Geotechnical Asset Management: Challenges and a Framework for Homogeneous Performance Assessment

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Applied Research Associates, Inc.

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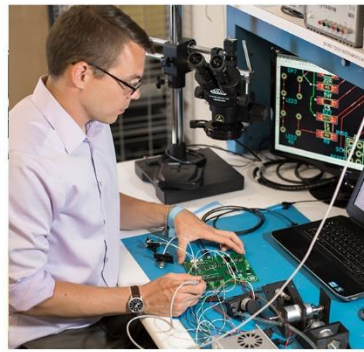
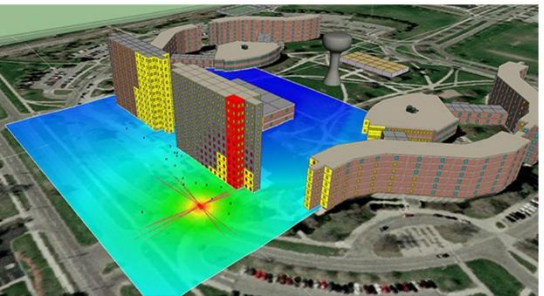


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Transportation (Infrastructure) Asset Management

- Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively.
- It combines engineering principles with sound business practices and **economic theory**, and it provides tools to facilitate a more organized, logical approach to **decision-making**.

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Where does TAM stand?

- The focus has been on pavements and bridges for the physical assets.
  - What about other assets?

- Transportation Asset Management Plans (TAMPs) should include the following:
  - **Asset Inventory and Condition**
  - Life Cycle Planning
  - Performance Assessment
  - **Risk Management**
  - Financial planning and investment strategies

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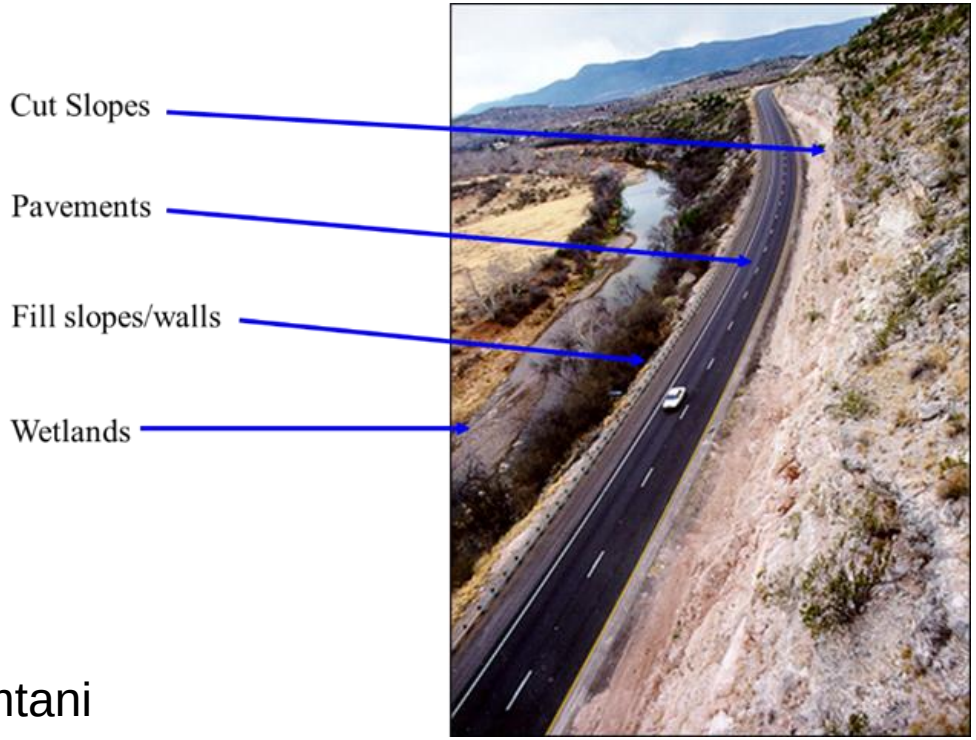
Which Geotechnical Assets?

- Geotechnical assets can include earth retaining structures, embankments, slopes, foundational elements, tunnels, culverts of other transportation assets.
- The term geotechnical feature could apply to all infrastructure features constructed on, in, or of soil and rock [NCHRP 20-126(3)].



Source: Naresh Samtani

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Benefits of GAM

- Geotechnical assets have typically been handled as permanent assets with unlimited service life.
- Experience shows that these assets degrade overtime leading to serviceability and other limit state failures (strength and extreme) that cause major injuries, property losses, service interruption, and economic burdens on agencies.
- Geotechnical Asset Management (GAM) programs reduce life-cycle costs, reduce performance and operational disruptions, and lead to fewer emergency stabilization projects.

