How Optimization Works in Enterprise Asset Management

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Why We Need Optimization

With tight operational budgets and limited resources, making the most of your available funds is a top priority. Optimization helps you do just that: get the greatest benefits from your project investments.

For years, organizations have been reasonably successful at managing their assets with the resources available to them. But funding limitations and other constraints have led organizations to find new ways to make better asset lifecycle management decisions and trade-offs.

This guide shows how traditional approaches such as a simple ranking or a cost-benefit analysis may not lead to the best decisions to get the most asset value for your available funds. Instead, only true optimization analysis provides a consistently reliable way to identify the best choices for investing available funds to meet your organization's performance goals.

How To Use This Guide

This guide provides a simple explanation of how optimization works. You'll find:

- **Visualizations and Comparisons**

  Simple examples that show why optimization is better than other approaches to solving common problems. (Jump to pages 4–12.)

- **Industry-Relevant Applications**

  Illustrations and explanations that show how optimization can improve your enterprise asset management strategy. (Jump to pages 13–14.)

- **Case Studies**

  Highlights of how successful organizations are using optimization to improve performance and reduce costs. (Jump to pages 15–17.)

- **Key Takeaways**

  A summary of useful insights and actions you can take to see whether your organization is ready to integrate optimization into your asset lifecycle management strategy. (Jump to pages 18–19.)

What is Optimization

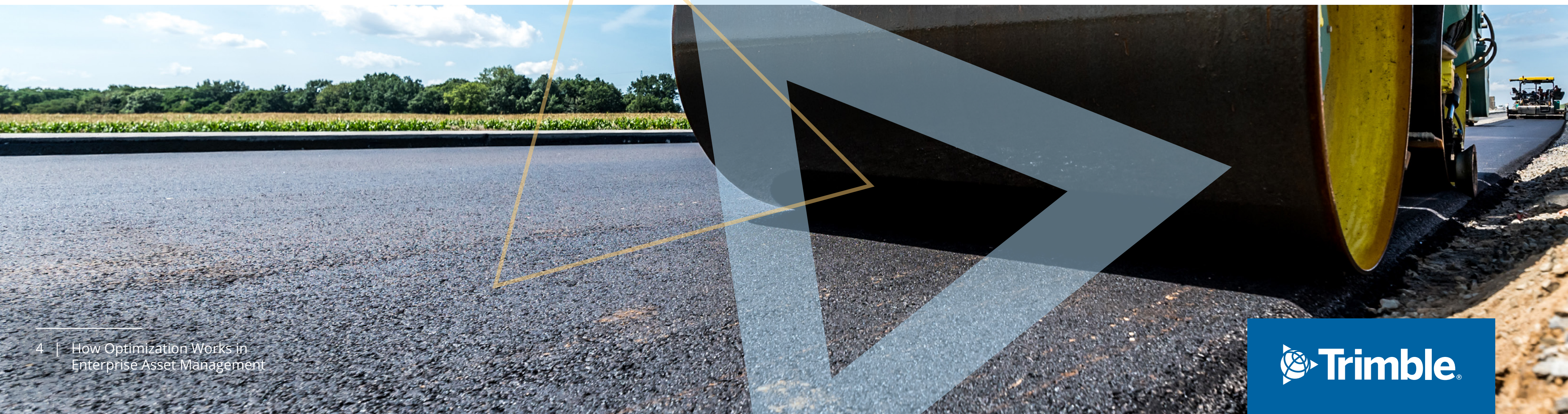
Optimization is a method for identifying the best solution to a complex problem. In enterprise asset management, a central complex problem is identifying the right mix of projects to fund in order to best meet the organization's goals within the available budget.

Organizations often simplify the problem by reducing the number of variables to consider or using relatively small data sets. However, modern complexity requires asset managers to take a growing volume of information into account and to be more effective at using this information to make better investment decisions and trade-offs.

True Optimization vs. Other Approaches

Organizations use many methods to decide which projects to fund and implement, but the most successful organizations use true optimization. For example, Texas Department of Transportation effectively manages the largest state-owned road network in the United States by using optimization to save an estimated $20 million to $40 million per year on pavement maintenance and rehabilitation projects. (**See case study on page 15.**)

More commonly, organizations use a traditional, non-optimized approach, such as a simple ranking or a cost-benefit analysis. In both these traditional approaches, the organization prioritizes projects according to a single criterion, such as asset condition or project cost. However, we all know that many factors affect the quality of the decisions about how to best manage infrastructure assets—so taking multiple factors into account gives organizations a distinct advantage.



