Jump Starting a Geotechnical Asset Management Program

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  - Landslide Technology
What are we talking about?

• Transportation Asset Management (TAM)
  “Strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle” – AASHTO

• TAM for Bridges and Pavements is required, 
encouraged
for ancillary assets

What it means: No Federal directive or requirement … may be (likely?) considered optional by management
Why Apply TAM to Geotechnical Assets?

Trans Alaska Pipeline
Dalton Highway
Yukon R. Bridge
O&G accounts for 85% of State Revenue

Major Landslide
Why Apply TAM to Geotechnical Assets?
~7,546 MMS Geo Events Statewide
Why a Section-led Jump-Start?

• Failures cause frequent disruption & unplanned costs
• Top down directive is lacking – MAP-21, FAST Act doesn’t require (but encourages) ancillary assets
• Materials/Geotech still expected to know where GAM assets are and their condition
  – How many bridges does bridge manage… is ‘I don’t know’ acceptable?
• Risk analysis (safety, mobility, long-term costs)
• Permits budgeting, forecasting, informed decision making
• How Geotech/Materials will manage their assets
What you Want in the End

• Performance Measures
• Inventory and Condition Assessments
• Performance Measurement
• Rates of Deterioration
• Investment Models
• Condition Forecasting
What you Want in the End

“My Department has 5,000 geotechnical assets and 70% meet performance criteria. If we do nothing, in 10 years it will be 65% and will result in accumulated direct costs of $10,000,000 and indirect costs of $30,000,000. We’re forecast to have 8 road closures per year, growing to 9.

If we invest $2,500,000 per budget cycle, we’ll reduce unforeseen state expenditures by 50%, reduce forecast road closures to 7, and project that 75% meet performance criteria.”
Asset Condition

- Majority of inventoried rock slope square footage in Fair condition
- Majority of inventoried soil slope/embankment footage in Good condition
- Retaining walls inventoried in Ketchikan, Juneau, and Sitka largely in Good condition
Funding vs performance

- More funding gives better condition (as expected)
- 10-year fiscally-constrained condition targets based on expected funding allocated to slopes
- Computed from current condition, deterioration and cost models

For example, funding of $12.2 M/year is expected to yield 31% Good and 8% Poor
Where to begin – 5 Step Process

1. Identify Purpose and Need for GAM
2. Identify Existing Data
3. Identify Data Gaps
4. Acquire New Data
5. Improve Data Gathering and Analysis Tools
Where to begin – 5 Step Process

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Step 1: ID Purpose and Need

- **Agency Mission Statement**
  
  "To responsibly provide our customers the safest and most reliable transportation system possible, given available resources." – Maine DOT

- **Agency TAM Plan or Long Range Transportation Plan**

- **Section’s Own Responsible, Informed Decision Making and Planning**

- **Acceptance of ‘If you can’t measure it, it doesn’t exist’**

- **Are Geotech Assets Undermining or Supporting Goals?**
I-90 Failures

- MP 24 before/after
I-90 Failures

- MP 6.5 before/after
I-90 Failures

• MP 22 before/after
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Step 2: Identify Existing Data

• Unstable Slope Inventories (RHRS, RHRON, USMS, etc.)
• As-built inventories (Walls, Culverts, Subgrade Improvements)
• Maintenance (Management Systems, Job Activity Codes, Employee Recollections)
• Geotechnical Section Histories (Oral, Reports, Photo Files)
• Other Agency Data
Step 2: Identify Existing Data

States (black) with *some* rockfall rating systems, 2010
Data Formats

- Data formats – Excel, Access, Enterprise DB, GIS, Paper
Event DB Example: State Police Call-out Locations

ISP Calls to ITD to clean rocks off the road
Example: Maintenance Survey

<table>
<thead>
<tr>
<th>Questions</th>
<th>Answers</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rockfall History, please select one that best applies.</td>
<td>Few Falls: Rockfalls occur only a few times a year (or less), or only during severe storms. This category is only used if no rockfall history is available.</td>
<td></td>
</tr>
<tr>
<td>2. What appears to be the triggering mechanism of rockfalls? Check all that apply.</td>
<td>Rain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freeze/Thaw periods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wind</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water Erosion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other (Fill in comments box)</td>
<td></td>
</tr>
<tr>
<td>3. Would you describe the rockfall events as composed of single blocks or many blocks of different sizes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. What is the average and maximum rock block size?</td>
<td>Average size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum size</td>
<td></td>
</tr>
<tr>
<td>5. What is the average and maximum volume of rockfall debris in cubic yards per event? Enter a number only. (Not required for single block events)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Where do the rocks come to rest?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Have there been accidents or vehicle damage events due to rockfall?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. How many times a year is ditch maintenance required to remove rockfall debris? Enter a number only.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. A road patrol to check for rockfall debris on the road is required (check one):</td>
<td>Daily year round.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Daily during seasons/weather indicated in 1 and 2 above, as reported the rest of the time.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weekly during seasons/weather indicated in 1 and 2 above, as reported the rest of the time.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only as reported year round.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other (Fill in comments box)</td>
<td></td>
</tr>
<tr>
<td>10. From a maintenance perspective, how would you evaluate the rockfall problem?</td>
<td>A - Significant rockfall problem</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B - Moderate rockfall problem</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C - Low rockfall problem</td>
<td></td>
</tr>
</tbody>
</table>
Other Data Sources