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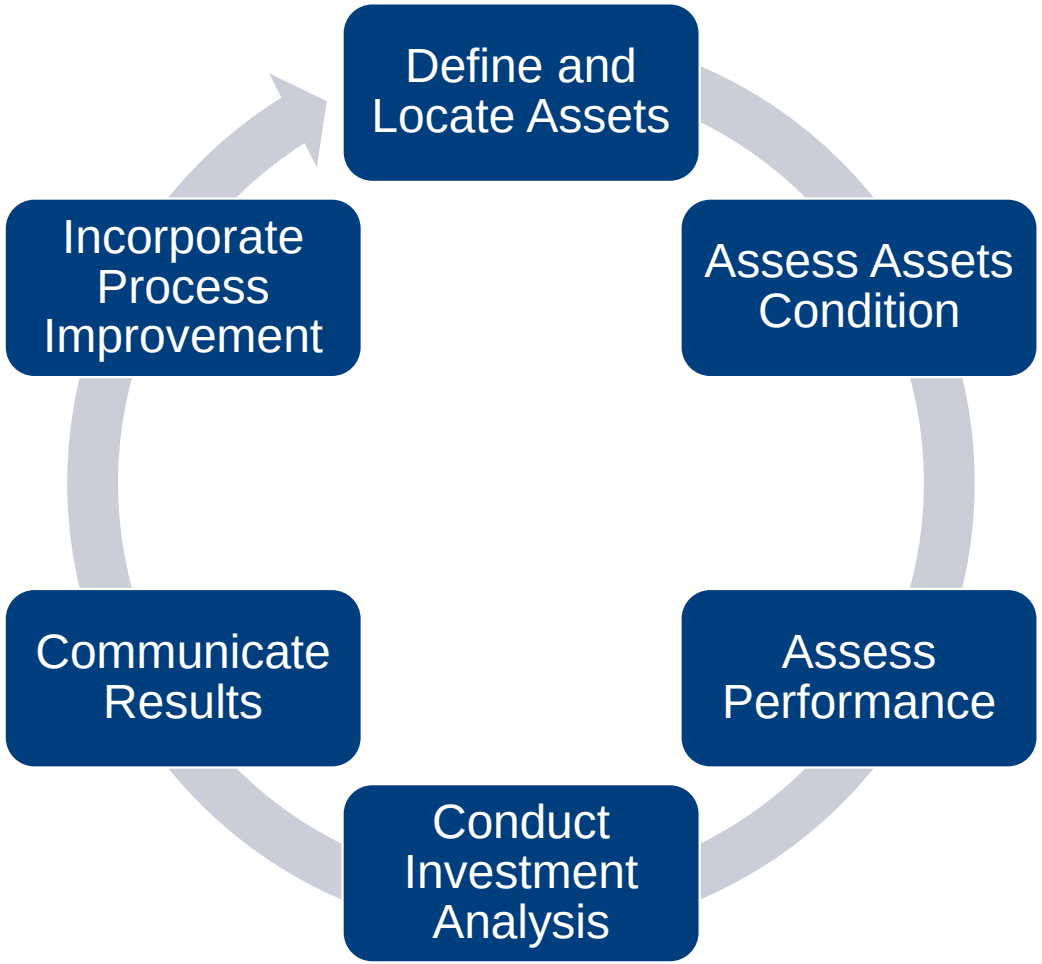
The GAM process

- GAM includes several components and the agencies' focus can vary.
- Generally, a GAM program includes multiple steps and requires an iterative and cyclic to improve and refine the program throughout its implementation.



Implementation steps, NCHRP Project 24-46

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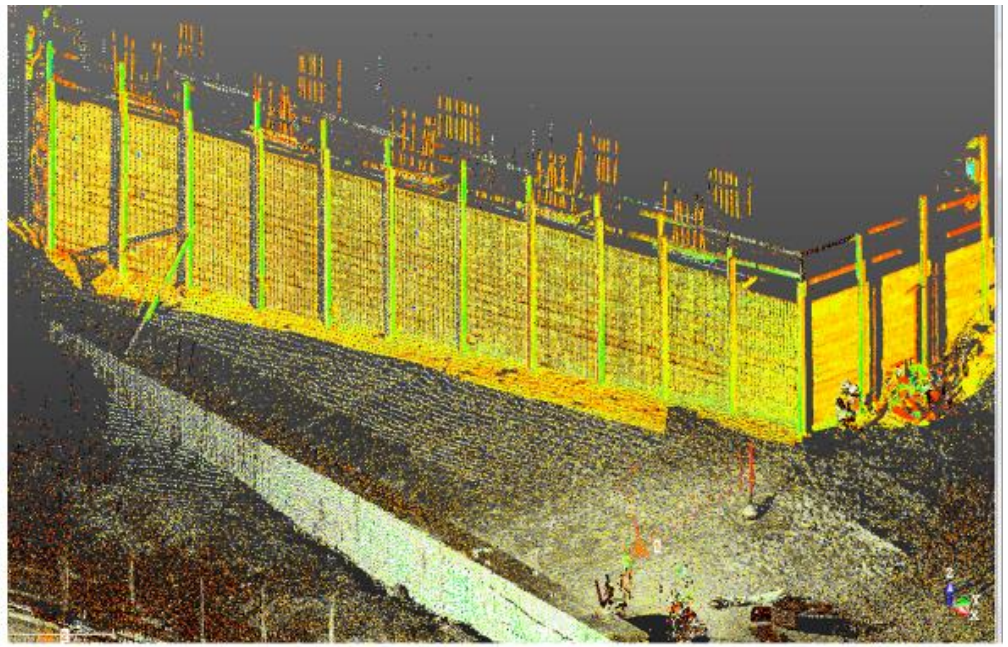
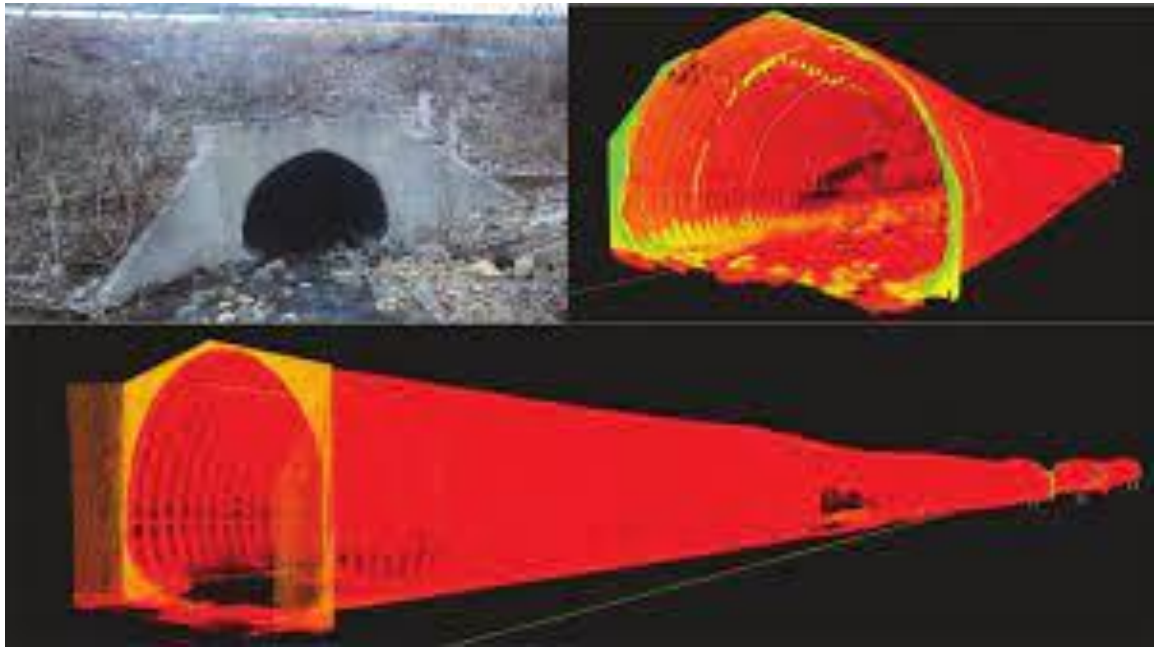
Asset Inventory and Condition: Defining and Locating Assets

