SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE
25-70 (*combined 25-76) Mobile Lidar Evaluation of Road Marking Condition for Federal Reporting.

PROBLEM SUMMARY
New FHWA regulations require states to report methodology and values for keeping minimum retro-reflectivity standards on pavement markings (PM). ODOT's past research found using Lidar data can substitute for reflectometer readings. ODOT purchased new equipment for both reflectometer and mobile lidar scanning. The need is to compare new and old equipment to meet FHWA requirements. Conducting this work through research, allows for discovery, better optimization, long-term data collection, multiple methods to report with confidence, supports climate change initiatives, supports ODOT's choice for its own timeframe to implement, and helps to determine PM's lifespan.

ODOT OBJECTIVES
Compare and calibrate the two mobile lidar systems, and mobile & handheld retro-reflectometers. Develop a workflow and reporting methodology that meets FHWA reporting requirement while minimizing the in-field effort and manual processing. Provide recommendations to meet the FHWA required reporting, create a transition plan to full mobile system reporting in 5 years, and identify long-term software needed for operation.

BENEFITS
This project would enable automation of PM evaluation using the statewide mobile lidar data by comparing multiple systems. The new equipment will measure higher quality levels of retro-reflectivity efficiently and establish a data repository for FHWA reporting requirements. If funded, this proposal will save ODOT money in reducing processing effort and field time. Reductions to long-distance travel for field work support climate change initiatives and will lead to cost-effective maintenance strategies. The results may help ODOT enforce vendor warranties for PM. The QA/QC process will be improved using continuous mobile coverage and reflectivity analysis. This research enables safety, financial, and environmental benefits by ensuring high-quality markings while minimizing material usage. The research will discover if long-term datasets can be the foundation for tracking the actual lifespan of PM, which can lead to further improved safety and reducing future maintenance costs.

SCHEDULE, BUDGET AND AGENCY SUPPORT
Estimated Project Length: 24 months.
Estimated Project Budget: $280,000
ODOT Support: Rhonda Dodge, Engineering and Tech Services Branch, Lead Remote Sensing Surveyor - Dean Chess, ODOT Construction Section & Materials Lab, Product Evaluation Coordinator - Tony Perez, Field Services Coordinator, Maintenance & Operations Branch - Mike Woodford, Chief Data Officer, Data Solutions Office, Support Services Division, "Will fund post-research implementation." - Frank Belleque, Traffic Markings & Sign Engineer, Engineering & Technical Services Branch

FOR MORE INFORMATION
For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:
https://www.oregon.gov/odot/Programs/ResearchDocuments/25-70.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2025

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25-70 *(*combined with 25-76)* Mobile Lidar Evaluation of Road Marking Condition for Federal Reporting.

RESEARCH PROBLEM STATEMENT

Pavement Markings are crucial traffic control devices; however, maintaining high retro-reflectivity during nighttime can be vital to drivers. Currently pavement marking crews use a mobile reflectometer and hand-held device (as needed) to make maintenance decisions. In 2022, FHWA published a final rule with new provisions to the MUTCD [1] relating to minimum pavement marking retro-reflectivity requirement.

The ODOT mobile lidar system scans the entire state highway system every two years. It can not only capture the location and geometry of the transportation assets (e.g., signs, road, barriers), but also the radiometric attributes of the object in the form of intensity values. The lidar intensity value is a measure of the strength of the return signal, which was shown to have a strong correlation with the retro-reflectivity of the surface. In a prior research project SPR799 [2], an OSU research team investigated using a Pegasus mobile lidar system to evaluate the retro-reflectivity of the pavement markings and signs. The team had great success in correlating the lidar data to retro-reflectivity values of pavement markings. The study showed ODOT can use this data and correlation to create maps to illustrate poor performing retro-reflectivity markings. This helps to identify, plan, and set priority of work with crews. In fact, use of the SPR799 products on a single ODOT region 5 project resulted in cost savings higher than the cost of the research itself. SPR799 was recognized as a “sweet sixteen”, high value research study in 2023 [3].

