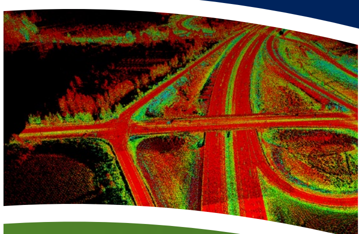
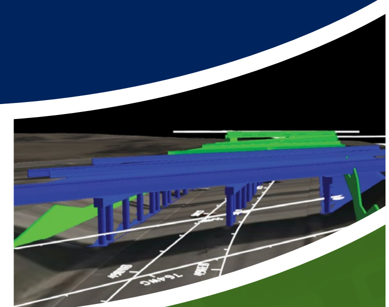
Guide for

Determining the Return on Investment for using 3D Engineered Models in Highway Construction

Summer 2017



3D Engineered Models:

Schedule, Cost, and Post-Construction

*An **Every Day Counts** Innovation*

U.S. Department of Transportation
Federal Highway Administration

Contents

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Introduction

Today more than ever, government decision makers are required to optimize limited resources while responding to ever-increasing demands for improved performance and new technology. These competing demands create close scrutiny of new technology investments, such as the use of 3D engineered models. Additionally, these demands create a unique opportunity to evaluate how the benefits of these investments permeate across the enterprise as opposed to just providing benefits to the business silos, e.g., bridge or construction.

A return on investment (ROI) process provides decision makers with a transparent, data-driven decision support tool that guides investments in the most urgent and most valuable initiatives that generate the quickest positive return. This guide provides an ROI process that State Transportation Agencies (STAs) can use to assess implementing 3D engineered models in their project delivery process. Further, this guide discusses how to accelerate benefit capture through deliberate organizational improvements.

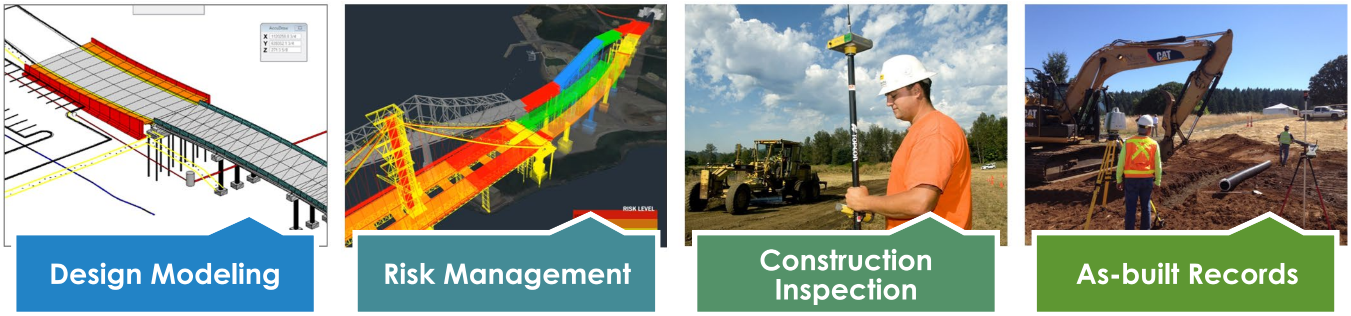


Figure 1: 3D engineered models add value to all phases of project delivery.

Government agencies continue to favor a more detailed analysis of benefits and costs for substantial investments to ensure alignment with their fiscal responsibilities. Investments in technology by STAs represent both a significant commitment of taxpayer funds and an important strategic tool to realize benefits across multiple agency functions. For instance, the New York State Department of Transportation (NYSDOT) used a 3D engineered model from design as the basis for processing construction payments.[1] The benefit of using 3D engineered models throughout project delivery demonstrates a versatile, cross-functional value that saves taxpayer money by using data multiple times and for different purposes. This benefit could be extended into asset management by integrating 3D as-built models into the already established programmatic asset inventory data collection process. The ROI realized from implementing 3D engineered models can be calculated through a detailed benefit-cost analysis (BCA) using a predefined process in order to justify expenditures that support a specific need.

Data Governance

Sound data governance is achieved through a series of coordinated investments in technology and policy to create, collect, and consume 3D asset data that supports immediate primary functions, but is stored in a manner that supports future, cross-functional, and agency-wide uses. A robust data governance framework that facilitates data integration and cross analysis is a prerequisite to fully exploit the ROI.

