings were investigated through visibility computations based on the COST 331 model. Findings suggest luminescent road markings could strengthen the visual guidance of drivers on the road with traffic by increasing the visibility distance beyond the headlamp beams during the first few hours of the night, and in unlit areas such as bicycle paths, but the performance depends on the night-time illumination level.

Lin, Hongwei; Chen, Feng; Zhang, Hongchao. **Active luminous road markings: A comprehensive review of technologies, materials, and challenges.** Construction and Building Materials, Volume 363, Issue 0, 2023, 129811
https://trid.trb.org/view/2077214

Abstract: Road marking is a core part of traffic safety facilities that plays an irreplaceable role in traffic control. With the increasing requirement for road marking, active luminous road markings (ALRMs) have been proposed and have progressed over the years owing to their compelling features of autoluminescence and good recognition. However, there are still some limitations to be further studied, including the luminescence performance, long-term durability, and economic cost. In this study, a comprehensive analysis was conducted to understand the state-of-the-art progress and required future work on ALRMs. Different types of ALRMs were classified, including fluorescent road markings (FRMs), persistent phosphorescent road markings (PPRMs), and electric luminous road markings (ELRMs). Moreover, this paper elaborates on the technical principle, service performance, applications, and existing problems associated with various ALRMs technologies in detail. Furthermore, the challenges and future prospects involved in the development of ALRMs are emphasized to provide avenues and opportunities for future research. It is anticipated that PPRMs and ELRMs, as next-generation road markings, will exhibit the unique advantages of traffic safety improvement, smart traffic control, and an intelligent transportation system.

***

Other references

2024 ODOT Pavement Condition Report

Oregon Department of Transportation sent this bulletin at 03/25/2025 11:28 AM PDT

https://content.govdelivery.com/accounts/ORDOT/bulletins/3d81d59

March 25, 2025

For more information, contact Kacey Davey, (Kacey.L.Davey@odot.oregon.gov), 541-280-2716.

SALEM– Oregon's highway system is facing ongoing challenges as the condition of many roads continues to decline, according to the Oregon Department of Transportation's 2024 Pavement Condition Report. The report highlights that while 87% of Oregon's 18,000 lane miles of pavement are still in fair or better condition, the quality of roads is slipping, with the percentage of "good" pavement reaching its lowest point since 2001.

***

ENHANCEMENTS TO PAVEMENT MARKING TESTING PROCEDURES Final Report SPR 681 (August 2010)

https://www.oregon.gov/ODOT/Programs/ResearchDocuments/Pavement_Marking_Testing.pdf

The Oregon Department of Transportation (ODOT) requires performance and durability testing of all pavement marking materials before they can be applied on construction projects on state highways. Manufacturers apply materials on a two-year test deck where the product is evaluated regularly until a determination can be made regarding the suitability of the marking material. If it is determined that the material is suitable, it is included on the Qualified Products List (QPL). The testing and evaluation on ODOT test decks are limited to measuring the thickness of the marking material; assessing dry weather retroreflectivity; and subjective evaluations of appearance and durability. It was determined that a review of pavement marking testing procedures especially those followed in states with climatic conditions similar to Oregon could be useful. The research project includes recommendations to enhance the pavement marking testing and selection process. The recommendations relate to application procedures, monitoring and evaluation, and final selection of products. Proposed minimum retroreflectivity requirements are discussed.

***

Traffic Line Manual Delivery & Operations Division | Traffic-Roadway Section January 2025

https://www.oregon.gov/odot/engineering/documents_trafficstandards/traffic-line-manual.pdf

***

Pavement Marking Design Guidelines Delivery & Operations Division | Traffic-Roadway Section January 2022

https://www.oregon.gov/odot/Engineering/Documents_TrafficStandards/Pavement-Marking-Design-Guide.pdf