B.2.6 Cross-asset optimization

Overview

Cross-asset optimization (CAO) is a tool to help agencies allocate resources across asset classes. Traditionally, resources are allocated based on precedent and/or engineering judgement. This approach is likely sub-optimal in that decision making is exposed to the biases of decision makers and precedents may be outdated and not representative of contemporary priorities.

Modern CAO tools typically use a Delphi approach and/or a multi-objective decision analysis (MODA) approach.

In a Delphi approach, resource allocation decisions are made by a committee of agency decision makers and experts (either internal to the agency or from a third party) from different subject areas. The approach uses an iterative process to forecast outcomes of different resource allocation decisions and then refine decision making until a consensus is reached.

A MODA approach has many similarities with multiple-objective optimization approaches (see the Multi-Objective Optimization Tool). Optimal resource allocation decisions can be identified considering multiple interrelated and/or conflicting objectives. The MODA approach can be conducted in a top-down or bottom-up fashion.

In a top-down approach, program level trade-off analysis is conducted to identify funding levels based on how each asset or program will respond to a given funding level. The responses (i.e. performance) are used to create response curves, showing performance measures as a function of the funding level. Projects are then prioritized based on the level of funding available for that asset and the ability to satisfy the goals identified for that asset or program.

In a bottom-up approach, a set of projects are selected from potential projects spanning all assets, which maximize the overall measure of performance (i.e. utility). The trade-off analysis is conducted at the project level. Unlike the top-down approach, there are no direct results showing the implications of the level of funding applied to an asset class. This approach can have technical challenges associated with developing robust and universal algorithms and the collection of quality data.

Characteristics

	Low	Med	High	Unable to assess
Effectiveness	☐	☐	☑	☐
Data needs	☐	☐	☑	☐
Required level of expertise	☐	☐	☑	☐
Effort for implementation	☐	☐	☑	☐
Overall performance	☐	☐	☑	☐

Key sources

- Spy Pond Partners (2019)
- Bryce et al. (2018)
- Porras-Alvarado et al. (2016)
- Maggiore & Ford (2015)
- Fwa and Farhan (2012)
- Geiger et al. (2005)

Both approaches can provide insight into how projects or asset classes can perform at different funding levels, how projects can affect multiple objectives and how projects can have different effects when combined with each other.

Agencies can implement the following framework, which uses similar themes to the MODA approach but leans toward a more finance-oriented perspective:

- *Use the agency's goals and objectives to guide its priorities* – The framework begins with strategic planning, including goals, resource allocation philosophy and objectives which govern the operation and performance measurement of agencies.
- *Categorize various assets* – In this step, assets are identified in terms of a physical asset class, asset ownership and other relevant information (e.g. urban versus rural, functional class, traffic volume, usage type).
- *Develop performance metrics to evaluate progress toward goals and objectives and assess performance* – The objective is to evaluate the condition of the infrastructure system, to generate an overall score for each of the assets being analyzed. An asset performance prediction model is essential for predicting asset value conditions in the future. As part of this step, performance-funding relationships should be developed and used to measure the effects of funding levels on overall condition scores for each asset. Transportation agencies can use historical funding and performance data to develop and calibrate the asset performance models.
- *Apply decision science (the approach that guides the selection of alternatives through weighting, scaling, scoring, prioritization and optimization techniques) to score differing projects on a level playing field* – Selection is optimized based on the relative importance of benefits to the decision maker, often based on the expected value of a project per dollar spent.
- *Conduct trade-off analysis to refine scenario planning and to compare priorities with fiscal constraints* – Optimization accounts for fair allocation of budget to investment categories in relation to the total available budget. In a transportation asset management decision-making context, there are often multiple objectives that need to be achieved and fair allocation is important. In general, there are three categories of equity that should be considered in transportation funding allocation: rate of return, performance and need:
  - *Rate of return* – Programs should receive the same percentage of resources as they contribute.
  - *Performance* – This is concerned with the allocation of resources between programs or districts that differ in performance or condition. Funding allocation policies are considered equitable if they favour conditionally disadvantaged programs, therefore compensating for overall inequities.
  - *Need* – This concept is used to support allocation based on demand, which means that resources should be allocated according to the actual needs of different programs or districts.

Advantages

- Considers performance against multiple, diverse, potentially interrelated and/or conflicting objectives
- Compares overall impact of projects in different asset classes
- Illustrates how different levels of funding enable or hinder the achievement of policy goals
- Identifies trade-offs present at various funding levels

Disadvantages

- Requires careful definition of optimization functions, which can be difficult when many variables exist
- Complex optimization function definitions can make it difficult for stakeholders to understand the analysis
- Reliability of evaluations depends on how accurately project impacts are assessed against each criterion
- Requires subject-matter experts from many fields

Examples of available software

The following software programs were identified through the literature review but have not been evaluated as part of this study. Practitioners interested in applying any of these software packages are encouraged to investigate their effectiveness prior to application.

Asset Optimizer. Cloud-based software-as-a-service (SaaS) application accessible from a web browser. Algorithms generate risk-based, system-wide multi-year asset renewal plans. Optimization settings can be tweaked to maximize network-level condition improvement, minimize risk, or minimize life-cycle costs. Output can help users to assess how funding levels and investment strategies impact risk at the level of individual assets, asset classes and the entire system.

Cross-Asset Resource Allocation Tool. Spreadsheet or web-based tool initially developed as part of an NCHRP project, allowing users to set weights for various objectives and optimize resource allocation based on scoring.

AgileAssets. Asset management software for planning and analysis, as well as operations management. Includes functions for internal rate of return on investment, trade-off analysis and cross-asset optimization and can consider transit assets including vehicles, stops, garages and other facilities.