The financial ROI is an important consideration, but a STA likely will need to evaluate many other factors before making an investment. These include intangible factors, such as increased transparency, greater stakeholder understanding of project alternatives, and the value of prioritization of infrastructure assets. It is important for STAs to measure the full value of their investments transparently to pass the scrutiny and meet the expectations of the public.

The proposed initiative should create value for the organization; the goals and expected benefits should elevate it to relatively higher priority compared to alternative initiatives. Data is an asset, and through good data governance, the asset can be leveraged for efficient data mining and effective data analytics. Thus, 3D engineered models are a valuable component of a STA's plan to meet requirements for operating and maintaining the highway network with transparent, data-driven decision-making. Prioritizing coordinated investments creates a sense of urgency relative to competing initiatives.

Strategy and Alignment

Support from the highest levels of the organization is important for a strategic initiative to succeed. However, garnering this level of support can be difficult without demonstrating a robust business case, which relies on assessing the ROI. As stewards of public funds, STAs have the responsibility to develop investment strategies that align with the vision and mission of the organization, as measured by the key performing indicators (KPIs). The end goal should guide the strategic planning process, leading to an implementation plan that will fulfill the needs of the organization.

Currently, STAs vary widely in their approach, prioritization, and level of maturity in using 3D engineered models for cross-functional purposes. Focusing on incremental investments may be prudent, but evaluating the potential positive impact of small, disruptive changes may yield the highest value for the organization. Figure 2 shows the various components of a comprehensive 3D engineered model strategy by funding impact and ease of deployment. These investment areas all add value and maturity to a 3D engineered models implementation, yielding residual benefits to the project delivery process.

1 FHWA. 2016. "*4D and 5D Modeling: NYSDOT's Approach to Optimizing Resources.*" Washington, DC: Federal Highway Administration.