Recently, a mobile retro-reflectivity measurement system (reflectometer based) as well as a second mobile lidar system (Reigl) were acquired by ODOT. Both can significantly improve the efficiency of the pavement marking retro-reflectivity measurements. Notably the Reigl system is capable of reading higher retro-reflectivity values where the previous system saturated. However, there is a need for rigorous sensor characterization, accuracy assessment, method development, and assessment of the workflow to determine the optimized strategy in leveraging these emerging technologies. Moreover, one challenge ODOT is currently facing is that there is a new federal requirement to report methodology, report values, and have a pavement marking maintenance strategy to meet minimum retro-reflectivity levels.

Besides measuring retro-reflectivity, another ODOT requirement is to consider the expected service life of the pavement marking. Maintenance plans are created based on the expected lifespan and can vary depending on various factors including material types (e.g., paint, thermos), type of highway (e.g., asphalt, concrete), and others. To accurately model the correlation between all the factors and lifespan of the markings can be difficult and requires a lot of measurements over a long period of time. To address this issue, ODOT has utilized a TESTDECK approach, testing new products on a small stretch of asphalt and concreate roadway (in a transverse direction). This provides ODOT a means to evaluate the pavement markings inside and outside of the wheel lane in a shorter timeframe with known traffic volumes. ODOT could disqualify products that failed prematurely and initially approve well-performing products. The evaluation allows ODOT to discover products that are likely to reach their desired lifespan. In SPR799, TESTDECK was used to calibrate the older lidar equipment (Pegasus) for converting the intensity values to retro-reflectivity readings. Unfortunately, new products and measurements at the TESTDECK have not been conducted for several years. The data from SPR799 could be re-used to support this current research, which is comparing data collected from the newer pieces of equipment.

ODOT Office of Maintenance has decided to invest in another TESTDECK (June 2024), despite limited resources. Even though it is still unclear how to determine lifespan and reporting requirements, utilizing a new TESTDECK

as a data source can be very valuable. The new TESTDECK could be used for calibrating and evaluating all systems (Pegasus, Riegl, reflectometer, and handheld) given the dense samples, variety of markings, and pavement types. Comparing new and old data with new and old equipment helps validate if older lidar data (statewide) can be used for lifespan discussions. After comparing the equipment and data, the mobile systems will be able to establish a statewide data repository for decision making, federal reporting, future research in better tracking and predicting the lifespan of the markings, and much more. Even better, the new process to evaluate retro-reflectivity can be done with improved safety, less emissions (less in-field inspection), and reduced maintenance costs. The ROI for this project is estimated to be high.

RESEARCH OBJECTIVES

To address the challenges mentioned in the problem statement, the following research objectives need to be achieved:

1. Calibrate the two mobile lidar systems such that the intensity values can be used to retrieve retro-reflectivity of the road markings consistently between the systems.
2. Compare the two mobile lidar systems, mobile retroreflectometer, and handheld retroreflectometer in terms of their sensor characterization, data collection and processing workflow, measurement accuracy, and overall cost and benefits.
3. Develop a workflow and reporting methodology that meets FHWA reporting requirement leveraging the mobile systems to minimize the field effort and manual processing.
4. Provide recommendations for ODOT to meet the federal requirement reporting (one recommended option with at least two alternatives), roadmap for transitioning into full mobile system reporting (in 5 years), and software needed for consistent and efficient long-term monitoring,

WORK TASKS, COST ESTIMATE AND DURATION

Task 1: Literature Review (4 months)

The team will review the FHWA reports and manuals on the topic and summarize highlights that are relevant to ODOT operations. A literature review of the state-of-the-art technology with retro-reflectivity will be conducted. The team will also summarize the key procedures with the data from different systems.

Task 2: Sensor characterization (4 months)

The team will conduct a series of lab tests in a controlled environment (e.g., an ODOT facility) to evaluate the impact of various factors including the precision, accuracy, repeatability, spatial resolution, sensitivity to the configuration, weather conditions, lighting conditions, etc, to the mobile lidar, mobile retroreflectometer, and handheld retroreflectometer.