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Worst First

A traditional simple ranking is the worst-first method, in which the organization prioritizes projects that address the assets with the worst condition ratings—for example, a crumbling roadway segment or a failing bridge. However, with this approach, the organization often uses up its budget on a few “bad” projects rather than maximizing the performance of the entire network.

The worst-first approach is similar to addressing the needs of “the loudest voice in the room” during a department meeting, rather than benefiting from the whole team’s input. The result is to solve short-term, “squeaky wheel” problems at the expense of the organization’s more strategic objectives.

Cost-Benefit Analysis

Another common approach is the cost-benefit analysis. In this approach, the organization calculates the ratio of the project costs to the estimated project benefits and ranks the projects according to the lowest ratio (or highest benefits per cost). Then the organization prioritizes and selects from the highest-benefit projects until the budget runs out.

The problem with this approach is that it only takes into account two factors—costs and benefits—without considering the multiple criteria for determining benefits, such as gains in safety, reductions in environmental impacts, and the effects on the quality of the entire network, to name just a few.

Optimization

A much better solution is to use advanced data analysis and optimization to identify and fund the best combination of projects that will maximize benefits across the whole network by meeting multiple criteria—or **constraints**—such as achieving various performance targets over a given time period while staying within financial and other limitations.

Optimization analysis can simultaneously take into account a virtually infinite number of factors—including cost, time, asset features, geographic boundaries, and any number of pre-defined performance measures—to identify the optimal mix of projects that will maximize asset lifecycles throughout the network by making the best use of available funds across time.

Other Approaches

- Take a partial view using limited data
- Focus on assets and projects
- Meet a few short-term goals
- Fail to get the most value from funds

True Optimization

- Take a holistic view using unlimited data
- Focus on network performance
- Meet many short- and long-term goals
- Get the most value from available funds

A Simple Example

To illustrate the advantages of optimization over non-optimized approaches, we can start with a very simplified example of selecting pavement projects to fund with an available budget of $10.0 million. The challenge is deciding which projects will add the maximum years of service life for the maximum roadway length without exceeding our budget.

Objective and Constraints

In our simple example, we have five types of pavement projects to consider. These may include a variety of preventive maintenance, repair, rehabilitation, replacement, and many other types of projects. For simplicity, we'll name the projects A, B, C, D, and E.

The cost and roadway length are two constraints within the problem we are trying to solve. Our objective is to maximize the added years of service life while staying within our budget (cost constraint) and treating a minimum of 10.0 lane miles (roadway length constraint).

Units of Measure

In the examples throughout this guide, we use lane miles as a U.S.-standard unit of measure for roadway length. The concepts apply equally well using lane kilometers as a global standard.

Visualizing the Problem

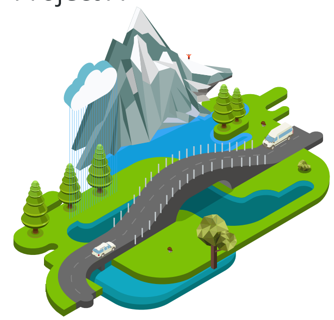
To sum up: We want our project selection to meet two constraints by identifying a combination of projects that costs no more than $10.0 million (constraint #1) while adding the maximum years of service life (objective) for a minimum of 10.0 lane miles (constraint #2).

There are many other constraints we could consider—for example, the geographic locations of the pavements, the length of time needed for each project, the targeted level of service of the roadways, and so on. From the potentially countless number of possible constraints, we will focus on satisfying only the two constraints that are most critical to us: maximum cost and minimum roadway length—all while meeting the objective of maximizing service life.