- Need to identify the asset type and the size of the assets to be included in a GAM.
- Currently, most agencies do not have the assets in a single database.
- Remote sensing, geophysical technologies, and other sensors can facilitate the process.



A Alhasan, MP McGuire, PKR Vennapusa, DJ White. (2016)



Mickel, H. B., & Hagert, J. R. (2016)

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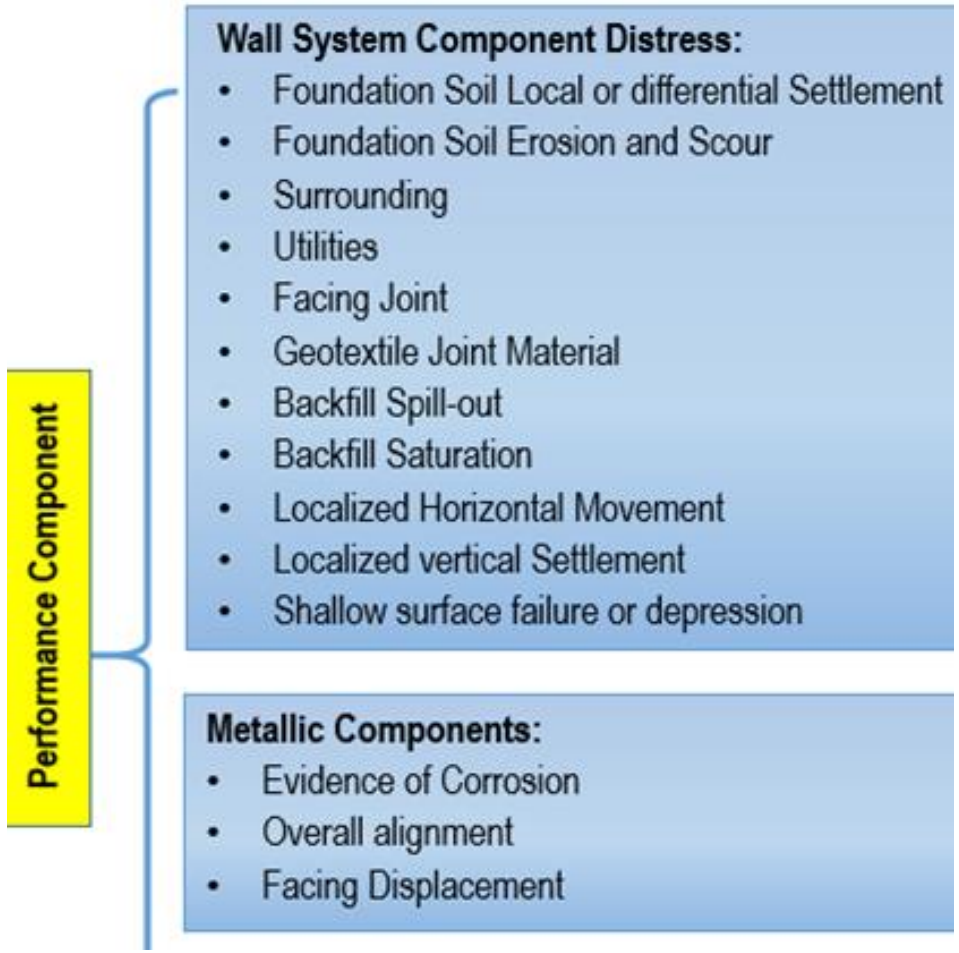
Asset Inventory and Condition: Assess Assets Condition (1 of 2)

- Unlike other transportation assets such as pavements and bridges, geotechnical assets do not have clear definitions of homogenous condition indices or measurements.
- Condition assessment has mainly focused on the ultimate limit state.
- Homogenous Performance metrics should account for ultimate and serviceability limit states.



