**American Association of State Highway and Transportation Officials**

**Special Committee on Research and Innovation**

**Deterioration Rates and Life-Cycle Costs for Geotechnical Assets**

**Background**

“The term ‘asset management’ means a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost.’’ (23 USC 101(a)(2))

Federal rules in 23 CFR 515.9 encourage transportation agencies to incorporate in their Transportation Asset Management (TAM) Plans all infrastructure assets within the highway right of way. This may include geotechnical assets such as retaining walls, unstable slopes, embankments, and other asset classes whose functionality may affect the whole life cost, performance, and resilience of the network. Additional benefits for agencies that implement statewide geotechnical asset management (GAM) programs include facilitating 23 CFR 667 compliance by providing a framework for tracking assets that have been repeatedly damaged by emergency events. AASHTO guidance on asset management notes that best practice is the use of deterioration and cost models as central tools in forecasting future preservation needs and estimating life cycle cost.

Agencies implementing geotechnical asset management will need to develop consistent quantitative models to forecast deterioration and costs for best practice asset management and to provide accurate investment plans in the TAM Plan. For many agencies, lack of data and lack of staff or resources to collect data needed to develop these cost and deterioration models are a major impediment to the initiation of a GAM program. Like bridge and pavement asset management programs, early Delphi-based probabilistic deterioration models are replaced by models based on 10 or 20 years of historic data as it becomes available. Fortunately, the deterioration of some geotechnical assets, particularly rock slopes and unstable soil slopes, have some statewide datasets to build upon and be supplemented with Delphi-based models. Maintaining geotechnical asset performance with cost-effective preservation measures rather than relying on a worst-first method selecting projects has been modeled to significantly reduce costs for the same network outcome; $7 million in savings annually in Montana’s highway rock slopes alone. Preliminary models of retaining wall deterioration were developed in Alaska’s GAM program. Understanding deterioration rates and unit costs are required to calculate these benefits.

This problem statement has been updated from an earlier version that had been advanced to NCHRP by TRB and AASHTO. This revised statement is intended to capture the interest that led to success previously and provide background that will help a new NCHRP panel understand the context and value of this work with respect to NCHRP Report 903 (2019), and advance the project.

**Literature Search Summary**

NCHRP 24-46 has developed implementation guidance for geotechnical asset management but was not scoped to perform the research necessary to develop the quantitative models described here. Many agencies have developed Rockfall Hazard Rating Systems that build on a visual assessment of slope characteristics to characterize the vulnerability of rock slopes. In recent geotechnical asset management practice, this information has been used to develop judgment-based deterioration models, most commonly utilizing Markov models. Research completed in 2017 for the Montana Department of Transportation (MDT) successfully applied Markov models. This allowed MDT to estimate deterioration of their rock slopes and applied results to estimate annual budgets to require to preserve network condition. Similar methods have been used for soil slopes and retaining walls although the Alaska’s Geotechnical Asset Management Program, proving again the approach to estimating deterioration rates using judgement-based risk estimation methods. A number of agencies incorporate retaining walls within their bridge management systems and use deterioration and cost models developed for those systems.

**Research Objective**

The objective of this research is to develop measurable, consistent, broad-based deterioration and cost models for the three most significant types of geotechnical assets; retaining walls, embankments, and unstable slopes. The models will be developed mainly using existing condition assessments already gathered by transportation and other agencies, and may be supplemented by field surveys conducted by the researchers, particularly to follow up on earlier surveys or to fill in asset classes not covered by available data. Agencies with existing data include those that have implemented full or partial geotechnical asset management programs (Alaska, Montana, Colorado, Idaho) or those that have inventory and ratings information (Hawaii, Washington, Ohio, Tennessee, Vermont, New Hampshire, North Carolina, and many others). In approximately 2014, Colorado DOT initiated an agency wide wall inventory and asset management program and the second cycle of inspections began in 2019. These existing data are available to calibrate deterioration models for retaining walls. Additionally, there are other state and federal wall inventories that could be selectively updated for additional calibration efforts with follow up field investigations.

Agency data on quantities and costs of past risk mitigation, preservation, and reconstruction projects will also be used. Within the limitations of available data, the models will provide guidance on customization of the models to fit agency variations, regional differences in climate, hydrology, geological character, and other significant variables. Statistical analysis of historical data would be relied on to the greatest extent possible with supplementation from professional engineering judgement from practicing engineers and geologists. Limitations and assumptions would be documented that lead to a consistent and broad-based approach to cost analysis. The models must be suitable for use with TAM performance measures (such as condition states) commonly used by transportation agencies. These models can be used by agencies to overcome the lack of deterioration and cost data as an impediment to the initiation of their GAM programs. Once initiated, these GAM programs will generate data needed to enhance and improve these models, tailored to their particular regions.

