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U.S. Department of Transportation
Federal Highway Administration

FHWA Climate Resilience Pilot Program:

Alaska Department of Transportation and Public Facilities and Alaska Federal Land Management Agencies

The Federal Highway Administration's (FHWA)'s Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) in enhancing resilience of transportation systems to extreme weather and climate change. In 2013–2015, nineteen pilot teams from across the country partnered with FHWA to assess transportation vulnerability to extreme weather events and climate change and evaluate options for improving resilience. For more information about the pilots, visit: **http://www.fhwa.dot.gov/environment/climate_change/adaptation/**.

The Arctic climate is rapidly changing, and impacts to transportation from thawing permafrost, loss of sea ice, and changing precipitation patterns are already evident throughout the State of Alaska. The Alaska Department of Transportation and Public Facilities (ADOT&PF) and Alaska Federal Land Management Agencies tasked FHWA Western Federal Lands Highway Division (WFLHD) with performing a statewide vulnerability assessment. The study team chose three locations within the state to serve as representative case studies of specific transportation asset/stressor combinations. The three case study assessments utilized U.S. DOT's 11-Step General Process for Transportation Facility Adaptation Assessments for considering future climate vulnerabilities as part of engineering design to assess site vulnerability, identify feasible adaptation options, and assess their benefits and costs.

Scope

Due to the expansiveness of the state and range of climate impacts across Alaska, the project team used a representative case study approach to assess a set of three projects to highlight specific asset/stressor combinations:

1. **Dalton Highway.** This case study analyzed the potential impacts of thawing permafrost along Dalton Highway and assessed how such thawing could affect decisions about paving the roadway.
2. **Kivalina Airport.** This case study analyzed the increased risk of storm damage at an airport in the Native Alaskan village of Kivalina due to diminishing sea ice, which has historically protected the coastline when autumn coastal storms occur in the region.
3. **Denali Park Road.** This case study analyzed landslide risk along Denali Park Road in Denali National Park at the site of a recent slide. The study also analyzed the potential for increased risk associated with permafrost thaw and increased precipitation in the area.

A rock revetment in Kivalina, Alaska.
Photo credit: USACE

Frost on the Igloo Creek Landslide.
Photo credit: NPS

Existing roadway along the Dalton Highway.
Photo credit: ADOT&PF

Objectives

- Assess how changing climate conditions, both observed and anticipated, will impact the transportation system
- Identify how decisions are currently made on transportation projects in the state and how this process can be modified to bound future uncertainty
- Develop a process for incorporating climate uncertainty into future project engineering decisions
- Test the FHWA conceptual model and recommend improvements to FHWA

Figure 1: Kivalina's 2007 Revetment. Source: USACE

Approach

Each of the analyses followed U.S. DOT's 11-Step Process for considering future vulnerabilities as part of engineering design. Although the engineering design approaches identified in the study are hypothetical, the methodology of applying derived climate data to identify potential future scenarios of climate-related stressors can be applied to future engineering efforts on similar projects across the state. Highlights of two of the case study approaches follow.

Runway Exposure to Coastal Climate Patterns at Kivalina Airport

Assess coastal impacts from sea level rise. The assessment sought to determine whether projected changes in wind, sea ice, and sea level rise patterns associated with climate change would pose shoreline erosion risk to the facility and, if so, to develop and evaluate a representative adaptation option for managing that risk. In order to model climate change-driven erosion impacts to the airport, the study team used a cross-shore sediment transport model that incorporated water levels and wave action under storm conditions. Due to the study scope and limited data availability on ice extent, the analysis used one high-emissions climate change scenario (RCP 8.5), an ice extent model dataset, and projected winds information from the Scenarios Network for Alaska + Arctic Planning (SNAP). The study also incorporated land subsidence and uplift information to determine relative sea level rise. The study team then used a beach erosion model to determine erosion activity at the Kivalina Airport's beach during storm events when Kivalina is not iced in.

Identify and assess adaptation options. The study team explored various adaptation options to reduce airport damage, settling on a rock revetment as the most viable option. The study team conducted a lifecycle assessment of the cost of the structure, including accumulated capital repair costs. Using these costs and physical damage and socioeconomic costs, the study team conducted a benefit-cost analysis (BCA) of the revetment versus a baseline consisting of beach repairs to determine the cost-effectiveness of the adaptation option. To evaluate the efficacy of the adaptation option, the total discounted costs and benefits of the option were compared to calculate a net present value and a benefit-cost ratio.