Example of performance assessment framework for MSE walls

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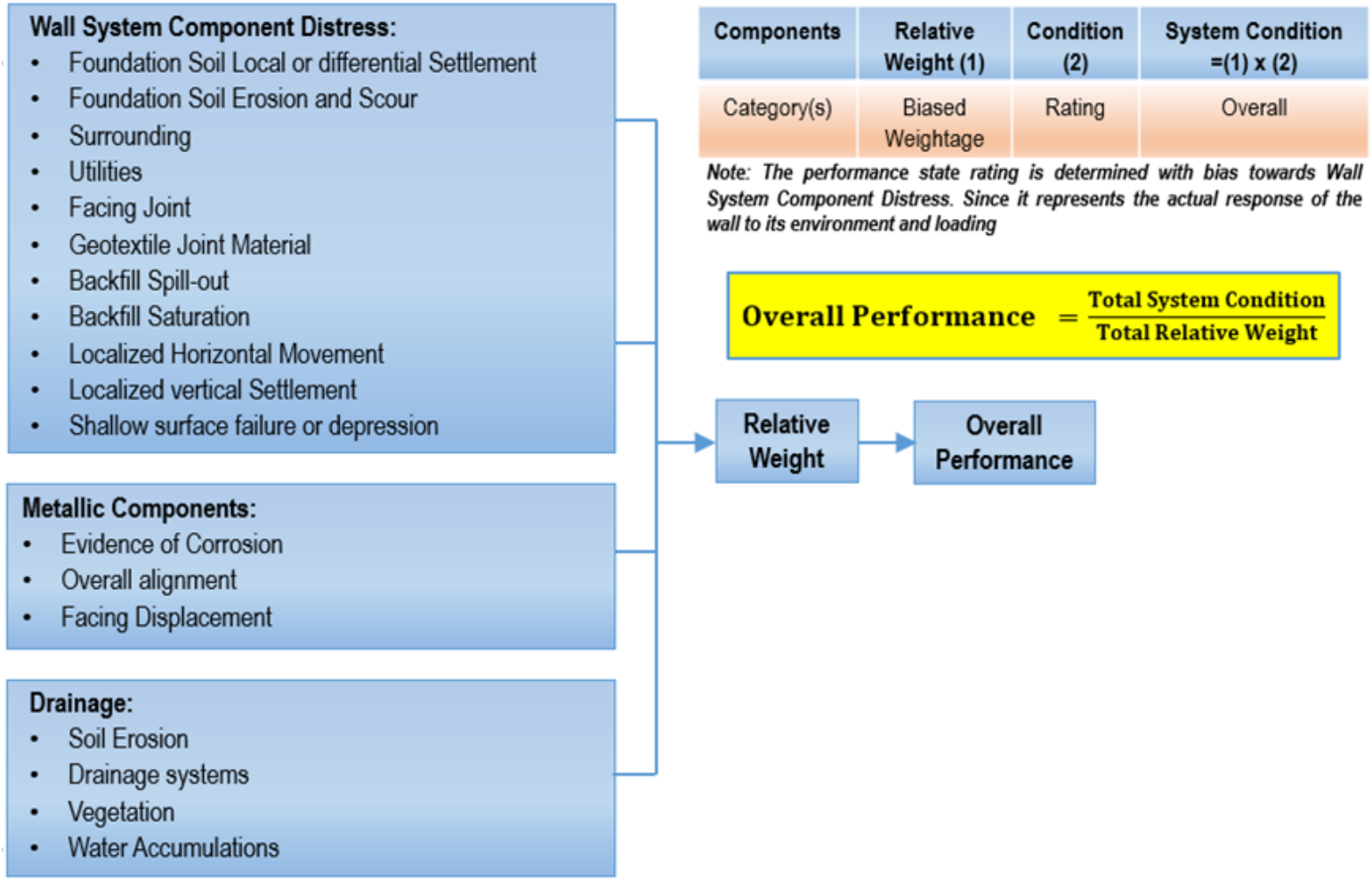

Example of performance assessment framework for MSE walls

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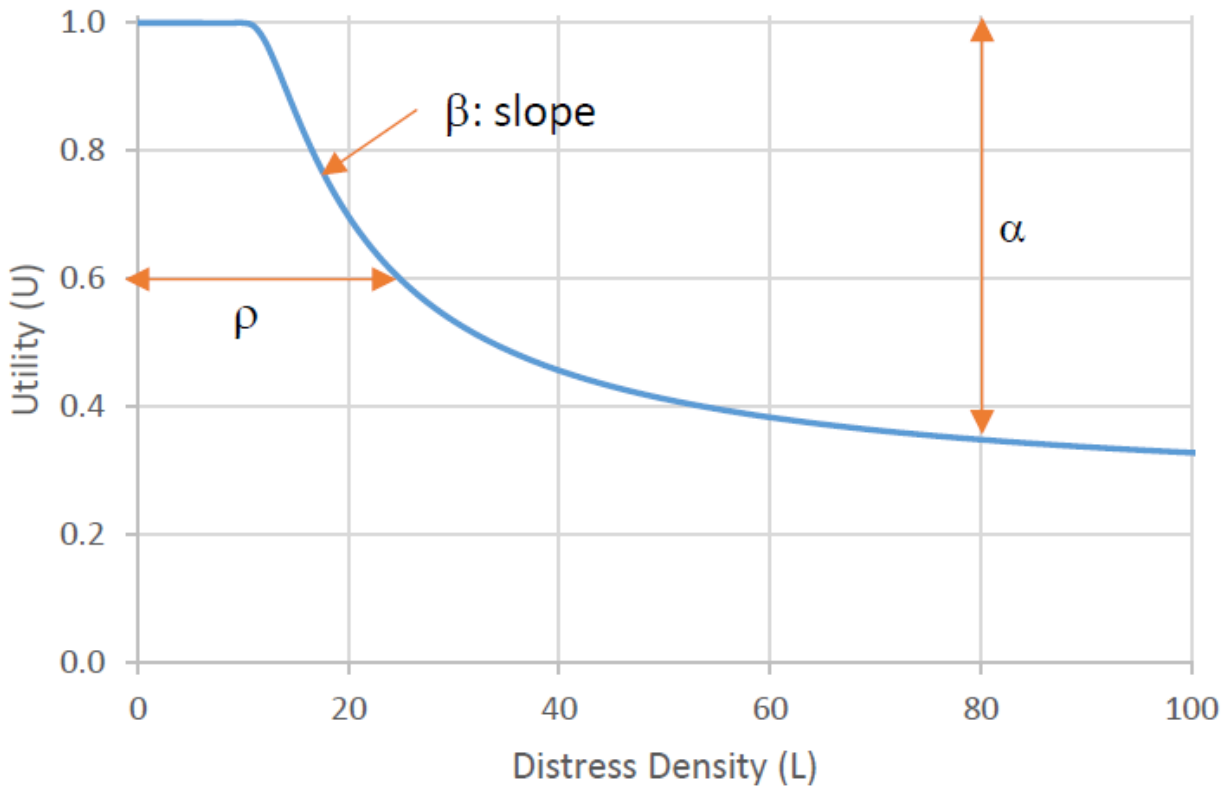
Asset Inventory and Condition: Assess Assets Condition (2 of 2)

- There are different analytical techniques used for other transportation assets to develop a condition index.
- One approach is utilizing the utility theory; where each distress has a utility curve indicating how bad is a distress based on its impact on limit states.
- Other techniques can include the deduct value methods: start with the maximum possible value and define deduct points based on distresses.