For this example, we note the following values:

Simple Pavement Management			
Projects	**Cost** (in Millions)	**Added Service Life** (in Years)	**Roadway Length** (in Lane Miles)
A	$3.0	4.8	4.0
B	$5.0	8.0	5.0
C	$2.0	4.0	3.0
D	$6.0	10.0	2.0
E	$10.0	15.0	9.0

Project A

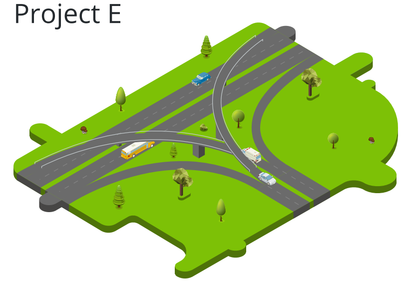


Project B

Project C

Project D

Project E



Worst-First Solution

Let's assume Project E has the worst condition, since it has the highest cost. It also has the most lane miles to repair, so on first look—after "eyeballing" our options—choosing Project E seems like a good solution. By selecting Project E, we would spend all our money and get 15 years of added service life but would treat only 9.0 lane miles, falling 10% short of the desired minimum of 10.0 lane miles.

Projects	**Cost** (in Millions)	**Added Service Life** (in Years)	**Roadway Length** (in Lane Miles)
E	$10.0	15.0	9.0

The worst-first approach seems intuitive on first glance, without too much analysis. However, on closer examination, we see that this solution does not give us the best return—nor does it consider the many other criteria that we know matter to an agency's many stakeholders. So, let's look further to see the results we get from the other approaches.

> Conducting true optimization analysis requires highly complex calculations that go beyond the capabilities of standard planning tools.

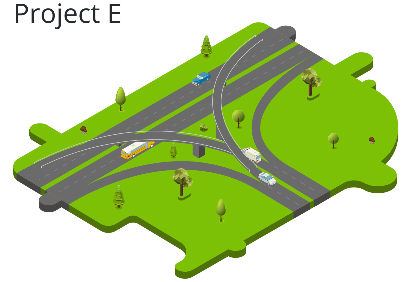
Project A

Project B

Project C

Project D

Project E



Cost-Benefit Analysis

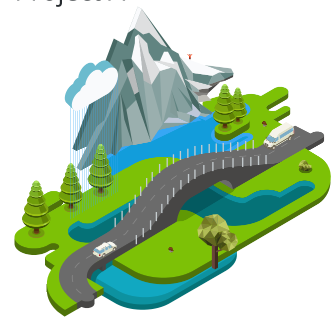
A common way to try to identify the best buying option is to do a cost-benefit analysis. Let's calculate how many added years of service life (benefit) per million dollars (cost) we would get for each project. The calculation looks like this:

Projects	Cost (in Millions)	Added Service Life (in Years)	Benefits per Cost (Added Years Per $M)
A	$3.0	4.8	4.8 ÷ 3.0 = 1.60
B	$5.0	8.0	8.0 ÷ 5.0 = 1.60
C	$2.0	4.0	4.0 ÷ 2.0 = 2.0
D	$6.0	10.0	10.0 ÷ 6.0 = 1.67
E	$10.0	15.0	15.0 ÷ 10.0 = 1.50

We can choose the projects with the highest return for our money, in that order, until the money runs out.

The projects with the highest benefits (added years of service life) for the cost are Project C and D. If we selected those projects, we would pay $2.0 million for Project C and $6.0 million for Project D, or a total of $8.0 million for a total of 14.0 years of added service life.

Project A

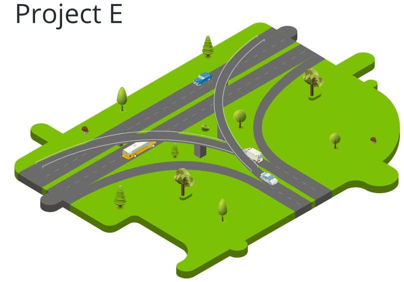


Project B

Project C

Project D

Project E



Cost-Benefit Solution

We can visualize the results of the cost-benefit analysis like this:

Projects	**Cost** (in Millions)	**Added Service Life** (in Years)	**Benefits per Cost** (Added Years Per $M)
C	$2.0	4.0	4.0 ÷ 2.0 = 2.0
D	$6.0	10.0	10.0 ÷ 6.0 = 1.67
Total	**$8.0**	**14.0**	**14.0 ÷ 8.0 = 1.75**

