SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE
25-66 Mobile Illuminance Measurement for Safer Oregon Roadways

PROBLEM SUMMARY
Between 2016 and 2020, 52% of urban area fatal traffic injuries occurred during dark hours of the day with a substantial portion occurring on streets without street lighting (ODOT 2022). According to the *Oregon Triennial Highway Safety Plan FFY 2024-2026*, “Time of day and lighting continue to be one of the most important factors in crash injury severity” (pg. 113), with 74% of Oregon’s pedestrian fatalities occurring in dark lighting conditions and 65% during nighttime (6 PM and 5:59 AM). Despite ODOT’s recognition of the link between lighting and transportation safety, ODOT does not have a uniform inventory of street lighting conditions that would enable safety studies and empower ODOT to proactively identify vulnerable locations at higher risk for crashes.

ODOT OBJECTIVES
Since roadway illuminance conditions have been correlated with crash risk, this project will develop instrumentation and methodologies that will empower ODOT to maintain an accurate lighting inventory and evaluate the relationship between roadway lighting illuminance and crash risk. To this end, this research will create a prototype mobile illumination measurement system and accompanying analysis scripts to create georeferenced illuminance layers in GIS software for asset management on state highways.

BENEFITS
This research will provide the instrumentation and methodologies to measure roadway illuminance at driving speeds, with data that can subsequently be visualized and exported into a GIS databased compatible with ODOT’s TransGIS. Illuminance data gathered by this instrument system will support ODOT processes that include safety studies, crash forensics, compliance with ANSI/IES roadway standards, maintenance operations, and evaluation of corridor and intersection roadway lighting equity. ODOT does not currently have equipment to perform geolocated illuminance measurements at a scale to support these goals.

SCHEDULE, BUDGET AND AGENCY SUPPORT
Estimated Project Length: 24 months.
Estimated Project Budget: $215,000
ODOT Support: Ernest Kim, PE, ODOT State Illumination Engineer

FOR MORE INFORMATION
For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:
https://www.oregon.gov/odot/Programs/ResearchDocuments/25-66.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2025

PROBLEM NUMBER AND TITLE

25-66 Mobile Illuminance Measurement for Safer Oregon Roadways

RESEARCH PROBLEM STATEMENT

Despite the recognized link between street lighting and transportation safety, the Oregon Department of Transportation (ODOT) lacks a comprehensive inventory of street lighting conditions, hindering its ability to identify vulnerable locations and proactively address safety concerns. Between 2016 and 2020, 52% of fatal traffic injuries in urban areas occurred during dark hours, with a significant portion occurring on road segments without streetlights (ODOT 2022). The *Oregon Triennial Highway Safety Plan FFY 2024-2026* acknowledges that "Time of day and lighting continue to be one of the most important factors in crash injury severity" (pg. 113), with 74% of Oregon's pedestrian fatalities occurring in dark lighting conditions and 65% during nighttime (6 PM and 5:59 AM).

Effective street lighting can reduce crash risk by up to 42% (Li et al., 2021), and poor illuminance uniformity is associated with increased nighttime crash risk (Yang et al., 2019).

Currently, ODOT employs a rating scale of 1 to 5 (e.g., from darkness with no street lighting to daylight) to coarsely bin lighting condition within the TransGIS crash database. In ODOT's crash data, the street lighting condition of the crash site is derived from associated police and DMV crash reports where the daylight (dawn, daylight, dusk, darkness) condition is assigned along with the streetlighting condition (darkness with streetlights, darkness without streetlights) either based on reported information or if no information was reported based on the hour of the day and the month of year. This data element has the potential to be subjectively determined by the reporter. Evaluation by ODOT staff have found numerous instances of two crashes occurring at the same location, within a minimal time difference (e.g. same day) between the crashes but reporting different (nighttime) street lighting conditions.

A high-resolution inventory of spatially resolved illuminance measurements across the roadway network would enable ODOT to systematically evaluate existing street lighting conditions, identify deficiencies, and prioritize roadway lighting upgrades proactively, rather than reactively at crash locations.

Using mobile technologies and a "big data" approach to characterize the illuminance distribution on roadways offers several advantages over manual measurements. Handheld illuminance surveys are time-consuming, costly, and put data collection staff at risk, especially in poorly lit locations. Mobile measurements can yield a significantly higher number of measurement points, providing a more granular understanding of illuminance distribution while improving safety for road users and road workers, and measurement speed.

Spatially resolved illuminance measurements will enable the quantification of illuminance variability using relevant statistical and graphical methods, supporting compliance with Illuminating Engineering Society (IES) recommended practices (ANSI/IES 2021). Remote sensing techniques using georeferenced vehicle-mounted illumination detection sensors could offer a cost-effective solution to provide the spatially resolved data needed to systematically understand street lighting conditions on Oregon roadways.

RESEARCH OBJECTIVES

This research project will involve building a mobile illuminance measurement system, testing it, and gathering sufficient data to demonstrate feasibility at scale.

WORK TASKS, COST ESTIMATE AND DURATION

Task 1 Literature Review (Q1): Review, evaluate, and summarize literature related to: (a) illumination measurement sensors; (b) metrics to describe illumination and its variability; (c) use of illumination for both compliance with standards and in support of transportation safety; (d) illuminance and georeferencing sensor integration and calibration.