General shape of utility curves used for computing TxDOT pavement performance indices (Bektas, Smadi, and Al-Zoubi, 2014)

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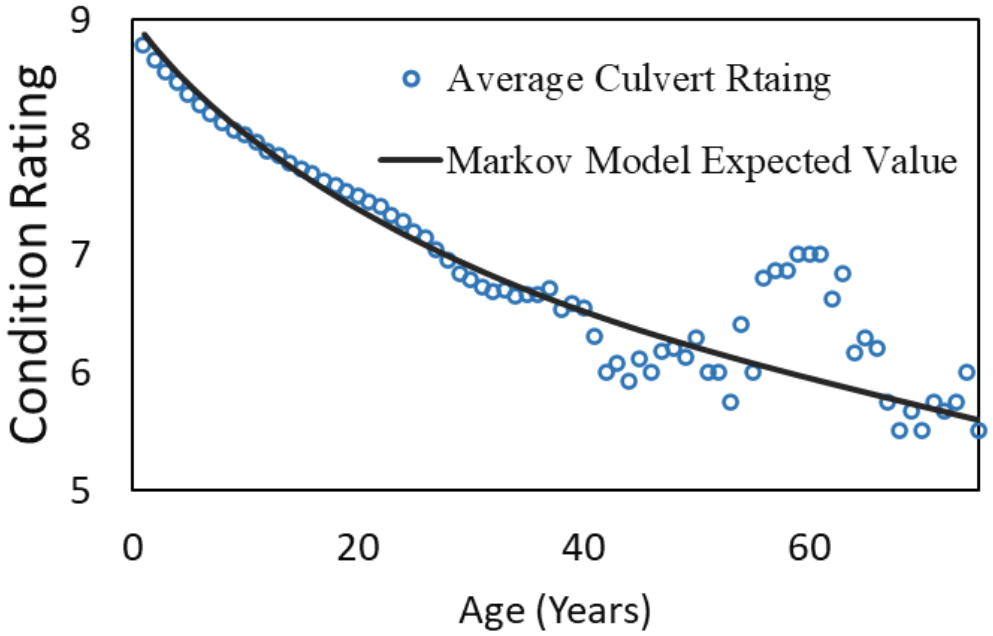
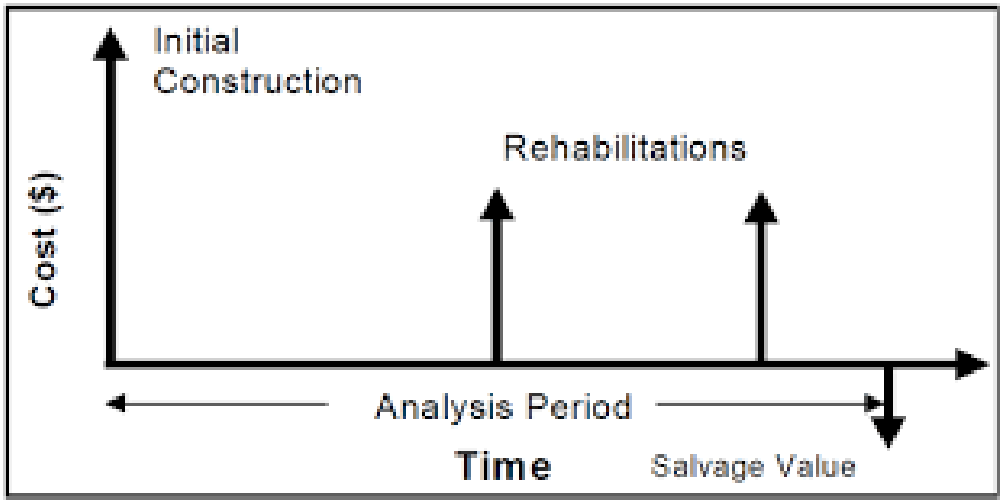
Assess Performance: Life Cycle Planning

- Performance at individual asset level includes a time component.
- Deterioration models can be deterministic or probabilistic.
- Life cycle cost analysis is important for proper economic analysis and investment strategies.