Task 3: TESTDECK calibration and testing (6 months)

The team will design, coordinate, and conduct a field test on the TESTDECK to calibrate the mobile lidar systems while comparing the mobile lidar systems, mobile retroreflectometer, and handheld retroreflectometer. This will also include a new software tool to streamline the data processing and analysis.

Task 4: Testing dataset compilation and analysis (6 months)

The team will compile a data repository including several sites identified by the TAC covering a variety of markings and road conditions leveraging the mobile lidar data. The dataset will include the mobile lidar covering the same sites during multiple years such that the change in retro-reflectivity conditions of the road marking can be tracked. These data will then be analyzed to help ODOT better understand the lifespan of the pavement markings and degradation over time. The team will investigate a proof-of-concept case study to compare the degradation rates with factors such as time in service, precipitation magnitude and intensity, AADT, temperature fluctuations, etc. and to identify potential correlations. The team will compare and analyze the 5 methods listed by FHWA and identify the best option for ODOT considering ODOT's architecture and strategy to meet the FHWA

requirements for pavement marking retro reflectivity reporting.

Task 6: Documentation and Reporting (4 months)

The team will compile a final report including the chapters that ODOT can use for federal reporting such as method selection in maintaining the pavement marking retro-reflectivity. The team will present a reporting method with at least two potential alternatives. Recommendations will be provided to help ODOT transition to statewide lidar-based retro-reflectivity measurements within 5 years. The team will also identify the need for software solutions to further reduce the need for manual data management.

Key Deliverables:

- A standard operating procedure with recommendations on each sensor/measurement type will be developed to maximize efficiency and accuracy with some research tools and scripts used to extract and analyze information from each sensor.
- Correlation function to translate intensity values from ODOT's new mobile lidar system to retro-reflectivity measurements through a radiometric calibration.
- A final report documenting the findings, analysis, testing results, and recommendations with chapters that ODOT can use for federal reporting with minimal edits and modifications.

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IMPLEMENTATION

ODOT has seen great success and high ROI with the implementation of SPR799. This project would build upon that momentum. The results from this new research would directly be utilized in STIP projects in decision making of material selection based on their performance. There is also potential that this project could spur the development of a statewide standard on pavement marking requirements for STIP projects.

POTENTIAL BENEFITS

The proposed research will compare multiple systems. ODOT's new mobile lidar system (Riegl) was purchased to replace its aging Pegasus system. The Riegl system requires validation and calibration in order to be implemented for road marking assessment. It is likely that this system would be able to measure higher levels of retro-reflectivity based on current research work being conducted by MassDOT (using a different Riegl scanner) and using findings from SPR 799. Prior and current research could help evaluate the condition of pavement marking retro-reflectivity with new equipment efficiently and establish a data repository for federal reporting requirements.

This project has the potential to save ODOT significant money in reducing field time and effort, as well as incorporating retro-reflectivity data from multiple sources. Reductions to field work support climate change initiatives and will lead to more cost-effective maintenance strategies. Additionally, the results will help ODOT better utilize existing warranties for road markings. The QA/QC process can also be improved using the continuous mobile coverage and reflectivity analysis, as compared with the handheld measurements. Improved marking maintenance strategies enable safety, financial, and environmental benefits by ensuring high-quality markings while minimizing material usage. This project would enable automation of pavement marking evaluation using the statewide mobile lidar data, which can minimize the labor-intensive point cloud processing. More importantly, such long-term datasets will be the foundation for future effort in tracking the actual lifespan of different types of markings and pavement, which in turn, will guide ODOT to further improve safety while reducing maintenance costs.

PEOPLE

ODOT champion(s): Frank Belleque, Rhonda Dodge, Dean Chess, Tony Perez

Problem Statement Contributors: Dr Ezra Che, Dr Michael Olsen, Frank Belleque, Rhonda Dodge.

REFERENCES

[1] FHWA (2023). *Manual on Uniform Traffic Control Devices 11th Edition*. US Department of Transportation, Federal Highway Administration.