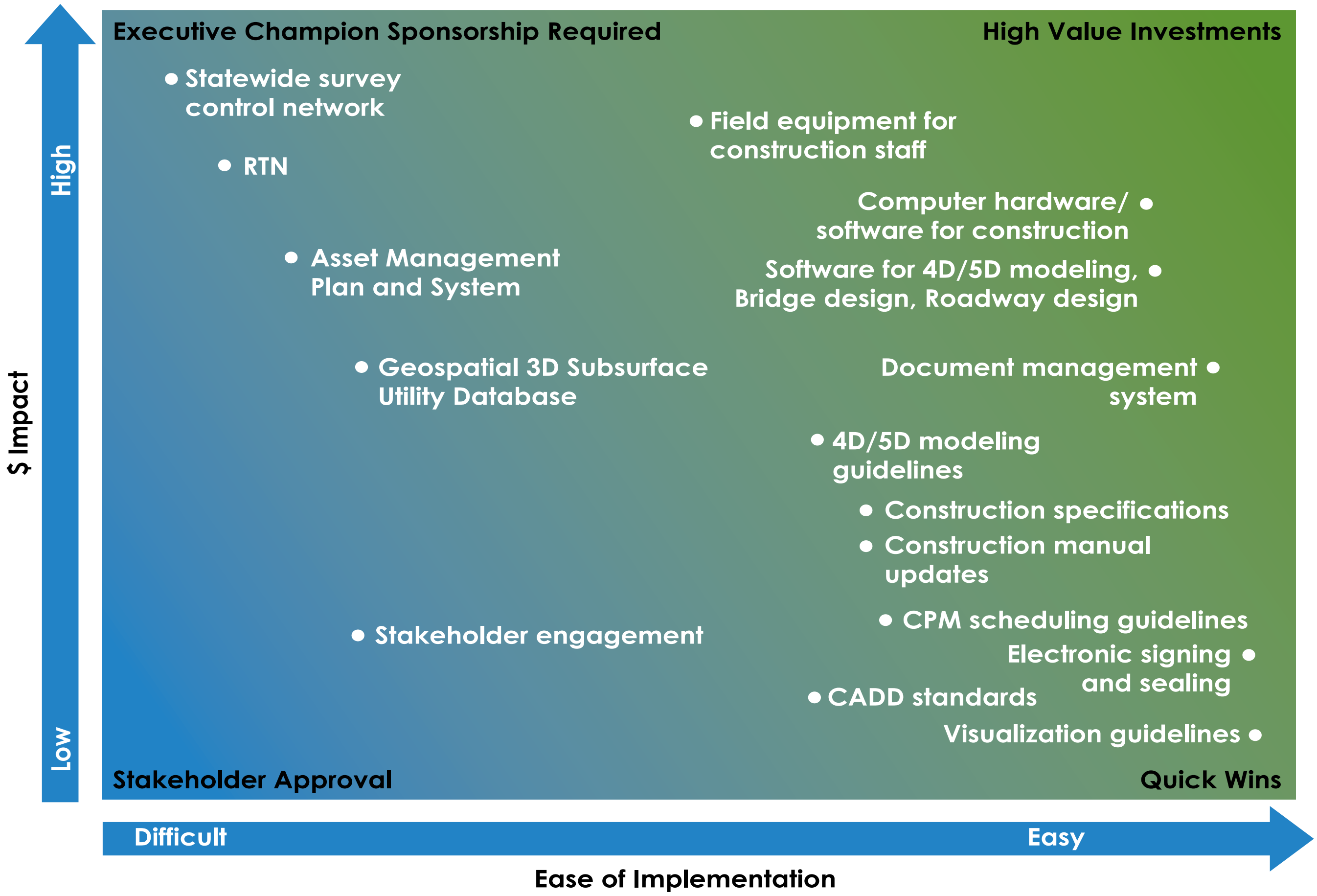


Figure 2: Funding Impact and Ease of Implementation for Investment Areas

"Alignment" means that the initiative is synchronized with the agency's mission. The mission remains constant over time, but the priorities and organizational structures may change. Agencies can test alignment by asking these simple questions:

1. How well does the initiative satisfy the STA's mission?
2. How well does the initiative contribute to the KPIs?
3. How well does the executive leadership support achieving the initiative?

A successful business case for 3D engineered models implementation starts with setting the vision, followed by reconciling the purpose and need for the implementation to the agency's KPIs and mission as shown in Figure 3.

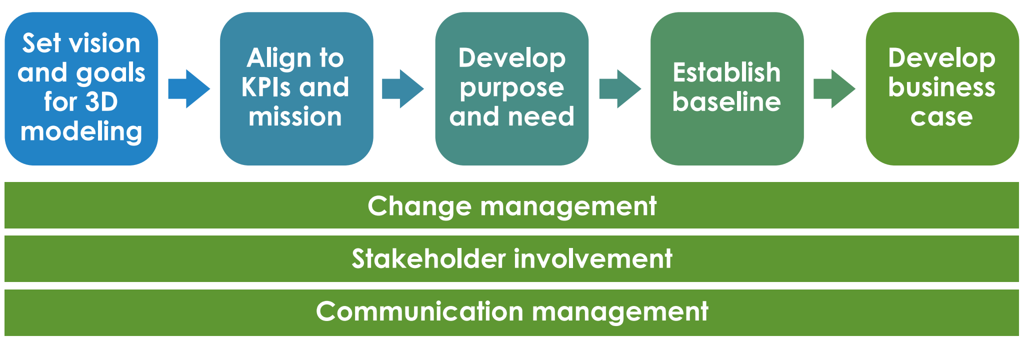


Figure 3: Typical process for developing a business case for 3D modeling implementation.

ROI Process

An ROI process enables STAs to make coordinated and considered investments. Figure 4 illustrates the process for calculating an ROI. The process starts with planning the benefit and cost categories for data collection, ensuring that they are aligned to the STA's KPIs and mission. Then, selecting suitable pilot projects to capture the baseline and comparison data. Next, executing the pilot projects while collecting data, and finally, computing the ROI by comparing the aggregate baseline benefits and costs to the comparison data.