• Estimated Mitigation Cost Databases
  – Montana (RF), Washington (RF/LS), Others?
• Bid Tabs for Average Prices and Inflationary Effects
• AASHTO ‘Red Book’ for User Costs
• Accident causation records (limited)
• ‘Borrow’ risk analysis parameters from states with similar geology and network, if they’ve got them
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Step 3: Analyze Data and Close Gaps

- Address TAM Compatibility
- Formulate Derivative Condition Measures
  - Criteria that worsen in absence of maintenance/mitigation
- Compare Condition to Other Records
  - Maintenance costs, adverse events, mitigation costs, risk
  - Determine/Formulate Relationships
**Example: Condition v. RHRS Scores**

<table>
<thead>
<tr>
<th>Cond. State</th>
<th>Condition Index Range</th>
<th>Analysis of MDT RHRS Values by Condition State Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High  Low</td>
<td>Average RHRS Score</td>
</tr>
<tr>
<td>1, Good</td>
<td>100  80</td>
<td>227</td>
</tr>
<tr>
<td>2, Fair</td>
<td>80   60</td>
<td>289</td>
</tr>
<tr>
<td>3, Fair</td>
<td>60   40</td>
<td>330</td>
</tr>
<tr>
<td>4, Poor</td>
<td>40   20</td>
<td>427</td>
</tr>
<tr>
<td>5, Poor</td>
<td>20   0</td>
<td>597</td>
</tr>
</tbody>
</table>

### RHRS vs Condition Index

![Graph showing RHRS vs Condition Index](image-url)
### Example: Condition Relation v. Mit. Cost

**Condition State vs. Mitigation Cost per Square Foot of Rock Slope Face**

<table>
<thead>
<tr>
<th>Condition States Improved</th>
<th>Cost per sq ft</th>
<th>W/ OH Costs (105%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$3.56</td>
<td>$7.30</td>
</tr>
<tr>
<td>2</td>
<td>$7.12</td>
<td>$14.60</td>
</tr>
<tr>
<td>3</td>
<td>$10.68</td>
<td>$21.90</td>
</tr>
<tr>
<td>4</td>
<td>$14.24</td>
<td>$29.20</td>
</tr>
</tbody>
</table>

- **Mitigation Cost** vs **Condition State**
- **Average Cost** vs **Average Condition State**
- **Mitigation Cost Trendline**
### Example: Condition v. Event Occurrences

#### Analysis of MDT District 1 Survey Data by Condition State Group

<table>
<thead>
<tr>
<th>Cond. State</th>
<th>Reported Annual Events (closures and slowdowns)</th>
<th>Inventoried Square Footage</th>
<th>Likelihood per sq. ft. of rock slope face</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, Good</td>
<td>0</td>
<td>1,891,759</td>
<td>1.19E-08*</td>
</tr>
<tr>
<td>2, Fair</td>
<td>0.39</td>
<td>8,262,371</td>
<td>4.75E-08</td>
</tr>
<tr>
<td>3, Fair</td>
<td>2.14</td>
<td>5,461,018</td>
<td>3.91E-07</td>
</tr>
<tr>
<td>4, Poor</td>
<td>3.86</td>
<td>3,060,990</td>
<td>1.26E-06</td>
</tr>
<tr>
<td>5, Poor</td>
<td>0.57</td>
<td>282,968</td>
<td>2.02E-06</td>
</tr>
</tbody>
</table>

* CS-1 Likelihood estimated from CS-2 likelihood and engineering judgement

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#### Condition State vs Event Likelihood

![Condition State vs Event Likelihood Graph](#)
Example: Expert Elicitation

• Structured Inquiry of Specialist’s Experience & Judgement
  – Example: You have 100 Condition State 1 slopes. How many years until 50 of them have deteriorated to CS 2?
    • 35, 20, 75, 45, 30, 25 years…Consensus of 38.3 yrs
  – Same question for CS 2 deteriorating to CS 3 and so on.
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Step 4: Acquire New Data

- Fill the Gaps
  - Improve Event, Cost, Closure, Consequence Tracking
  - Complete Inventory & Condition Assessments
  - Determine Condition Assessment Intervals
  - Update Sites when Altered
- Improve/Refine Relationships
- Additional Analyses, Confirm Expert Elicitation
Step 4: Acquire New Data

• Explore Additional Data Gathering Techniques
  – Change Detection (Mobile LiDAR, Photogrammetry, etc.)