[2] Olsen, M. J., Parrish, C., Che, E., Jung, J., & Greenwood, J. (2018). *Lidar for maintenance of pavement reflective markings and retroreflective signs* (No. FHWA-OR-RD-19-01). Oregon. Dept. of Transportation.

[3] Smith, C (2023). *AASHTO RAC Value of Research (VOR) Task Force*. Mississippi Department of Transportation, URL

STAFF REVIEW PAGE

Literature Check

TRID&RIP

☒ A review of TRID & RIP databases found no existing research that answers the research question

There are two relevant studies underway (started 2023-09-19 and 2023-02-01, respectively). Both studies were undertaken before the FHWA reflectivity requirements were released, therefore it is unclear if these studies will change scope to address them. The first study from Utah DOT uses data from Maverick system, which uses a Velodyne scanner. These data are very challenging to work with for retro-reflectivity for a variety of reasons. TxDOT tried to use it for retro readings several years ago and couldn't get a good correlation. OSU professors agree that this data is different enough to ODOTs Lidar equipment. Additionally, the ODOT Stage 2 research is looking at a comparison between two Lidar systems (one older and one new equipment) as well as a new mobile reflectometer data collection device. This Stage 2 proposal will focus on the FHWA retro-reflectivity requirements reporting, of which ODOT's method and data will be unique to ODOT with the comparison between these two pieces of equipment. The trid link for the Utah study is here: https://trid.trb.org/Results?txtKeywords=retro-reflectivity#/View/2262828

The second study from MassDOT is using a Riegl VZ2000 system operated in mobile mode. This is a different scanner compared with ODOT's even though it is the same vendor. However, they mentioned that they will consider FHWAs regulatory requirements. It is already assumed their research will lead to findings that will make this research more efficient. Dr Olsen is already in collaboration with them and estimated efficiencies with this submitted budget. It is unclear what methodology they will be using but assumed that some of the MassDOT work will contribute to knowing what (or what not) to do, leading to efficiency with this Stage 2. Here is MassDOT's study link:

https://www.mass.gov/doc/a-pavement-marking-inventory-and-retro-reflectivity-condition-assessment-method-using-mobile-lidar-phase-2/download

Technology & Data assessment

☐ No Identified T&D output

☒ At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

Mike Woodford, Chief Data Officer, has been involved with the development of this Stage 2. He has offered support. Here is his comment during review of the draft Stage 2: "I think we can help on the data side of things to have a scalable data repository if there is a need."

Cross-agency stakeholders

List ODOT partners or impacted units.

- Engineering and Tech Services
- Office of Maintenance, specifically the Pavement Markings Committee and statewide paint crews;
- Data Solutions, specifically GIS mapping of retro-reflectivity values
- PDAD, Specifically Transportation Data

Identify any issues of concern raised by an ODOT partner(s). Note expected mitigation that addresses these concerns.

- From Tech and Data Services: - note that because of collection timelines it is not likely we can fully transition to lidar-only-based retro-reflectivity collection, but ultimately will be a hybrid approach of lidar

and retro-reflectometer data. This also applies to FHWA reporting as we learn how best to implement. This is another reason why we need and support research with multiple pieces of lidar equipment AND to include mobile reflectometer equipment. This allows ODOT the flexibility to control its own timeline and methodology for required FHWA reporting.

- From Maintenance – There is a concern that if this research is funded, the research contract and equipment may not be available to capture the TESTDECK data. Currently, TESTDECK is installation is planned for June 4, 2024 and ideally, lidar scanning would need to be done when the pavement markings are new (before traffic damages them). Dr Olsen has indicated he and his staff are unavailable that week. If funded, the contract may need to be signed early and allow for a few days of work by ODOT with instruction from OSU. This may need to happen before a research project typically starts in September. It is unclear if multiple scans are needed thereafter, so the research scope may need to be adjusted to include additional scans (extra work).
    - Response from Research Coordinator – the budget was increased by $15k to accommodate expenses related for additional scanning.