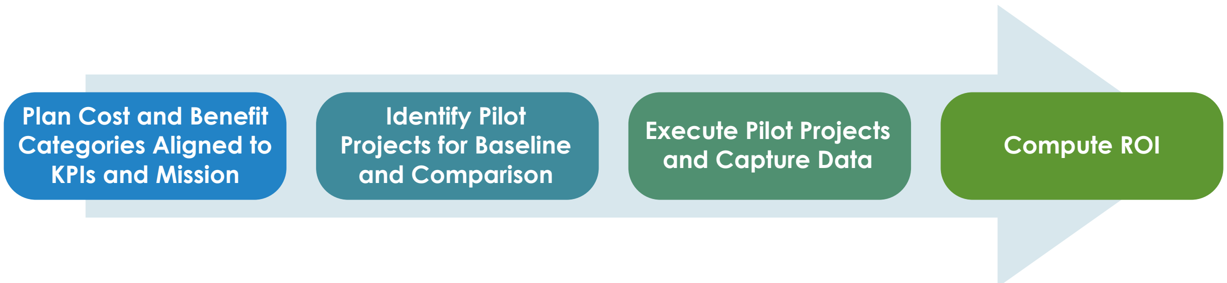


Figure 4: Flowchart of the ROI Process

Plan Data Collection

This step builds on the Strategy and Alignment, going into the specifics of identifying the broad benefit and cost categories that will be captured through the pilot projects. This occurs before selecting pilot projects in order to minimize any bias associated with any specific project; objectivity will yield a more accurate ROI. This is the most important step to ensure that computing an ROI is achievable with meaningful data. Alignment to the agency's mission and KPIs ensures the result has meaning to agency leadership, but designing the data collection so that it happens without burdening the project teams ensures their support and that robust data will be available for the calculation.

It is important to brainstorm the full disruptive impacts from the initiative. There may be costs associated with, for instance, adding more detailed asset attributes in design, which may yield benefits like more efficient asset commissioning post-construction. By identifying all possible benefit and cost categories, they can be measured during piloting and assessed to determine maturity and viability, even if they are incidental to the primary initiative.

The benefit and cost categories for a 3D engineered model initiative should include labor costs associated with the effort of creating or using 3D engineered models throughout the project delivery process and developing standards and policies, as well as the direct costs to implement enabling technologies. While an ROI is numerical, it is also important to identify any qualitative and unquantifiable benefits and costs to capture that may support a broader business case.

It is important to note that piloting cannot capture costs associated with programmatic implementation. Costs associated with the administrative and operational functions of the STA, such as enterprise IT systems and developing policy, will need to be estimated.

The following types of benefits and costs should be considered during the BCA and ROI determination:

Project-level benefits and costs. These benefits and costs are isolated to the project and can be scaled out either numerically (per project) or by contract value. Labor efficiencies due to technology are benefits that scale linearly across multiple projects and the entire construction program. Full-time equivalent (FTE) costs should be at the normal rates and not reflect the rates of any subject matter experts who are involved in the pilots. The incremental cost difference for subject matter experts should be allocated as one-off costs.

Prorated project-level benefits and costs. These benefits and costs are scaled across multiple projects, for instance, equipment that depreciates over several construction seasons. A pilot project would capture the full cost of purchasing surveying equipment to take advantage of the 3D models during the construction. However, that cost needs to be prorated in the ROI calculation across the depreciation period. When scaling the ROI across the entire program, another adjustment is needed to account for volume discounts. Purchasing surveying equipment in low quantities is typically significantly more expensive than making programmatic, enterprise acquisitions.

Singular and recurring costs. Pilot projects may incur costs such as training or support that are singular or recurring. These need to be quantified through the pilot process, but scaled appropriately in the ROI computation. The cost associated with initial training would be a singular cost scaled across the number of inspectors, and annual maintenance training would occur at a reduced rate, e.g., 5 days for initial training, but 2 days for annual maintenance training.

Programmatic costs. Costs associated with process improvements or policy changes (e.g., upgrading standards and manuals) are difficult to capture through piloting. It is also debatable whether these costs should be included in the ROI analysis or be assigned to baseline costs of doing business. If they are included, these costs need to be allocated over several years. For example, the cost for upgrading the software should be distributed over the duration of the enterprise agreement, typically 3–5 years.

Identify Pilot Projects

The pilot projects need to be carefully selected in order to capture the benefits and costs associated with predefined categories. The first step is to define pilot project selection criteria. Then, a range of potential baseline and initiative pilot projects should be identified. The best combination of baseline and initiative pilot projects can then be studied to capture the benefits and costs. The degree to which the project team supports the ROI process is an important project selection criteria, as their cooperation will be needed to collect the data.

Pilot and Gather Data

Once a baseline and initiative pilot projects have been selected, the next step is to document the previously identified data to be collected. The party responsible for documenting the benefits and costs will need to work with other agency staff to collect the data. For example, it may be helpful to work with risk management and public information staff to obtain benefit data related to stakeholder involvement and risk assessment. It may also be helpful to work with procurement and information technology staff to obtain cost information. Further, specific milestones during the project delivery process offer good opportunities to capture benefits related to process improvements and data quality.