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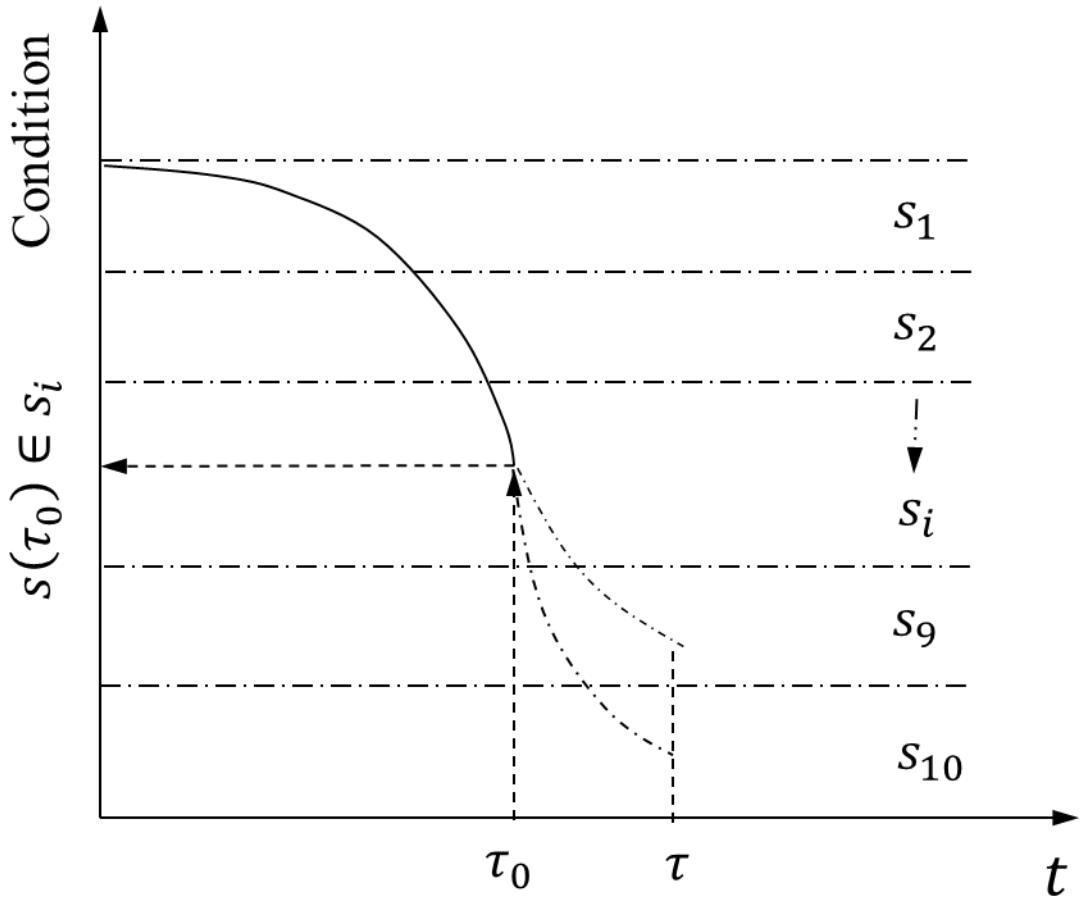
Assess Performance: Back to Condition and Performance

- Remaining service life uses the same measurement units for different assets.
- Remaining service life can help defining the utility/deduction and accordingly homogenous condition index.
- Condition states are a discretized scale on the condition indices range.
- Condition states are important to summarize the overall condition at the network level and for investment strategies.



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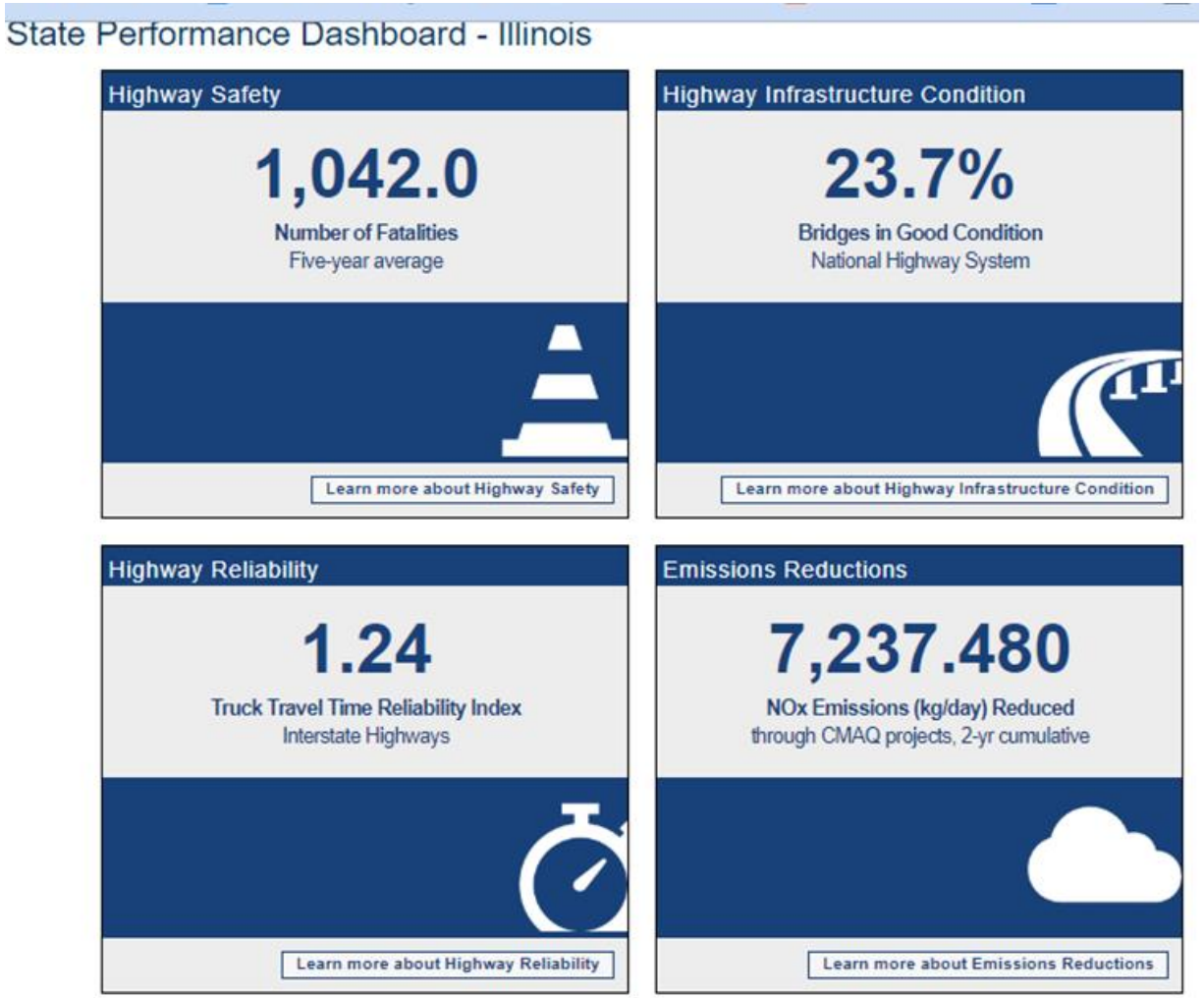
Assess Performance: Network Performance Assessment

- Performance of individual constitutes performance at network level.
- Typically, future performance at network level is estimated holistically based on average performance.
- Due to the heterogenous nature of geotechnical assets, the holistic approach may suffer from major limitations.



