Oregon Department of Transportation

Research Stage 1 Problem Statement

Number 26-10 – "Incorporation of Aging and Deterioration in Seismic Fragility Models at ODOT"

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

Given Oregon's aging bridge infrastructure and its susceptibility to seismic events, there is an urgent need to integrate deterioration e;ects into fragility models. The newly implemented National Bridge Inspection Standards (NBIS) and the Specifications for the National Bridge Inventory (SNBI) highlighted a shift to predominantly element-level inspection data for bridges. This presents a unique opportunity to refine the seismic fragility models of aging bridges, particularly using element-level condition data of substructure components.

ODOT is currently developing the next generation of bridge fragility models that can better capture and delineate characteristics of seismic demands and capacities of Oregon bridges. The goal of this research is to incorporate aging and deterioration into ODOT's new fragility models. This will be primarily achieved through physics-based and uncertainty-incorporated deterioration models that can (a) be calibrated with element-level condition data and (b) update structural models to determine seismic capacity. Ultimately, the developed models will enable ODOT to accurately assess risk, better coordinate and prioritize resilience-enhancing e;orts, and thereby reducing long-term cost and GHG emissions associated with bridge maintenance and retrofitting.

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

The final project of this research will be a set of age- and condition-related fragility models, building upon the recent ODOT fragility study (Project 25-23). Dr. Farahnaz Soleimani, a contributor to the aforementioned project, has agreed to collaborate on the proposed research. To achieve the ultimate goal outlined in Question 1, closed-form equations representing the developed fragility models will be provided in the project final report. The equations will be easily implementable in spreadsheet applications. Furthermore, the fragility model will be incorporated into existing bridge management systems (e.g., AASHTOWare BrM) for practical decision-making based on long-term cost and seismic risk of bridge networks. The latter will build upon the approach to hazard scenario selection developed by the submitter in a previous FHWA project and follow the existing implementation strategy in NCHRP Project 20-07/Task 378.

The final deliverables will directly support ODOT's decision-making for seismic resilience enhancement and maintenance budget allocations. These tools will ensure long-term adaptability and relevance as bridge conditions and environmental factors continue to evolve. The results can also be utilized to update maintenance and retrofitting priorities along corridors identified in the ODOT Seismic Plus Program (ODOT 2014).

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
Farahnaz Soleimani	Assistant Professor, Oregon State University	farahnaz.soleimani@oregonstate.edu	781-605-8378
Albert Nako	Senior Seismic Standards Engineer	albert.nako@odot.oregon.gov	971-283-5558

4. Decision making lenses

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 high value research need.

Climate

Oregon recognizes the climate crisis and makes systemic changes to reduce emissions caused by travel. Every mile driven in Oregon is powered by a clean source of fuel. We seek research that supports construction and maintenance operations are carbon neutral and investments in mobility that support travel by low and no emission modes. While every research project may not result in a reduction in emissions, transportation investments overall support emission reductions to achieve state goals. Oregon envisions a transportation system that is resilient in the face of seismic and climate events and impacts to the degradation of the natural environment are reduced. Our vision includes a transportation infrastructure is built in a way that avoids impacts on key habitat and results in better 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.

4f. 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 gasses (GHG)?

☐Yes ☒No ☐Unsure

4g. 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

4h. Will the 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

4i. Will the 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

4j. Will the solving the **transportation issue** in question 1 lead to work that will support, measure, monitor, transportation system resilience in response to expected climate events, e;ects, or natural disasters in general?

☒Yes ☐No ☐Unsure

4k. Will the 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

4l. If you answered yes to any of the climate questions above or can provide alternative details related to climate, please provide additional information:

- 4j: Improved fragility models that account for deterioration can directly contribute to the resilience assessment and enhancement of aging bridge structures and transportation systems, particularly in anticipation of large-scale Cascadia subduction zone earthquakes. Additionally, the use of physics-based deterioration models allows for the inclusion of impacts from rising temperatures and varying precipitation patterns on bridge deterioration. As a result, the additional climate risk due to potentially accelerated deterioration can be properly reflected.
- 4g: We plan to conduct a case study on the coordinated planning of substructure maintenance and retrofitting enabled by the developed models. The potential benefits will be quantified by reductions in both operational costs and GHG emissions, realized by eliminating redundant or competing maintenance and retrofitting work candidates.