• Adjust Performance Measures to Event Frequency, Detected Changes

• Consider Additional Evaluation Criteria
  – Rock Mass Rating, Geologic Strength Index, Instrumented Landslides, Displacement Rates

• Build it into your Design Criteria
  – Target Condition State
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Step 5: Improve Data Sharing & Gathering

- Clear Communication
  - Planners will ask ‘What else can we do on this project’ rather than ‘There was no indication that work was needed’
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- Clear Communication
  - Planners will ask ‘What else can we do on this project’ rather than ‘There was no indication that work was needed’
  - MAPS!
Inventory – Soil Slopes & Embankments
Step 5: Improve Data Sharing & Gathering

• Clear Communication
  – Prepare Easy-to-Follow Explanation of the Program
US-26 Swan Valley Geotechnical Investigations

Executive Summary

Purpose
The goal of this project was to create a comprehensive geotechnical asset dataset for the US 26 corridor from the Swan Valley Bridge to the Wyoming border. The assets investigated in the field included cut slopes, rock slopes, and embankments. From these assessments, a geodatabase was generated compiling site-specific information and site photos. Web-based applications make the results accessible to various users. Geotechnical hazards and their potential impact on the highway are described and illustrated for managing these assets and for planning future highway improvements.

Methods
Data compilation began with reviewing and compiling previous subsurface investigations, available geo-spatial datasets, and geotechnical and roadway information supplied by ITD. Geotechnical investigations of landslides, rockfall, and embankments within this US 26 corridor section were systematically documented and entered into the geodatabase. Hazard condition assessment and risk evaluation frameworks were developed to identify specific site data to be obtained during the investigations and subsequent analyses. Attribute data was appended to spatial data in order to complete the final asset geodatabase.

Results Summary
From the information gathered, the geodatabase was transferred to an online ArcGIS platform. This resulted in a user-friendly, easy access product that not only ITD officials use, but also other agencies and public stakeholders. Due to this online application, the contents can be updated in the future, creating a living database and planning tool.

Recommendations for Improving the Geotechnical Planning Tool
Step 5: Improve Data Sharing & Gathering

• Data Tracking Tools
  – Geotechnical Event Trackers
    • ArcGIS Based
    • Paper Based
    • Email w/ photos
Data Entry Form

Unstable Slope Event Data Entry

Fill out all the information you have on the unstable slope event below. Failures would incorporate individual rockfall and landslide events, regardless of road closure. Costs are typically as contained in the UMS system. For sites assessed directly from the UMS system, and only events that can be assigned to a single location of less than one mile post range.

For categories that require additional information or have documents available, please attach appropriate files at the end of the form.

1. Enter Information

- Event Date
- Event Type
- Landslide or Rockfall: Landslides encompass all unstable soil slopes including debris flows, earth flows, and earthslide failures.
- Soil Type
- Event Type
- Avalanche, Debris Flow, landslide, Shrubfire, Tree Fall, Rockfall, Freestones, Alligator Cracking
- Rockfall - Largest rock size (ft)
- The largest rock associated with the event. Enter an integer only.
- Rockfall Event - Event Volume (cu)
- The volume (cu) of rock associated with the event, contained in the ditch or on the road. Enter an integer only.
- Landslide Event - Size (ft)
- Length of the road affected. Enter an integer only.
- Landslide Event - Volume (cu)
- Volume of debris on road. Enter an integer only.
- Event - Lanes Affected

2. Select Location

Specify the location for this entry by clicking/tapping the map or by using one of the following options.

3. Complete Form

Add this information to the map.
Step 5: Improve Data Sharing & Gathering

• Performance Dashboard

Rock Slope Condition State
- POOR: 10%
- FAIR: 24%
- GOOD: 69%

Soil Slope Condition State
- POOR: 21%
- FAIR: 17%
- GOOD: 59%

Retaining Wall Condition State
- POOR: 4%
- FAIR: 10%
- GOOD: 87%

Mobility
- Track in-city bus ridership: 234,831
- Track bicycle volumes: 95.9
- Increase streetcar ridership: 51.3
- Track pedestrian volumes: 42.2

Roads
- Repair potholes quickly: 98%
- Improve arterial street conditions: 64.3%

Safety
- Achieve zero traffic fatalities by 2030: 176
- Reduce employee illness and injury rates: 64
Closing
Closing

• Get Started!
• Be Comfortable with Network-Level Approach and Generalities
• Use the System as a Decision-Support Tool
• Engage Planners & Designers to Improve Fair Sites with other Projects
• Include GAM in TAM Plans