Performance Dashboard for Illinois

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Risk Management as an Integral Part of GAM

- Risk management, has been commonly handled as a separate parallel process to the other TAM components to estimate the overall risks due to extreme events and agency risks to implement TAMPs effectively.
- In many cases, except for few specialized applications at project level, agencies use qualitative risk management.
- Risk and uncertainty are inherent attributes of geotechnical assets and their performance throughout their service life.
- Risk management has been an integral part of the reliability-based design methods (i.e., LRFD in the US).

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Risk and Uncertainty

The effect of uncertainty on objectives		
Effect	**Uncertainty**	**Objectives**
Positive *or* **Negative**	**Always** in the future May or may *not* happen	**Know** what you are trying to achieve **Apply** to organization, program, or project

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The Two Flavors of Risk Management

Qualitative

- Subjective evaluation of probability and impact
- Quick and easy to perform
- Dependent on expert input
- May lead to an overall biased description of the future

Quantitative

- Probabilistic estimates of future condition and cost
- Dependent on quality data availability
- May require specialized skills*
- Measurable on the long-term

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Uncertainty Decomposition

Categories

- Measurement Uncertainty
- Model Uncertainty
- Inherent Process Variability
- External Effects Uncertainty

Examples

- Funding Uncertainty
- Performance Uncertainty
- Project Execution Uncertainty

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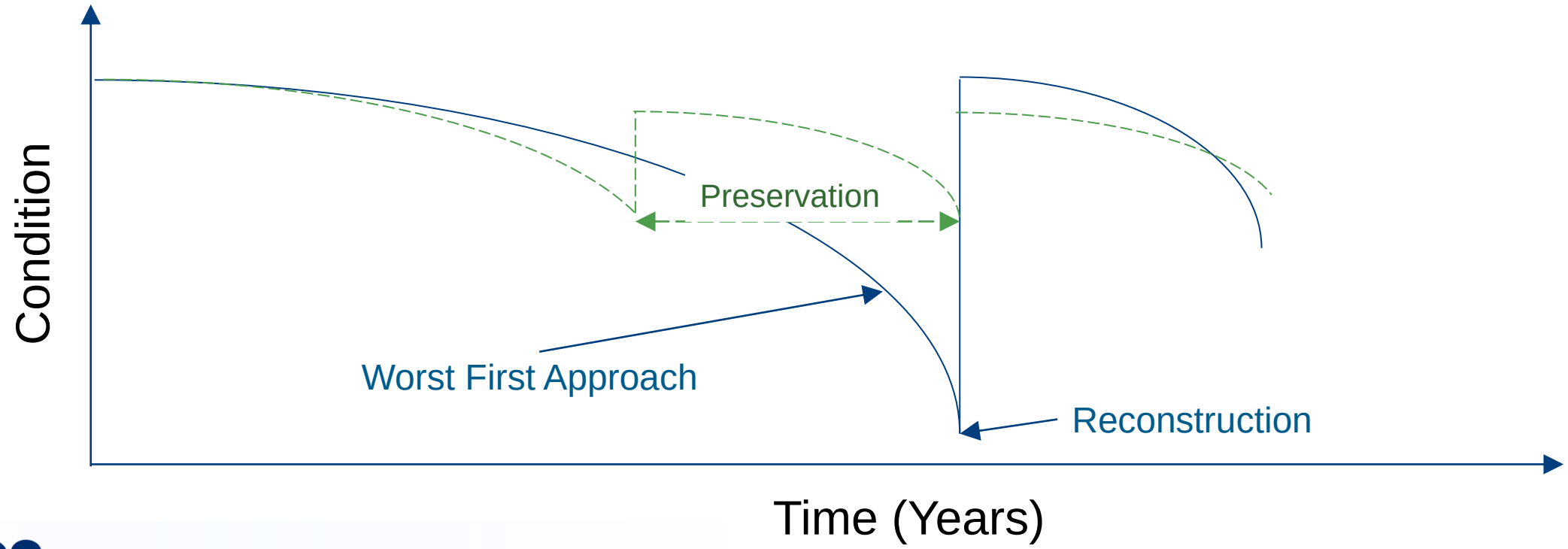
Conduct Investment Analysis : Financial planning and investment strategies (1 of 3)

- Investment strategies and financial planning builds on all previous components.
- There are several important factors:
  - Benefits accrued from maintenance and repair programs