Slope Instability from Permafrost Thaw and Intense Precipitation at Denali Park Road

Collect information on future permafrost thaw and impacts on slope stability. The study team collected climate information to understand the impact on slope instability from loss of permafrost, severe freeze-thaw cycles, and heavier rainfall events. Due to the uncertainty of

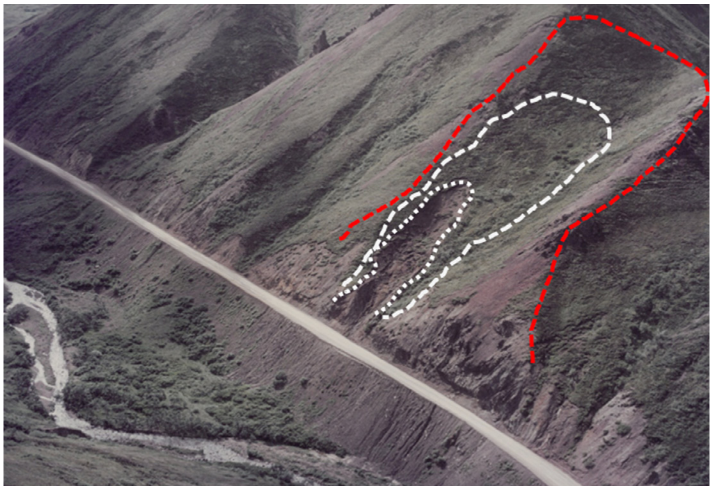

Figure 2: Aerial photo for the Park Road and site vicinity from 1996, prior to the 2013 Igloo Creek Slide. The white dotted line displays the extent of a slide that occurred in the late 1980s. The white dashed line displays the approximate extent of the 2013 Igloo Creek Slide. The red dashed line displays the study limits of the assessment. Source: NPS

the composition of the slope along the road and its response to climate variables, the study team developed several plausible scenarios that bound the range of likely future slide movements and levels of slide severity. The study team then estimated the time it would take to clear and reopen the road under each of these plausible scenarios.

Identify and assess adaptation options. The study team evaluated the effectiveness of feasible adaptation options, including revegetation, horizontal drains, a retaining wall, and a hardened protective structure. The team conducted a BCA of the different adaptation strategies to determine the most cost-effective protection measure under each plausible slide scenario over the 50-year analysis period. For each scenario, the damages under each adaptation option were evaluated against the baseline alternative (monitoring and cleanup after events). The differences between the damage costs that would have been experienced under the no-action baseline and those expected under the adaptation measure represent the net benefit of each adaptation strategy.

Key Results & Findings

The results of the Kivalina Airport and the Denali Park Road case study BCAs indicated the most cost-effective options.

Kivalina Airport. The analysis found that the effect of sea level rise on coastal water levels between the periods of 2011–2040 and 2071–2100 is 40 percent higher than the effect of storm surge due to winds and sea ice extent on water levels. Using the erosion model, this increased exposure would require a repair at the airport approximately once every ten years, on average, and would cost about $5 million per repair. The lifecycle analysis of the rock revetment adaptation option found that it would be most suitable to develop a 2.8 foot revetment through 2060 and enhance it to 3.9 foot rocks in 2061. The first revetment would cost approximately $38.9 million, and the second would cost another $27.9 million. However, the study found that the option is not cost-effective over the time period of analysis compared to the baseline alternative, and that the most cost-effective option under the single-storm event sequence is to pursue the baseline option of periodic beach repairs.

Denali Park Road. The study team found that near surface permafrost would decrease from 49 percent of the park during the first decade of the century to six percent by the 2050s and one percent by the 2090s, causing greater slope instability. According to the BCA, the only adaption strategy that produced a positive net present value and consistently high benefit-cost ratios was the revegetation option. This indicates that it is the most cost-effective of the scenarios and options considered.

Lessons Learned

Incorporating climate change conditions into engineering decision-making requires coordination between state agencies and research institutions. The multi-agency data effort was coordinated with representatives from SNAP and the University of Alaska Fairbanks to generate variables needed for decision-making, such as thaw rates for permafrost, failure scenarios for slopes, sea ice concentrations, and others. The study team found that the process for integrating climate data into engineering projects requires significant dialogue with study partners about specific assumptions and outputs of data models. This coordination will help accelerate the analysis process and will also help increase the availability of data related to transportation assets, such as environmental conditions, site conditions, construction assumptions, and maintenance information.

The case study approach provides transparency but requires buy-in from project partners. The study team found that the case study approach could be employed to assess future planning and design projects and allows for information to be presented to stakeholders interested in understanding how policy decisions are determined. However, the 11-Step Process is outside of normal engineering practice and requires significant commitment, coordination, and training among staff in order to successfully apply it.

Traditional BCAs should consider broader benefits of investments for smaller populations. Unlike other parts of the United States, transportation systems in Alaska require significant investments for the benefit of a small number of individuals. The significance of this commitment is not reflected in traditional BCAs, and therefore these assessments may need to consider broader factors of concern, such as social pressure, to reflect appropriate response measures.

Next Steps

The analysis and findings from the pilots will be used to inform how to incorporate climate uncertainty and economic factors into transportation design and decision-making processes. In addition, the project team expects to meet with transportation engineering staff in Alaska to discuss incorporating changing climate conditions into decision-making processes on other project types.

"These studies are forward-focused in how they approach project decisions, combining research and engineering best practices to determine an engineering response to challenges faced today while considering potential future events to ensure that those decisions reflect likely future conditions."

– ADOT&PF Pilot Team

For More Information

Final report available at:
www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/

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