Equity

Equity can have many dimensions and impacts relating to communities, and transportation. It is important that problem statement proposals clearly explain in what capacities are equity dimensions or impacts being examined within problem statements. It is a goal of the OTP to "Improve access to safe and aJordable 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". Proposed research may have the intent of studying elements of this goal or apply analysis to specific transportation topics to ensure the resulting research recommendations is consistent with our equity goals. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

4a Is the **transportation issue** identified as a need in Question 1 specifically focused on transportation equity?

☐Yes ☒No ☐Unsure

4b 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

4c 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

4d Is the intended final product or information expected to support ODOT's equity e;orts (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

4e 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.

4m. Will solving the **transportation issue** in question 1 support improving **safety culture** for either transportation workers or the traveling public?

☐Yes ☒No ☐Unsure

4n. Will the solving the **transportation issue** support improving safety through **healthy and livable communities**?

☐Yes ☒No ☐Unsure

4o. Will solving the **transportation issue** support improving safety through using **best available technologies**?

☐Yes ☒No ☐Unsure

4p. Will solving the **transportation issue** support improving safety through **communication and collaboration**?

☐Yes ☒No ☐Unsure

4q. Will the solving the **transportation issue** support improving safety through **investing strategically**?

☐Yes ☒No ☐Unsure

4r. If you answered yes to any of the safety questions above or can provide alternative details related to safety, please provide additional information:

5. Other comments:

A physics-based deterioration model refers to models that reflect deterioration mechanisms under various environmental and mechanical stressors. The submitter has been developing and applying such models to enhance the modeling and prediction of corrosion and fatigue damage in bridges. These models explicitly consider various uncertainties and their propagation in relation to the predicted damage extents. The obtained probability distribution of damage extents can be directly compared with the element-level condition data, thereby calibrating deterioration models suitable for ODOT bridges.

We plan then to embed the deterioration model and the resulting damage predictions, such as concrete cracking/spalling and steel corrosion, into the finite element models used in seismic capacity and demand analyses. The results will be developed into fragility models linked to element-level inspection outcomes. To ensure project success, the research will leverage (a) the ongoing ODOT project on bridge fragility development and (b) the submitter's FHWA project on seismic risk assessment for bridge inventory. The particular projects are shown below:

Soleimani F. and Nako A. 2024. Enhancing Seismic Resilience: Developing Next-Generation of Bridge Fragility Models for Oregon's Transportation Network. *ODOT*, Project 25-23.

Yang, D.Y., Khosravifar A., Moug D., and Unnikrishnan A. 2022-2025. Framework and Methodology for Risk-Based Bridge and Tunnel Asset Management. *Federal Highway Administration (FHWA)*, Contract No. 693JJ321C000030.

Other relevant references, especially those from the submitter and the collaborator, are listed below:

Yang, D.Y., Frangopol, D.M., 2020. Risk-based vulnerability analysis of deteriorating coastal bridges under hurricanes considering deep uncertainty of climatic and socioeconomic changes. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering* 6, 04020032.

Yang, D.Y., Frangopol, D.M., 2018. Probabilistic optimization framework for inspection/repair planning of fatigue-critical details using dynamic Bayesian networks. *Computers & Structures* 198, 40–50.

Mangalathu, S., Soleimani, F. and Jeon, J.S., 2017. Bridge classes for regional seismic risk assessment: Improving HAZUS models. *Engineering Structures*, *148*, pp.755-766.

Soleimani, F., 2017. Fragility of California bridges-development of modification factors. Doctoral dissertation, Georgia Institute of Technology.

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