UTC Project Information	
Project Title	A RAI of Data: Generalizing the Data-driven Rockfall Activity Index (RAI) based on Long-term Observations of Well Characterized Slopes
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Funding Source(s) and Amounts Provided (by each agency or organization)	University of Washington PacTrans $180,000 University of Washington $60,000 Oregon State University $60,000 University of Alaska Fairbanks $60,000
Total Project Cost	$360,000
Agency ID or Contract Number	69A3551747110
Start and End Dates	Mar 16, 2022- June 30, 2023
Brief Description of Research Project	With the support of previous PacTrans funding, members of our research team developed the Rockfall Activity Index system (RAI), a point cloud-derived, high-resolution, morphology-based approach for identifying, assessing, and mapping rockfall hazards at a high resolution across the entire surface of the slope. Ongoing assessment of the RAI indicated that the activity rates are not always consistent, generic values, but instead vary as a function of geology and rock material properties. In this project, we continued from and expanded on years of previous PacTrans research by: 1) collecting another epoch of terrestrial laser scanning data from six Alaskan sites and four sites in Washington and Oregon, all with extensive rock slopes adjacent to major highways; 2) characterizing the geology and major discontinuities of the Washington and Oregon sites; and 3) collecting 4,800 Schmidt hammer measurements from the field sites for a systematic evaluation of this tool to determine rock strength and to compare rebound values to rockfall activity rates. Coupled with the site characterizations for the Alaska field sites presented in a previous PacTrans report, the descriptions and discontinuity measurements collected during this project for the Washington and Oregon sites provide a framework for future studies of these rock slopes, such as kinematic or overall slope stability analyses. *Answering these questions is critical for transportation agencies to plan for and allocate resources optimally to address maintenance needs for rock debris removal and slope mitigation, thus ensuring efficient mobility of the transportation network*.

Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	• The systematic comparison of Schmidt hammer measurements to rockfall activity rates demonstrates a modest negative correlation using a power-law relationship. Specifically, there is a tendency to have lower Schmidt hammer rebound values in areas where we observe higher rockfall activity rates. There is, however, variability in these results, and we suggest that such analyses should be evaluated on a site-by-site basis. • Evaluation of uncorrected and corrected (per ASTM standards) Schmidt hammer rebound values demonstrates that the correction procedure provides a modest improvement of the correlation with rockfall activity. Further research could explore if other correction procedures provide better, more representative fits, including that associated with user bias. • Activity rates at each site varied significantly by year, but median and average values demonstrated reasonable correlation with Schmidt hammer rebound values. We suggest that prolonged monitoring and lidar differencing, as well as repeat collection of Schmidt hammer measurements, may lead to reduced uncertainty and more robust correlations, potentially at scales more generalizable to other rock slopes. • Evaluation of more geologic units with diverse structural controls may demonstrate the utility (or lack thereof) of Schmidt hammer measurements as a proxy for rockfall activity rates. Furthermore, we recommend using activity values suggested by Markus (2018) as the baseline parameters for RAI analysis; and if SH data are available and less than 20, we recommend adopting the upper range of failure rate values presented in this report. Markus, S. J., 2018. *Morphological Evolution of Rock-Slopes and Assessing the Rockfall Activity Index (RAI) Methodology*: MS Thesis, University of Washington.
Impacts/Benefits of Implementation (actual, or anticipated)	• The research team organized and delivered a webinar through the National Academies of Science, Engineering, and Technology, Committee on Geological and Geotechnical Engineering (COGGE). The webinar was entitled “Effective Utilization of State-of-the-Art Geospatial Technology for Geotechnical Investigations and Monitoring: The Future is Now.” Panelists came from industry, government, and academic backgrounds with diverse experience in geotechnical applications, including: Drs. Michael Olsen, Ben Leshchinsky, Chris Massey (GNS), and Zhangwei Ning (Sixense). This webinar explored examples of how geospatial technologies are used effectively in practice, the capabilities and limitations of the technology, and considerations for selecting which technologies are most suitable for a project. Work from this and prior PacTrans projects for slope monitoring were included. Over 500 people attended the webinar. A recording of the webinar is available at: https://www.youtube.com/watch?v=s7vfaCdn_fM. • Members of the research team held a trial all-day RAI training workshop hosted by ODOT in late 2021. Owing to restrictions for in-person meetings due to the COVID-19 pandemic, the

	event was held in a virtual format. Approximately 20 staff members from ODOT attended the interactive event. Presentation and activity topics included a review of the fundamental aspects of the RAI system and its associated input parameters, a discussion of RAI computer modeling and integration with software programs, and interpretation of RAI results and output, including identification and mapping of hotspots of rock slope activity. The ODOT training exercise served as a trial for an anticipated series of in-person training modules developed by the project research team. These modules will be targeted to the staff of DOTs, practicing engineers and geoscientists, and students in civil engineering and engineering geology. The workshop presentation materials are available upon request from the project team and will be continuously updated as additional training events occur.
	 Photograph of safety warning near the Nenana Canyon research site (photograph by M. Darrow).
Web Links • Reports • Project Website	Webinar recording: https://www.youtube.com/watch?v=s7vfaCdn_fM.