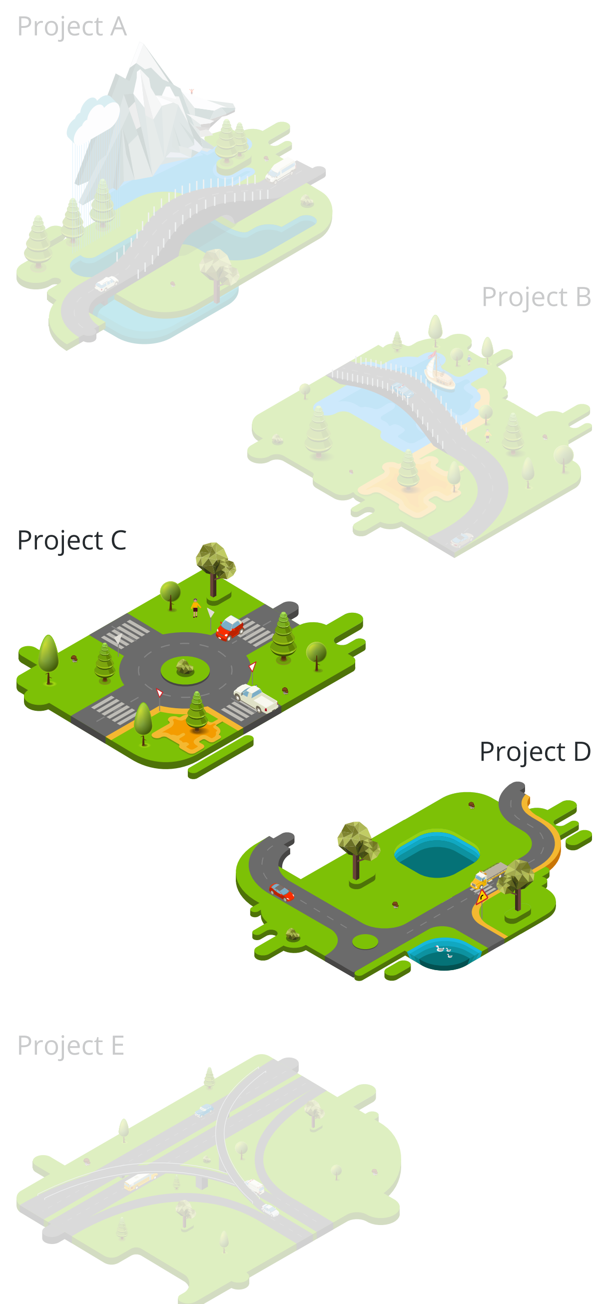
In this solution, we spend $8.0 million of our budget to add 14.0 years of service life. Although the cost-benefit analysis did not consider the additional constraint of lane miles, we know from our summary of the problem (p. 7) that the number of lane miles affected by this solution would be 5.0 (3.0 lane miles for Project C + 2.0 lane miles for Project D = 5.0 lane miles treated).

Now notice: We would end up with fewer years of added service life over far fewer lane miles here than in the worst-first example (14.0 added years on 5.0 lane miles here vs. 15.0 added years on 9.0 lane miles in the worst-first scenario). In addition, we would use only 80.0% of our available budget ($8.0 million out of $10.0 million).

A simple cost-benefit analysis does not necessarily give us the best solution if we want to maximize the potential benefits of using our entire budget. Notice also that the cost-benefit analysis cannot take into account our additional constraint of treating a minimum of 10.0 lane miles of roadway. (This solution treats only half that number.)

In fact, the main drawback of the cost-benefit approach is that it does not allow us to consider the multiple constraints inherent in more complex problems.

To solve complex problems such as those we face in enterprise asset management, we need to conduct an optimization analysis. An optimization analysis enables us to achieve the best outcome while meeting multiple constraints.