It is envisioned that the research will involve at least the following tasks:

1. Review and synthesize the relevant literature including the sources listed above and any other ongoing or completed work in the area.
2. Identify and recruit research partners, transportation agencies that are willing to contribute their historical data on condition assessments and activity costs. Obtain and characterize these contributed data sets in terms of coverage of national needs within the United States.
3. Document a data collection plan to supplement the data sources as needed to maximize the quality and coverage of the analysis. The plan will describe the data to be collected, including field procedures and coding of condition assessments and geological characteristics.
4. Prepare an Interim Report describing the findings and recommendations of the preceding tasks. Solicit comments from the project Panel. Meet face-to-face with the Panel for one day to discuss the comments and proposed recommendations.
5. Based on Panel discussions, refine and carry out the data collection plan. Analyze individual agency databases and collected data to develop deterioration and cost models using valid statistical analysis methods. The resulting models will be delivered as Excel spreadsheet files or other media as appropriate.
6. Prepare a draft Final Report describing the work that was done over the project. The report will fully describe the models and provide examples of their use in forecasting of needs. Submit the draft Final Report to the Panel for review and comment.
7. Finalize and submit the Final Report.

**Urgency and Potential Benefits**

Currently geotechnical asset management procedures rely exclusively on expert judgment because of the relative newness of the field and lack of sufficient historical data in many agencies. Expert judgment in matters regarding long lifespans may be unavailable in many situations, or of limited or questionable reliability. Using developed models, agencies will have a consistent basis for the initial forecasting models they will use in their TAM planning processes, to more credibly tie the forecasts to historical field assessments. Without initial models, GAM programs may not be initiated in many agencies.

Systematic and objective methods will ensure that geotechnical risks are managed consistently and fully considered in planning and programming.

**Implementation Considerations and Supporters**

This research is envisioned to feed directly into TAM Plans and management systems for geotechnical assets. Transportation Asset Managers, geotechnical personnel, and planners would utilize the research results to help prioritize projects in a cost-effective way. Continued FHWA and AASHTO support for asset management and performance management will help to ensure successful and widespread implementation. The recently published NCHRP Report 903 (2019) on geotechnical asset management implementation is already in place as a platform for implementation of the results of the proposed work. In the longer term, agencies should be able to repeat the methodology with data collected over longer timeframes to improve and further customize the models. Research work product awareness would be shared at regional geotechnical workshops, Transportation Research Board meetings, and AASHTO meetings. AASHTO Technical Committees on Materials and Pavements, Performance-Based Management, and Transportation System Security and Resilience would be interested in research results.

**Recommended Research Funding and Research Period**

Total overall project funding estimate: $600,000, Initial activities to gather available data from state DOTs: $150,000

Research Period: 24 – 36 Months.

**Problem Statement Author(s)**

TRB Joint Subcommittee for Geotechnical Asset Management AFP00(1) Co-chairs

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**Others Supporting the Problem Statement**

**Alaska** – “List AKDOT&PF as supporters of the new problem statement … I look forward to being able to supply some data that could aid the statistical analysis and modelling.” Barry Benko, Chief Engineering Geologist

**Colorado** – “CDOT's Geohazards Program has adopted a risk based asset management based performance metric to assess the affect geologic hazards have on the state's transportation system. The likelihood of an event occurring is critical to an accurate risk measurement and is directly affected by the deterioration of the asset. A process to better understand how to evaluate deterioration of geotechnical assets will greatly increase our performance metric and help evaluate how we can incorporate resilience into our network.” – Ty Ortiz P.E., Geohazards Program Manager Connecticut –

**Connecticut** - “With this research, we anticipate solutions to a major stumbling block for implementation of a GAM program. Deterioration data needed for life cycle cost analysis will be available to all States, regardless of the maturity of their GAM program or the amount of available deterioration data. This is particularly beneficial to smaller states or geotechnical engineering offices that often lack the resources to collect and analyze this data on their own.” Michael McDonnell, P.E., Supervising Engineer, Geotechnical Engineering

**Idaho** – “As the Idaho State Asset Management Engineer, I am in full support of this initiative. I have met with Alaska DOT and reviewed their GAM. Little doubt that their effort has heightened awareness that GAM creates a positive ROI. Idaho has completed recent research on MSE wall inventory. This effort demonstrates our commitment to developing a deeper understanding and best practice in the effective stewardship and management of all assets the tax payers of Idaho entrust to our care. For our part, consider us in full support and willingness to help as we are able and can.” – Jim Poorbaugh, Asset Management Engineer

**Montana** – Supports the problem statement. Jeff Jackson, P.E., Acting Materials Engineer and Scott Helm, P.G., Geotechnical Operations Manager

**New Hampshire** – Supports the problem statement. Krystle J. Pelham, Engineering Geology Supervisor

**New Mexico** - Supports the problem statement. Michelle R. Mann, P.E., Geotechnical Engineering and Exploration Section

**Oregon** – “We are very interested in this research. Deterioration or Depreciation of Geotechnical Assets is a wide-open subject that we would like to see progress in.” - Curran Mohney, Engineering Geology Program Leader

**Vermont** - Supports the problem statement. Callie Ewald, P.E., Geotechnical Engineering Manager

**Washington** – “It is highly likely that we will utilize the findings from this research in refinement of our systems here at WSDOT.” - James Struthers, Chief Engineering Geologist

**Potential Panel Members**

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