Task 2 Hardware Component Research and Procurement (Q1): Determine sensor design requirements and identify candidate hardware components to be integrated into a robust and reliable hardware solution, including: (a) illuminance detector heads with suitable precision, accuracy, durability, and calibration traceability; (b) optometer modules suitable for mobile use; (c) GNSS and inertial measurement units for accurate geolocation of illuminance measurements; (d) computing hardware to facilitate time-series integration of data streams; (e) components to attach to and consistently position the illuminance detector heads to a vehicle's roof rack; and (f) power source.

Task 3 Hardware Integration (Q2 – Q3): Physically assemble the prototype system by integrating the hardware components to support robust and reliable field use, including illuminance and georeferencing measurement devices, cable security, physical mounting connectors, and laptop integration.

Task 4 Firmware for System Operation and Time Series Integration of Data Streams (Q3 – Q6): This task includes two primary subtasks: firmware development and physical verification. First, firmware will be developed to ensure the illuminance detectors, optometer modules, and GNSS components are functionally integrated with synchronized data streams. Second, data stream synchronization will be tested in an OSU parking lot, collaborating with OSU Transportation Services and OSU Public Safety Department to secure permissions and safe access. Testing will consist of creating a grid of fixed measurement points in the parking lot and comparing mobile illuminance measurements taken while driving through the gridded area. Terrestrial laser scans will be collected to provide accurate geometric information related to the illuminance measurement grid and the lighting sources. Testing will be performed at different operating speeds to determine measurement consistency.

Task 5 Code for Data Analysis and Export (Q3 – Q7): Code will be developed to convert the raw data streams to user interpretable output. Subtasks include developing code to predict street-level illuminance from vehicle rooftop measurements, estimating roadway luminance from illuminance measurements, creating output grids comparable to ANSI/IES recommended spacings, creating visualizations (e.g., pseudo-color illuminance contours), and compliance checking with reference to relevant roadway lighting standards. Scripts will be developed to populate a GIS database suitable for ODOT's TransGIS.

Task 6 Field Verification (Q5 – Q6): Conduct field tests to evaluate the robustness of the mobile illuminance measurement platform at the spatial and temporal scales of interest. These tests will include evaluating different modes of averaging and interpolating sensor measurements and will also test predictions of street-level measurements from vehicle rooftop measurements. ODOT's existing mobile lidar data will be leveraged to provide detailed geometry and identify locations of lighting sources.

Task 7 User Guide (Q6 – Q8): Document the methodology to utilize the prototype system to collect illuminance data for any local site, scalable to a statewide survey of illuminance on all roadways.

Task 8 Reporting (Q1 – Q8): In addition to ongoing communication with ODOT throughout the project, and the delivery of a user guide, a final report will also describe example applications where illuminance metrics could support ODOT processes, including safety studies, crash forensics, compliance with ANSI/IES roadway standards, and maintenance operations.

Key Deliverables: This project will involve building a prototype mobile illuminance measurement system, testing it, and gathering sufficient data to demonstrate feasibility at scale. The key deliverable will be the prototype system itself, comprising the hardware, code for data analysis and export, and user manual.
Estimated Project Length: 24 months.
Estimated Project Budget: $215,000

IMPLEMENTATION

This new technology will be transferred to ODOT through presentations in meetings and workshops with ODOT personnel, supported by a written user manual. Findings will also be disseminated through conference presentations (e.g., Illuminating Engineering Society Street and Area Lighting Conference, Annual Meeting of the Transportation Research Board, American Society of Civil Engineers) and journal publications.

POTENTIAL BENEFITS

This project will launch a "big data" approach to understanding the illuminance conditions on Oregon roadways, supporting more granular analyses of the relationships between crashes and lighting conditions. The final report will describe applications where the illuminance data gathered by this instrument system could support ODOT processes, including safety studies, crash forensics, compliance with ANSI/IES roadway standards, and maintenance operations.

Light justice initiatives have also suggested inequity in outdoor lighting conditions, with affluent communities more likely to enjoy higher quality lighting (Creatura 2017). To test this hypothesis at scale within Oregon, particularly for the transportation network, it is first necessary to document lighting conditions at scale.

PEOPLE

ODOT champion(s): Ernest Kim, ODOT State Illumination Engineer

Problem Statement Contributors: Kevin Houser, PhD, PE (NE), FIES, LC, LEED AP, Oregon State University; Michael Olsen, PhD, Oregon State University; Erzhuo "Ezra" Che, PhD, Oregon State University; Josh Roll, ODOT Active and Sustainable Transportation Research Coordinator; Amanda Salyer, PE, ODOT Region 2 Traffic Investigations Engineer; Christi McDaniel-Wilson, PE, ODOT State Traffic Safety Engineer

REFERENCES

[ANSI/IES] American National Standards Institute and Illuminating Engineering Society. 2021. RP-08-21 Recommended Practice: Lighting Roadway and Parking Facilities, Parts 1 and 2. New York (NY): Illuminating Engineering Society.

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Li Q, Wang Z, Li M, Yang R, Lin PS, Li X. 2021. Development of crash modification factors for roadway illuminance: A matched case-control study. Accident Analysis & Prevention. 159:106279. https://doi.org/10.1016/j.aap.2021.106279.

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STAFF REVIEW PAGE

Literature Check

TRID&RIP

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

There is no off the shelf capability currently available to collect system wide illumination data

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.

Cross-agency stakeholders

- List ODOT partners or impacted units. Traffic Data, Traffic and Roadway and State Traffic Illumination
- Identify any issues of concern raised by an ODOT partners. Note expected mitigation that addresses these concerns