Quantifying benefits and costs related to efficiency, effectiveness, and essential improvements can be difficult due to the number of variables to consider; nonetheless, these challenges may be overcome with proper planning. Benefits will vary depending on internal expertise and the agency’s current state of the practice and technology, and costs will depend on contract agreements and procurement options. It is important to note that external factors such as contractual and legal issues may pose increased difficulty.[2]

The process of logging the benefit-cost data will need to follow consistent data collection protocols that are as objective and as simple as possible in order to lessen the burden on construction personnel (Figure 5). While capturing actual cost and benefit data is ideal, it may not be realistic in some instances. Estimated data can be useful, but should be carefully scrutinized to ensure the objectives of the pilot project are not compromised. In order to achieve the greatest accuracy and reliability, the estimated data would benefit from using a weighting adjustment that represents uncertainty of measurement. This adjustment will help qualify data that does not have equal effect on the calculation as actual data.

Define Approach

Define how the data will be collected

Having a standard approach for collecting information is important to conduct an objective and reliable benefit-cost analysis.

- **Will there be standard forms to capture benefit and cost categories?**
- **Will staff efficiency be captured by timesheet charges and/or contract invoices?**

Determine Timeline

Determine when the data should be collected

Setting the expectation will help staff responsible for providing and reporting the data plan their tasks.

- **Will data be collected during a particular timeframe (e.g., weekly)?**
- **Will data be collected by milestone (e.g., 30/60/90/100 percent completion)?**

Establish Protocols

Establish data management and reporting protocols

Establishing protocols for data exchange and reports will help staff providing and collecting the data with clear direction for gathering and managing the information so it can be easily reported.

- **Who will manage and aggregate all the data?**
- **Where will the data be stored (e.g., project collaboration tool or project management programs)?**
- **When will reports be submitted for review?**
- **How will reports be created?**

Create Review Process

Create quality control processes

Creating a standard process to review information being collected will result in a reliable BCA analysis and ROI determination.

- **Who will be responsible for quality control?**
- **When will data be reviewed?**
- **How will data be validated?**
- **How will these benefits and costs be shared throughout the organization?**

Figure 5: Considerations for Establishing a Robust Data Collection Process

Analyze Data and Compute the ROI

The benefits and costs can be analyzed to calculate the ROI using the process illustrated in Figure 6. The data collected during the pilot project will need to be compared to the baseline to calculate total costs incurred and benefits realized during the exercise. The benefits due to efficiencies and direct costs incurred during the exercise can then be used to calculate the ROI of implementing 3D engineered models. However, there will be situations where the benefits obtained from implementing 3D engineered models will create derivative opportunities (i.e., indirect benefits), such as increased accuracy in asset management models that yield more efficiency in that program, and should be documented.

2 O'Brien, William J., Bharathwaj Sankaran, Feranand L. Leite, Nabeel Khwaja, Ignacio De Sande-Palma, Paul Goodrum, Keith Molenaar, Guillermo Nevett, and Joshua Johnson. 2016. NCHRP Report 831. Civil Integrated Management (CIM) for Departments of Transportation, Volume 1: Guidebook. Washington, DC: Transportation Research Board.

The final ROI results will then be compiled and reviewed for concurrence by independent reviewers. This will ensure the methodology is confirmed and results are understood. This ROI process only assumes the agency benefits and costs. However, it is important to note that contractors and suppliers will also benefit from the implementation of 3D engineered models, which typically results in improved risk management that translates into savings to the owner via lower bids and accelerated project delivery.

ROI Determination

ROI measures the gains realized from a technology investment relative to the overall cost of implementation, as shown below:

$$\frac{\textit{(Gain from Investment – Cost of Investment)}}{\textit{Cost of Investment}}$$

