

SPR RESEARCH PROGRAM

SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

27-66 Building a Resilient Oregon: Aligning ODOT Seismic Design with Latest Science for Lifeline Reliability

PROBLEM SUMMARY

The 2025 ODOT Bridge Design Manual requires critical and recovery bridges to remain operational after a full-rupture Cascadia Subduction Zone Earthquake (CSZE). A 2016 online tool developed by Portland State University has provided consistent statewide CSZE design spectra for ODOT and consultants. Recent USGS National Seismic Hazard Model updates (2018 and 2023) include revised Cascadia rupture scenarios, basin effects for Portland and Tualatin, and new NGA-Sub ground motion equations—advances that must now be incorporated into Oregon’s bridge seismic criteria. ODOT must decide whether to update the existing deterministic CSZE framework or adopt a probabilistic uniform hazard approach, both aligned with current science. This research delivers a statewide quantitative comparison of the two methods, along with engineering and maintenance assessments, to give ODOT a solid basis for choosing the best long-term methodology for Operational Performance Level ground motions.

ODOT OBJECTIVES

The project will equip ODOT with a science-based foundation for modernizing its seismic design criteria. The team will perform a statewide comparison of the deterministic (CSZE-based) and probabilistic approaches for the Operational Performance Level, providing clear recommendations on the preferred framework. They will also develop a new implementation tool to generate appropriate ground motions for Operational Criteria, replacing the 2016 web tool while ensuring consistency with the selected method. To facilitate adoption, the project includes a user manual, hazard calculation examples for representative Oregon sites, and training webinars for ODOT staff and consultants.

BENEFITS

This work will align Oregon’s Operational Performance Level criteria with the latest Cascadia hazard science, enhancing bridge safety and reliability while maintaining statewide consistency and design efficiency. The updated methodology and tool will reduce variability across projects, support uniform application of the Bridge Design Manual, preserve time and cost savings, and minimize future challenges to criteria adequacy by incorporating recent USGS and NGA-Sub advancements—strengthening the long-term resilience of Oregon’s transportation infrastructure.

SCHEDULE, BUDGET AND AGENCY SUPPORT

Estimated Project Length: 36 months.

Estimated Project Budget: \$360,000

ODOT Support: Albert Nako, Seismic Standards Engineer, Albert.NAKO@odot.oregon.gov

FOR MORE INFORMATION

For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:

<https://www.oregon.gov/odot/Programs/ResearchDocuments/27-66.pdf>

SPR RESEARCH PROGRAM

SECOND-STAGE PROBLEM STATEMENT

FY 2027

PROBLEM NUMBER AND TITLE

Building a Resilient Oregon: Aligning ODOT Seismic Design with Latest Science for Lifeline Reliability

RESEARCH PROBLEM STATEMENT

The 2025 ODOT Bridge Design Manual (BDM) requires that bridges designated as recovery or critical be designed to remain operational during a full-rupture Cascadia Subduction Zone Earthquake (CSZE) (Section 1.17.2.3). These include highway bridges on the State Seismic Lifeline Routes, designated as recovery bridges, and bridges on other state highways designated as critical structures. US Geological Survey (USGS) provided the methodology for determining CSZE design spectra, but these would result in the need for complex individual scenario calculation for each bridge design. To promote consistency and efficiency in design, an [online tool](#) was developed in 2016 by Portland State University (PSU) to generate the CSZE design spectra for any Oregon location, simply based on latitude, longitude, and soil site classification. Due to its simplicity, this tool has been widely used in both ODOT and non-ODOT projects throughout Oregon, resulting in significant time and projects' design cost savings.

Several major developments in CSZE methodology calculation by USGS and the Pacific Earthquake Engineering Research Center (PEER) over the past decade have rendered this tool outdated. The USGS seismic source models have been updated twice (2018 and 2023) and now include new rupture models for the CSZ slab based on the latest science and added basin effects for the Portland and Tualatin basins. In addition, and perhaps the most consequential update since the development of the original CSZE tool, is the introduction of new Ground Motion Prediction Equations (GMPEs) developed specifically for the Cascadia region as part of PEER's New Generation Attenuation-Subduction (NSG-Sub) project in 2021.