Optimization Analysis

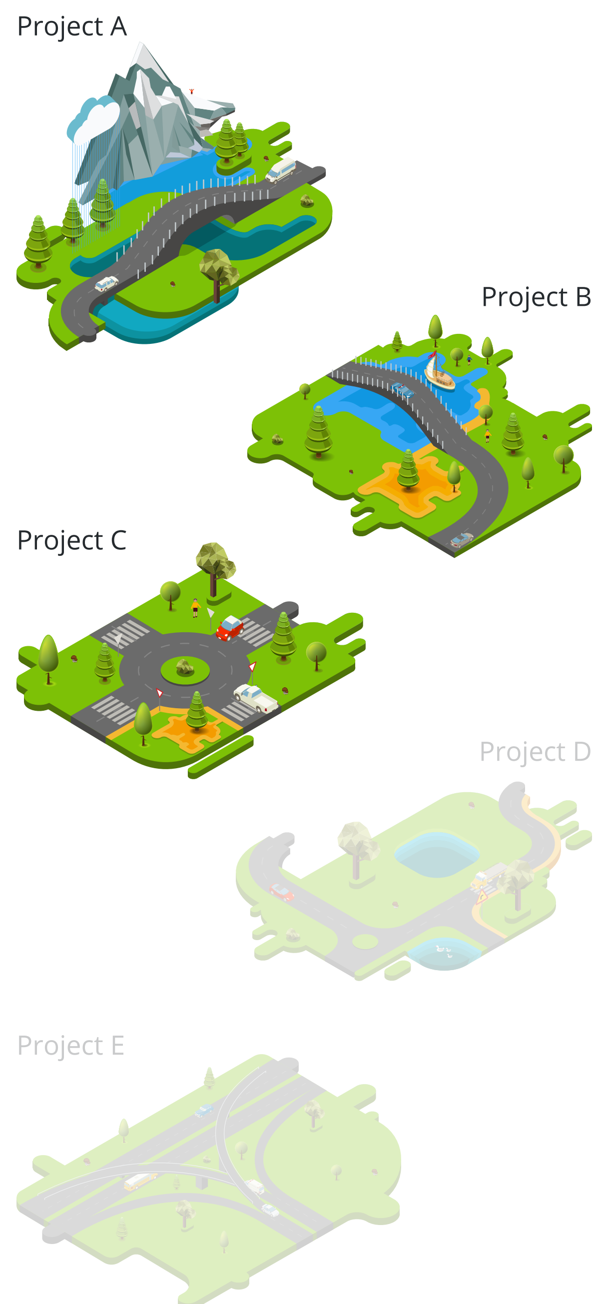
Using optimization analysis, we can take into account the two constraints of project cost and roadway length to identify the "best case" to reach our goal: getting the maximum years of added service life for a minimum of 10.0 lane miles while not exceeding a total cost of $10.0 million.

For simplicity, we will not show every step of the analysis here. A simple summary of the outcome looks like this:

Best Case			
Projects	**Cost** (in Millions)	**Added Service Life** (in Years)	**Roadway Length** (in Lane Miles)
A	$3.0	4.8	4.0
B	$5.0	8.0	5.0
C	$2.0	4.0	3.0
Total	**$10.0**	**16.8**	**12.0**

In the best case, we use our entire $10.0 million to get the highest possible added service life for the most possible lane miles. Now, we're getting 16.8 years of added service life for 12.0 lane miles. That's 12.9% more years and 33.3% more lane miles than we would have gotten with the worst-first method—and 20% more years and 140% more lane miles than we would get with the cost-benefit approach. We can even exceed our roadway length target by 20%, treating 2.0 more lane miles than the defined minimum of 10.0.

In short: Optimization leads to the best possible outcome while satisfying multiple constraints.



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Managing Complexity

We've seen that optimization analysis helps an organization identify the best course of action to achieve multiple goals.

