Research Stage 1 Problem Statement

PROPOSED TITLE: Mobile Illuminance Measurement for Safer Oregon Roadways

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

Between 2016 and 2020, 52% of Oregon's 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). Research has shown that 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). Additionally, lighting conditions can be highly variable based on socio-economic status of neighborhoods, leading to inequity and more risk to vulnerable populations. Despite ODOT's recognition of the strong connection between lighting and transportation safety, ODOT does not have a uniform data-driven inventory of street lighting conditions statewide. This limits ODOT's ability to conduct comprehensive safety analyses and to proactively identify vulnerable segments of the road where inadequate lighting may contribute to elevated crash risks. Moreover, systematic characterization of roadway lighting conditions would help ODOT develop equitable, energy-efficient lighting strategies that enhance both safety and sustainability across Oregon's transportation system. It would also allow ODOT to consider lighting from a multi-modal perspective as lighting conditions could be evaluated for bicyclists and pedestrians.

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

A statewide 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 after a crash occurs. Using mobile remote sensing technologies and a data-driven approach to characterize the illuminance distribution on roadways offers several advantages over manual measurements. Handheld illuminance surveys are labor-intensive, time-consuming, costly, and put field staff at risk, especially in poorly lit locations. By contrast, 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. This project will design, build, and test a prototype mobile illuminance measurement system, testing it, and gathering sufficient data to demonstrate feasibility at scale. The key deliverable will be a

prototype mobile illuminance system, comprising the hardware, code for data analysis and export, and user manual.

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.

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4. Other comments:

This proposed research introduces an innovative, data-driven system to assess roadway lighting performance in support of safety, equity, and sustainability goals. It is envisioned that the work would involve the following tasks:

Task 1 Literature Review: 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: 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 Prototype Development and Integration: 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. Firmware will be developed to ensure the illuminance detectors, optometer modules, and GNSS components are functionally integrated with synchronized data streams. Data stream synchronization will be tested in a controlled setting. 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 4 Data Analysis and Export Tools: Code will be developed to convert the raw data streams to user interpretable output. Subtasks include developing code to translate the vehicle rooftop measurements to

street-level illuminance, 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 automatically populate a GIS database suitable for ODOT's TransGIS.

Task 5 Field Verification: 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. It will assess repeatability, spatial coverage, and accuracy under different speeds and lighting conditions. ODOT's existing mobile lidar data will be leveraged to provide detailed geometry and identify locations of lighting sources.

Task 6 Reporting: Create a user guide to 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. 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.

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:

The mobile illuminance system will enable ODOT to make more informed decisions about lighting on its roadways. ODOT could be more efficient and thoughtful in lighting strategies, promoting energy efficiency. This could potentially lead to reductions in lighting use in areas where there is excessive lighting. Additionally, information on lighting can be beneficial to wildlife studies by identifying locations where lighting could be adapted to improve conditions for wildlife.

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:

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. The research team will coordinate with ODOT's equity and safety offices to identify pilot sites and ensure that the findings consider areas potentially affected by inadequate lighting conditions.

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 communities**?

☐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:

Despite the recognized link between street lighting and transportation safety, 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 conditions 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. Evaluations 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.

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.

6. Corresponding Submitter's Contact Information:

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