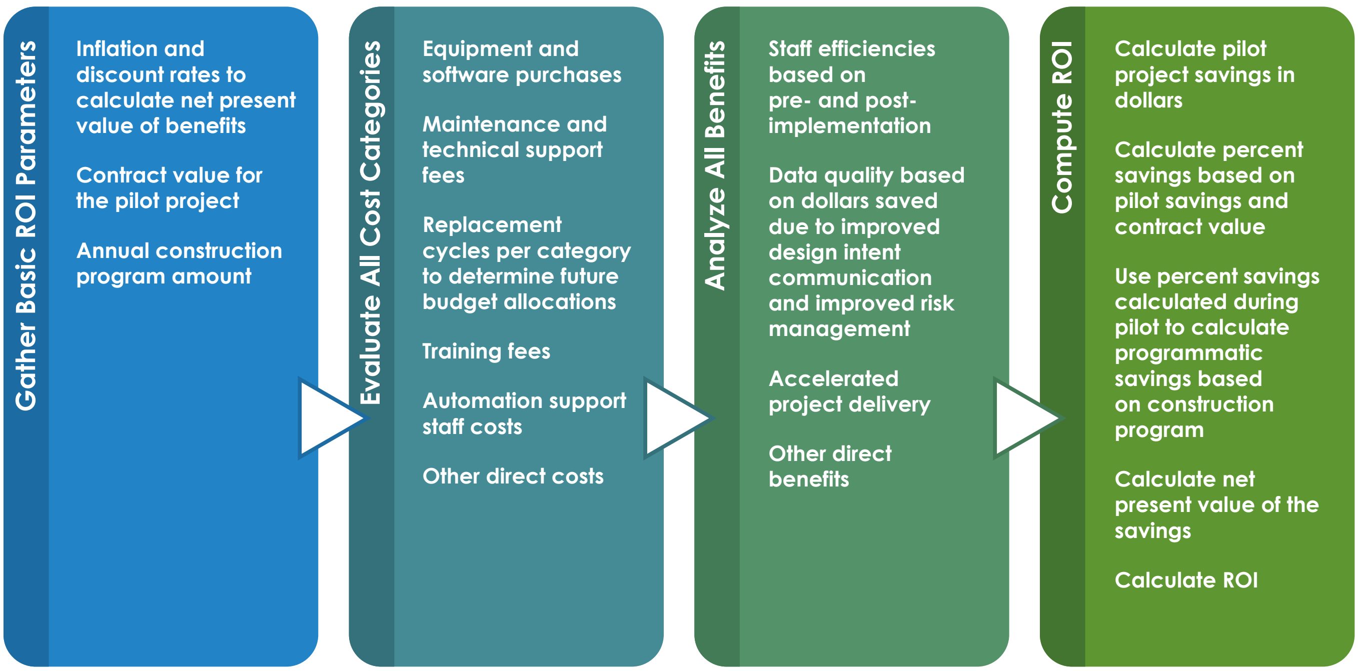


Figure 6: General Process for Conducting a BCA and ROI Determination

The BCA calculation follows a specific process once all variables have been quantified. If the STA self-performs the design phase of the project, the pilot project savings is the product of the number of hours saved and the average loaded hourly labor rate. These benefits will be realized over a transition period. It is assumed that only new projects will be designed in 3D, thus the benefits cannot be realized during the first year of implementation. As more projects are added to the 3D design process, more benefits will be realized. Thus, it is important to set realistic expectations for distributing the percent realization of benefits. It is recommended to use a period of 3–5 years to realize full benefits. Figure 7 demonstrates the distribution of benefits over a 5-year period.

Figure 7: Benefits Realized During Implementation

The Untapped Potential: Cross-Functional Use of 3D Engineered Models

Most STAs have a hierarchical business structure that assigns resources in silos. The benefits of using 3D engineered models in a single silo are relatively straightforward to compute. Computing the cross-functional ROI is more nuanced.

Implementing 3D engineered models across functional units will result in higher benefit realization and offers an opportunity to share the cost of data acquisition and technology deployment. For example, it is difficult to justify the cost of all the necessary information systems infrastructure to support the use, storage, sharing, and management of 3D engineered models and derivative products for one functional unit. However, if the data is being used across the project delivery functions (e.g., roadway and bridge design, construction, and asset management), the benefit realization will be much higher, therefore making the business case for implementation much stronger.

The following are some of the benefits that can be realized from cross-utilization of 3D engineered models:

Reduced cost for data collection. It is common for different functional units to procure data collection services separately for information that often is already available. STAs implementing 3D engineered models can expect many benefits, including gained efficiencies and better resource utilization in performing data collection and post-processing tasks to support pre-construction surveys, engineering design, construction inspection, as-built surveys, and asset inventories (refer to the *Guide for Efficient Geospatial Data Acquisition using LiDAR Surveying Technology*[3] for specific guidance regarding information requirements for enterprise data collection).