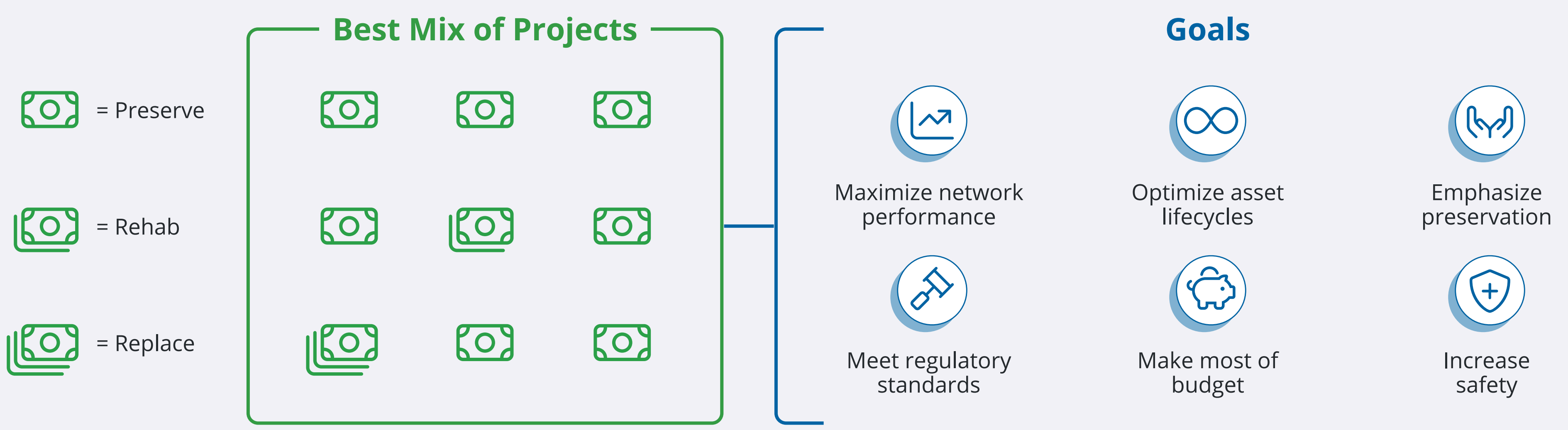
Results of Various Approaches			
Approaches	**Cost** (in Millions)	**Added Service Life** (in Years)	**Roadway Length** (in Lane Miles)
Worst-First	$10.0	15.0	9.0
Cost-Benefit	$8.0	14.9	5.0
Optimization	**$10.0**	**16.8**	**12.0**

However, most enterprise asset management problems are much more complex than our simplified example because they require satisfying many more constraints. In addition, depending on the size of the asset network, the number of asset management projects to consider may run in the hundreds or thousands, adding further complexity to the problem.

> Optimization helps organizations get the best possible outcome while satisfying multiple constraints.

Benefits of Optimization

Despite the complexity of optimization in enterprise asset management, we can illustrate its impact using, again, a simplified example that could apply to pavements, bridges, or other structural assets. In the illustration below, an optimization analysis results in identifying the best mix of projects to maximize network performance, optimize asset lifecycles, and meet regulatory requirements using the available budget, while increasing safety and emphasizing preservation over rehabilitation and replacement projects.



Even this simple example shows how optimization satisfies the multiple constraints of network performance, asset lifespans, regulatory targets, budget, safety, and treatment types while meeting multiple goals.

The same optimization principles would apply to similar scenarios for multiple asset types—such as a mix of pavement, bridge, and safety projects—and for dozens or hundreds of constraints. In addition, optimization works regardless of network size.

Managing Complexity Through Optimization

Optimization analysis becomes increasingly complex with increasing numbers of constraints—such as targeted levels of service for each asset, targeted asset lifespan increases, variable time frames, variable budgets, multiple asset types, and more.

Performing such complex analysis "manually" using spreadsheets requires more time and resources than most organizations are able to invest. As a result, organizations often resort to worst-first or cost-benefit approaches. However, using a non-optimized approach leads to planning decisions that fail to make the best use of available funds and fail to maximize the benefits to the asset network.

Conducting true optimization analysis requires managing multiple constraints through highly complex calculations that go beyond the capabilities of standard planning tools.

> Through optimization, organizations make better strategic decisions that generate the most value from the available resources.

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CASE STUDY

Texas DOT

Optimizing Pavement Maintenance and Rehabilitation

One of the largest road agencies in the United States, Texas Department of Transportation (TxDOT) manages about 200,000 lane miles of roadways that support more than 500,000,000 daily vehicle miles traveled.*

Using a Trimble enterprise asset management solution, TxDOT performs multi-year, multi-constraint analysis to create accurate 4-year forecasts and optimized work plans.

Based on an independent assessment by a national consulting group, saving just 1%–2% of its annual $2 billion pavement budget using advanced analysis and optimization saves TxDOT $20 million to $40 million per year on pavement maintenance and rehabilitation projects.

> Optimization saves Texas $20 million to $40 million per year on pavement maintenance and rehab projects.

According to TxDOT's Pavement Preservation Branch Manager, Jenny Li, Ph.D., the state's advanced pavement planning "allows Texas highway districts to get the most value from available project resources by optimally allocating taxpayer dollars."

* TxDOT Roadway Inventory Annual Reports, 2016.