The current CSZE tool is outdated, but the most effective way to update it and ensure it meets the requirements outlined in the BDM while still retaining its utility is less clear. Two possible solutions have been discussed with ODOT and USGS, including probabilistic and deterministic approaches. The probabilistic approach would involve changing the current BDM requirement from a deterministic full-rupture CSZE to a probabilistic uniform hazard spectrum corresponding to a selected return period that is approximately comparable to the deterministic CSZE. This would represent a major shift but may simplify implementation and long-term maintenance, given periodic USGS updates (every 4–6 years). The second solution is to maintain the current deterministic approach in the BDM and update the rupture model for the CSZ slab, incorporate basin effects for the Portland and Tualatin basins, and replace the outdated GMPEs in the existing tool with the NGA-Sub ground motion prediction models. Without evaluation of these updates, it is unclear whether the current deterministic framework continues to represent an appropriate Operational Level performance target.

RESEARCH OBJECTIVES

The objectives of this research are to:

- (1) Evaluate and quantify differences between deterministic and probabilistic methodologies for characterizing ground motions for the Operational Performance Level of seismic bridge design and provide recommendations to support ODOT's decision regarding the adoption of the most appropriate methodology (Task 1).

- (2) Develop and implement a replacement design tool consistent with the selected methodology, including documentation and training materials to support adoption (Tasks 2 and 3).

WORK TASKS, COST ESTIMATE AND DURATION

The objectives of this research will be accomplished through the following tasks.

Task 1. Evaluation of Alternative Methodologies for Operational Level Design Spectra (12-18 months)

This task will provide a quantitative comparison of two approaches for defining Operational Level seismic design criteria.

Deterministic Approach (Full-Rupture CSZE). The existing deterministic framework in the 2025 BDM will be updated to reflect current science. This includes incorporation of the 2023 USGS National Seismic Hazard Model (NSHM) Cascadia slab rupture geometry, inclusion of basin effects in the Portland and Tualatin basins, implementation of NGA-Sub ground motion prediction equations, and updated site coefficients for site response. CSZE design spectra will be developed for a statewide grid and for different site classes. Where feasible, required seismic source parameters will be obtained through USGS Web Services. If such datasets are not available in a usable format, required parameters will be computed directly by the research team.

Probabilistic Approach (Uniform Hazard Spectra). Uniform hazard spectra will be developed using probabilistic seismic hazard analysis (PSHA) based on USGS hazard curves. Spectra will be generated for various return periods and site classes across the same statewide grid. Equivalent return periods will be determined by matching probabilistic spectra to deterministic CSZE spectra. Because the equivalent return period is expected to vary at different locations and spectral periods, statewide maps of equivalent return periods will be developed for key spectral accelerations (e.g., PGA, 0.2 sec, 1.0 sec, and 3.0 sec). These maps will clarify how equivalent return periods vary across the state, particularly between western Oregon (dominated by CSZ hazard) and eastern Oregon (dominated by crustal sources), and the implications of those differences for Operational Performance Level design. If risk-targeted ground motions relevant to Operational Performance Level become available, they will be evaluated for alignment with identified equivalent return periods.

The deliverable for Task 1 will be a technical memorandum providing a statewide quantitative comparison of deterministic (CSZE-based) and probabilistic approaches for Operational Performance Level design spectra, including equivalent return period maps and a summary of the advantages and disadvantages of each method with respect to implementation and future updates associated with revisions to the USGS National Seismic Hazard Model. At the completion of Task 1, ODOT will formally select the preferred methodology before development of the replacement tool proceed.

Task 2. Development of an Operational Level Seismic Design Tool (9 to 12 months)

Once a decision is made by ODOT on the most appropriate approach, we will develop a new design tool that incorporates the latest advancements in seismic hazard analysis for the Cascadia region. This tool will aim to incorporate flexibility in maintenance, given the frequent updates to the National Seismic Hazard Model by USGS (with major updates occurring every 4 to 6 years). The new tool will be developed on a platform preferred by ODOT based on input from ODOT's IT team. The experience gained in developing the original CSZE tool by PSU in 2016 will help ensure that the new tool builds on the successful features of the original version that contributed to its widespread use, while incorporating the significant advancements made over the past decade.

Task 3. Implementation Support (9 months)

Implementation materials will be developed to facilitate smooth transition to the new methodology and tool. These will include a user manual, examples of hazard assessment for representative locations in

Oregon, comparison examples illustrating differences in design spectra between the current and updated methods, and webinars for ODOT engineers and stakeholders.

Key Deliverables:

The deliverables of this research project include:

- A technical memorandum providing a statewide quantitative comparison of deterministic (CSZE-based) and probabilistic methodologies for the Operational Performance Level of seismic bridge design.
- A replacement tool for estimating the earthquake ground motions to be used for the Operational Performance Level of seismic bridge design, consistent with the methodology selected by ODOT that reflects the latest science on CSZ and the USGS National Seismic Hazard Model.
- Implementation materials, including a user manual, examples of hazard estimation for representative Oregon locations illustrating differences in design spectra from the current tool and the new tool, and training webinars for ODOT engineers and stakeholders.