Improved workflows for pre-construction activities. The emphasis of 3D engineered models has been to enable automated machine guidance construction methods. However, being able to create models that integrate roadway and bridge designs can increase efficiencies for developing engineer estimates and contract documents, communicating design intent and stakeholder collaboration (e.g., constructability review), managing risk, and enabling real-time verification and quantity measurements in construction. Benefits from pre-construction activities translate into lower contractor bids and reduction of change orders or claims, improved workforce utilization for construction activities and technology to support construction inspection tasks, improved safety by reducing exposure to heavy equipment, and shorter project completion timelines.

Improved as-built records. 3D engineered models offer the opportunity to obtain better as-built records by using digital data gathered by the inspector during inspection or extracted from the model by the contractor as a final deliverable. This combination of efforts to collect as-built records using modern surveying tools and mobile technology between inspectors and contractors will dramatically enhance the current process used for managing asset inventory.

The benefits of using 3D engineered models multiple times and for multiple purposes minimizes duplication of efforts and resources, which leads to optimization of funds, improved data stewardship and management, and more efficient processes.

3 FHWA. 2016. "*Guide for Efficient Geospatial Data Acquisition using LIDAR Surveying Technology*." Washington, DC: Federal Highway Administration.

Procurement of technology. Procuring technology to support 3D engineered models at the enterprise level is a great way to plan a programmatic investment that will improve the budgeting planning process. Additionally, purchasing modern surveying tools and other technology to support enterprise-level use of 3D engineered models will result in better bids from vendors and suppliers, and will allow technical staff to manage all the equipment based on the capital improvement program and workforce utilization. When all interested functions are aware of equipment and training needs, the silos dissolve and new processes form that enable a reduction of administrative costs by streamlining the procurement process.

Incorporating the ROI into a Business Case

Ultimately, the ROI is just a number, and it is meaningless without context. It needs to be incorporated into a business case that frames the ROI results in the context of the STA's KPIs and mission. The business case should also include the qualitative information captured through the pilots, any qualifying information about what was included and excluded from the ROI calculation, and commentary on the STA's maturity with 3D engineered models compared to that of their business partners, as well as the risk of inaction. The business case will create a meaningful message that will resonate with the STA's leadership and legislators to support the initiative and secure funding.

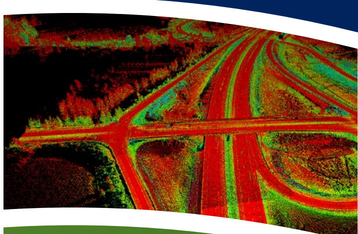
Conclusion

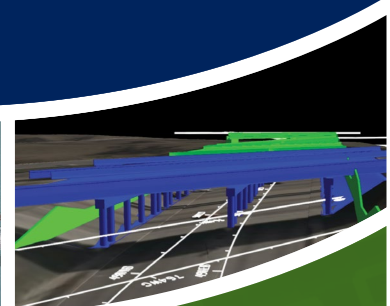
Coordinated and strategic investments in 3D engineered models lead to increases in efficiency and effectiveness and to essential enhancements. These investments require a rigorous analysis of the benefits and costs arising from investing in the technology, people, and processes that are influenced by implementing 3D engineered models.

Pilot projects offer the opportunity to quantify benefits and costs, provided that the data collection is carefully planned. Executing a deliberate process to categorize the benefits and costs before the pilot project is selected is absolutely critical to make a sound investment decision in 3D engineered models. The benefits and costs captured through pilot projects need to be analyzed and manipulated to scale the ROI across a program and across the agency, taking into consideration depreciation cycles and whether the costs scale by time, contract value, and with purchasing power.

Intangible benefits that accrue to the public, such as transparency and engagement, are difficult to quantify but important considerations in a holistic business case. STA leadership can use a comprehensive business case, which includes an ROI calculation, as the basis to demonstrate the complete value of this technology when providing their support for the initiative. Applying this recommended process to digital project delivery will help accelerate innovation and investment in implementing 3D engineered models.

__Every Day Counts__, a state-based initiative of the Federal Highway Administration's Center for Accelerating Innovation, works with state, local and private sector partners to encourage the adoption of proven technologies and innovations to shorten and enhance project delivery.





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For additional information about this EDC Initiative, please contact:

Christopher Schneider
Construction Management Engineer
Office of Infrastructure (HIAP-30) — FHWA
Phone: (202) 493-0551
Email: christopher.schneider@dot.gov

R. David Unkefer, P.E.
Construction & Project Management Engineer
FHWA Resource Center - Atlanta
Phone: (404) 562-3669
Email: david.unkefer@dot.gov

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