CASE STUDY

Connect Plus Services

Optimizing Network Asset Management

Connect Plus and its operational arm, Connect Plus Services, manage and maintain the M25 orbital motorway that circles London. The M25 is one of the largest and most congested road networks in the United Kingdom (UK). Carrying 15% of all UK motorway traffic, the M25 spans 117 roadway miles (188 km).

Using a Trimble enterprise asset management solution to manage its entire M25 asset portfolio—from pavements to bridges, tunnels, and other roadway assets—Connect Plus Services estimates it will achieve a 5% improvement in long-term operational efficiency through network optimization, saving £30 million (nearly $40 million) in pavement management and £18 million (more than $23 million) in structures management across 30 years of the asset lifecycles.

Through network optimization, Connect Plus Services will save an estimated £30 million (nearly $40 million) in pavement management and £18 million (more than $23 million) in structures management over 30 years.

CASE STUDY

Delaware DOT

Enhancing Decision-Making Through Optimization Analysis

DelDOT

The Delaware Department of Transportation (DelDOT) enhanced its pavement management program to save time and money while achieving higher performance targets. Using a Trimble enterprise asset management solution for optimization analysis, DelDOT has improved decision-making at both the network and project level.

DelDOT's pavement managers are able to forecast network budget needs with a greater level of confidence, turn field data into work plans with better operational results, and use advanced analytics to meet legislative requirements and network performance goals.

> Using optimization analysis, DelDOT has improved decision-making at both the network and project level.

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Key Takeaways

Today's organizations need to make the most of their available funds to maximize network performance and asset lifecycles.

While most organizations still use traditional project prioritization methods such as the worst-first approach or incremental cost-benefit analysis, the most successful organizations are using advanced analytics and optimization to identify the best mix of projects to meet their performance objectives within their specified budget.

Optimization analysis helps you do more with less.

Organizations looking to advance their asset management strategies and improve their strategic decision-making should consider the following key insights:

- True optimization analysis requires highly complex calculations that go beyond the capabilities of standard network planning tools.
- Using optimization algorithms, organizations can perform multi-year, multi-constraint analysis to identify the best set of projects to meet strategic priorities.
- Optimization models support complex, predictive analytics to forecast network performance, project outcomes, funding needs, and more.
- Through optimization, organizations can identify optimal project selections faster and more accurately—then make strategic decisions that create the most value for a given budget.
- Many organizations are successfully modernizing their asset management strategies using cloud-based SaaS solutions with optimization capabilities.

In today's world, with limited resources and tight funding, optimization analysis helps your organization do more with less.

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Actions You Can Take

To see whether your organization is ready to move toward making optimization a part of your asset management strategy, here are a few actions you can take.

1. **Evaluate Data Quality**
   Optimization analysis is most effective when you have high-quality asset data that inaccessible to all relevant stakeholders. Consider whether your organization has agreed-upon standards for data collection, recording, and reporting—and whether mechanisms are in place to validate data accuracy. Ideally, all relevant data would be consolidated into a "single source of truth" (unified database) so that multiple teams could benefit from having the most complete and current data.

2. **Update Performance Models**
   Optimization analysis relies on having performance models that accurately reflect asset conditions in your network as they change over time. Make sure your performance models have been calibrated to current asset conditions and other variables such as traffic volume, subgrade or sub-element condition, work history, and climate trends.

3. **Validate Decision Trees**
   Decision trees are important to outline possible courses of action and outcomes. Keep in mind that decisions for one part of your network may have implications for other parts and the corresponding teams that work on them, so having access to work history data is very helpful. Validate that the decision trees align with your organization's business processes,strategic goals, and target outcomes.

4. **Upgrade Your Solution**
   If your organization is not using a true optimization approach already, chances are you do not have access to an advanced asset management solution that can support multi-year, multi-constraint analysis. Consider upgrading to a cloud-based enterprise asset management solution with a centralized database and connected workflows that support optimized asset management across the lifecycle.

Whether adopting an optimized asset management strategy is part of your organization's short-term goals or long-term vision, Trimble can help identify the next steps to move your organization forward. Taking small actions now can help position your organization for big strategic benefits in the future.

For more information on enterprise asset management strategies and solutions, visit assetlifecycle.trimble.com.

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