Estimated Project Length: 36 months.

Estimated Project Budget: \$360,000

EXPECTED ODOT IMPLEMENTATION ACTIONS

Following completion of this research, ODOT will select the preferred methodology for defining earthquake ground motions to be used for the Operational Performance Level of seismic bridge design, based on the comparative assessment provided in Task 1. The Bridge Design Manual will be updated, as needed, to reflect the selected approach. The existing CSZE design tool will be retired and replaced with the newly developed tool consistent with the adopted methodology. Coordination with ODOT IT will be required to determine the most appropriate approach for hosting, deployment, and long-term maintenance responsibilities. Because the new tool will retain the same user inputs as the current tool (latitude, longitude, and site classification), the transition to the updated methodology is expected to be straightforward, with minimal disruption to current design workflows.

POTENTIAL BENEFITS

This research will provide a rigorous and quantitative evaluation of the impact of recent scientific updates on CSZ operational-level design criteria. The results will equip ODOT with the technical basis needed to determine the most appropriate path forward for adopting and implementing these updates. The accompanied tool will provide consistency and efficiency in the seismic design of bridges for Operational Level performance. Similar benefits were realized from the predecessor tool developed by PSU in 2016, which has been widely used in both ODOT and non-ODOT projects throughout Oregon. Continued availability of a simple, statewide tool will reduce project-level interpretation, promote uniform application of seismic design criteria defined by the Bridge Design Manual, and result in time and cost savings during design.

Because the current tool has not been set up to incorporate major updates by the USGS over the past decade, continued reliance on the outdated tool may result in unconservative designs or design assumptions that do not reflect current scientific understanding. Updating the methodology and tool will strengthen the technical basis of ODOT's seismic design practice and align it with the latest science. This will reduce potential exposure to future challenges regarding the adequacy of seismic design criteria.

PEOPLE

ODOT champion(s): Albert Nako, Seismic Standards Engineer, Albert.NAKO@odot.oregon.gov

Problem Statement Contributors:

Arash Khosravifar, Associate Professor, Portland State University (karash@pdx.edu)

Peter Dusicka, Professor, Portland State University (dusicka@pdx.edu)

Andrew Makdisi, Research Civil Engineer, USGS (amakdisi@usgs.gov)

REFERENCES

Oregon Department of Transportation. (2025). Bridge Design Manual (2025 ed.). Bridge Engineering Section. Salem, OR: Oregon Department of Transportation.

Petersen, M. D., Shumway, A. M., Powers, P. M., Field, E. H., Moschetti, M. P., Jaiswal, K. S., ... & Witter, R. C. (2024). The 2023 US 50-state national seismic hazard model: Overview and implications. *Earthquake Spectra*, 40(1), 5-88.

STAFF REVIEW PAGE

LITERATURE CHECK

TRID&RIP

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

ODOT DECISION LENSES

Climate: This research supports climate resilience by updating seismic design criteria and tools to reflect the latest science on Cascadia hazards, enabling more efficient bridge designs that avoid over-conservatism and reduce long-term material and construction impacts. It promotes sustainable maintenance of transportation infrastructure by minimizing potential future retrofit needs and supporting reliable post-event mobility, which helps limit emissions from detours or disruptions during seismic events.

Equity: This research advances equity by delivering a consistent, statewide seismic hazard tool and methodology recommendations that ensure uniform application of operational-level design criteria across Oregon, including in rural, tribal, and underserved areas. By reducing design variability, project costs, and reliance on outdated tools, it helps provide equitable protection and access to safe, resilient bridges for all communities, particularly those dependent on lifeline routes.

Safety: This research directly improves safety by quantitatively evaluating and updating Operational Performance Level seismic design criteria for critical and recovery bridges to incorporate recent USGS and NGA-Sub advancements. It provides ODOT with a defensible basis to select the most appropriate methodology (deterministic or probabilistic), develops a modern replacement tool for accurate ground motion estimation, and reduces risks associated with outdated hazard assumptions, thereby enhancing bridge operational reliability during a CSZE and protecting public and responder safety.

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 IMPACTS

- List ODOT partners or impacted units: Bridge Section. Seismic Committee.
- Identify any issues of concern raised by an ODOT partners. Note expected mitigation that addresses these concerns.