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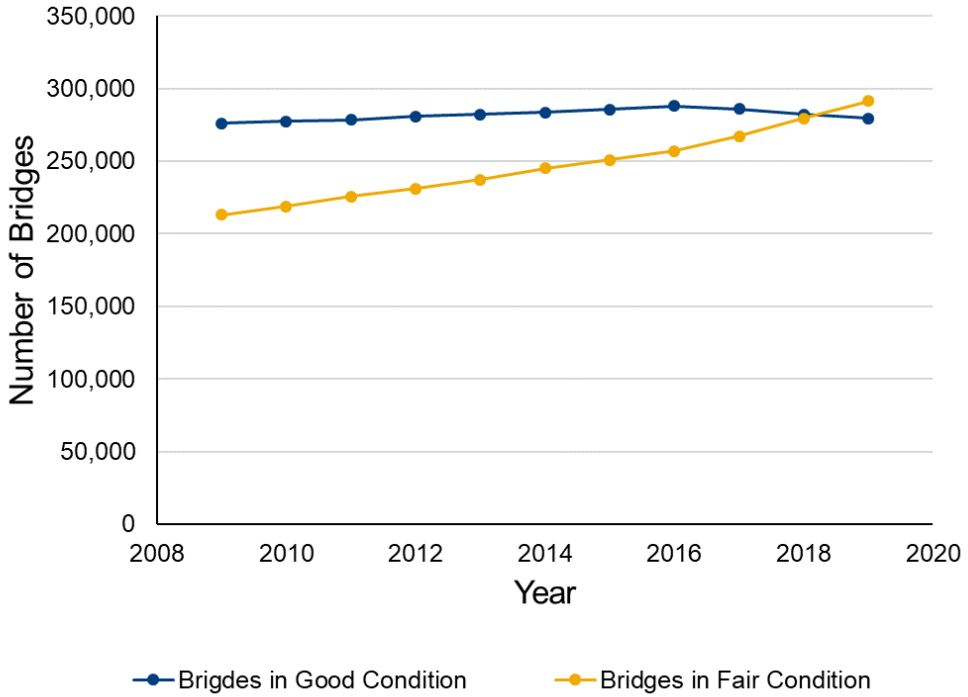
Conduct Investment Analysis : Financial planning and investment strategies (2 of 3)

- Investment strategies and financial planning builds on all previous components.
- There are several important factors:
  - Benefits accrued from maintenance and repair programs
  - Comparing scenarios



Source: U.S. Department of Transportation, Federal Highway Administration, InfoBridge:
Data: https://infobridge.fhwa.dot.gov/Data/Dashboard

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Conduct Investment Analysis : Financial planning and investment strategies (3 of 3)

- Investment strategies and financial planning builds on all previous components.
- There are several important factors:
  - Benefits accrued from maintenance and repair programs
  - Comparing scenarios
  - Setting targets (with measurable units) and budgets over a time horizon

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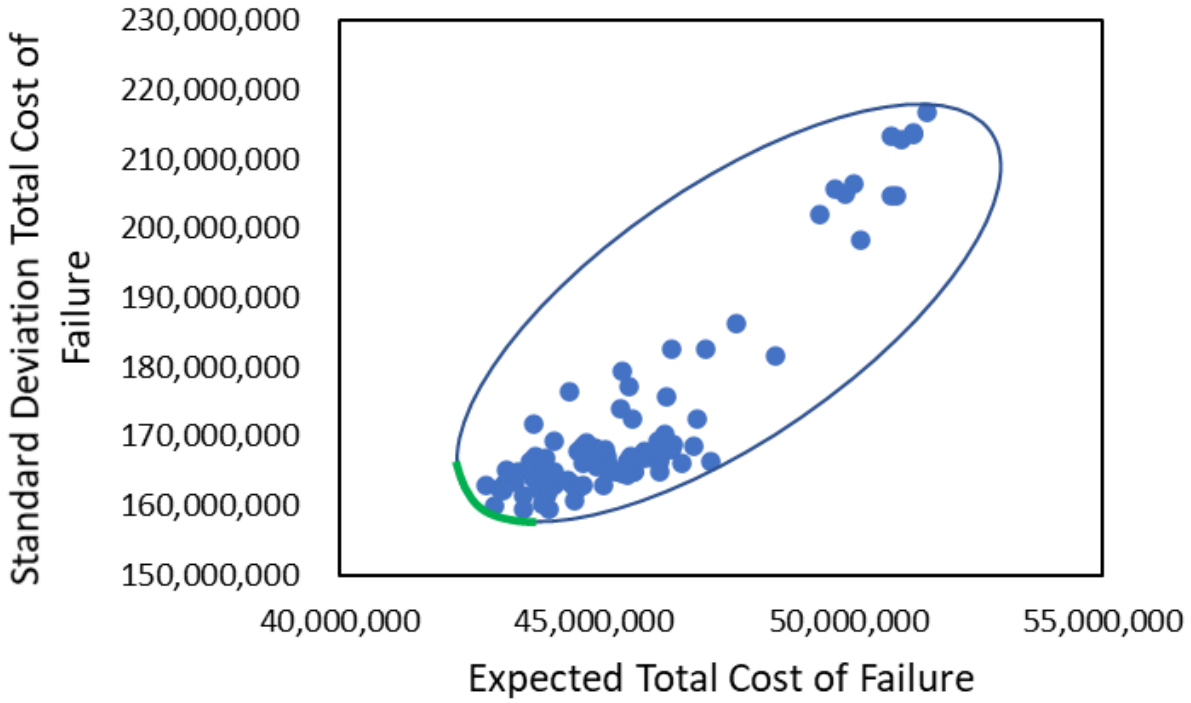
Conduct Investment Analysis: Using Risk and Return

- Incorporating uncertainty in investment strategies and financial planning provides greater insights to alternative scenarios.
- Provides several alternatives and can incorporate multiple sources of risk including, but not limited to contractor and material availability and scheduling.



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Communicate Results

- Cannot emphasize enough how important is communication and coordination.
- GAM program serves multiple groups and a wide range of purposes.
- Summarizing data-driven findings properly are the most critical to support decision makers.
- Understanding the challenges with the decision-making process is critical to have a realistic decision support tools

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Incorporating Process Improvements

- A proactive GAM program should include an assessment procedure of benefits over time.
- Strategies and models should be revaluated over time.
- Develop dynamic models that update as more observations and data are available.
- Formal gap analysis is vital after a sufficient period of monitoring.

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Remarks

- GAM programs are at a very early stage and still not considered by all agencies.
- GAM is a tool to improve planning and should not be considered as a burden.
- There is a lot to be learned and improved from other established TAM programs.
- Geotechnical assets are unique due to their heterogeneity and their uncertainty should be handled properly through robust models and techniques.

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