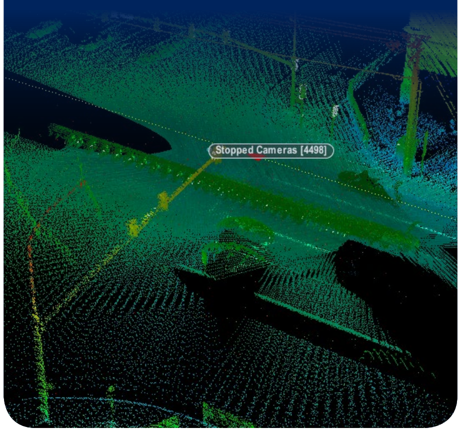
3D Engineered Models:

Schedule, Cost and Post-Construction

every day counts
An Innovation Partnership with States

PROGRAM CASE STUDY

This case study highlights how the Connecticut Department of Transportation (CTDOT) has successfully used a 4D modeling method for managing risk on the I-95 New Haven Harbor Crossing Corridor Improvement Program.



4D Modeling: A State Transportation Agency's Approach to Risk Management

State transportation agencies (STAs) are responsible for developing and managing a statewide transportation improvement program (STIP), which includes all transportation construction projects to be built in the state over a period of four to six years. One factor in the STIP's success is the management and performance of individual projects, especially during construction. Good project management practices are critical for keeping construction within schedule and budget, as is communicating the design intent accurately during the project's procurement phase.

Bidders interpret the design intent directly from the contract documents published during the project's advertisement. The contract documents are traditionally based on two-dimensional (2D) construction plans and specifications, which often lack the level of communication necessary to explain the design intent. This communication approach leaves the contractor to assume a level of risk when preparing a bid and planning the construction means and methods. These assumed risks can be costly, but more importantly, they become the owner's to bear as the project moves on to construction.

Figure 1: A 3D Rendering Showing the Complex Erection Sequence for an Overpass in the I-95 New Haven Harbor Crossing Corridor Improvement Program.[1]

1 Image courtesy of WSP | Parsons Brinckerhoff and the CTDOT

This project delivery challenge can be overcome by using three-dimensional (3D) and four-dimensional (4D) models during the procurement phase and keeping them up-to-date during construction. A 4D model is a visualization approach for communicating the design intent and time expectations by combining the engineering design model and the project schedule to develop a simulation of the sequence of construction activities.

The I-95 New Haven Harbor Crossing

The I-95 New Haven Harbor Crossing Corridor Improvement Program is a multi-year, multimodal transportation project that started in 2000 and was substantially complete by November 2016. The program used a total of 28 construction contracts to complete various phases of the project, including public transit enhancements, highway capacity improvements, and replacement of the Pearl Harbor Memorial Bridge that spans the Quinnipiac River (locally known as the Q Bridge).

Figure 2: Rendering of Proposed Reconstruction of the I-95/I-91/Route 34 Interchange (I-95 Harbor Crossing)[2]

This project involves multiple staging of roadway improvements over the 7.2 miles of the I-95 urban corridor running through New Haven, Connecticut, connecting the traffic between New York and Boston. Managing live traffic during the reconstruction of the bridge and interchange in this heavily congested area makes this a high-risk improvement project—an ideal choice for the use of 4D models to assess and mitigate potential project risks.

Although the CTDOT did not require the use of 3D and 4D models, the agency's program manager[3] recommended their use to aid in construction planning and to enhance project collaboration and communication. The CTDOT agreed that a visualization of the project would be helpful in identifying issues with construction staging, which was the main concern. The agency provided approval for the program manager to develop all the digital models, and a contract modification was issued to pay for all associated cost. After seeing the initial model, the CTDOT decided to share it with contractors during the advertisement phase for informational purposes only. A liability statement was included in the contract for using the 3D model, making the 2D plans the ruling contract documents.

2 Image courtesy of WSP | Parsons Brinckerhoff and the CTDOT

3 The CTDOT's program manager for the I-95 New Haven Harbor Crossing was engineering firm WSP | Parsons Brinckerhoff.

Construction Partnering for Digital Modeling

Once a construction award was made, the agency continued to pay for all associated work to update both the 3D and 4D models during construction. The contractors agreed to collaborate with the program manager by providing their individual schedules on a monthly basis, which were then combined to produce the Program Master Schedule. The contractor and program manager used the models for verifying timelines of separate contracts, as well as means and methods for construction. The CTDOT used the models for public outreach, especially to communicate major traffic shift changes. The biggest benefit to the contractors was seeing how the work in separate contracts would impact each other's schedules.

Ultimately, the agency's goal was to use 4D models to reduce risk and costs while expediting project delivery, increasing safety and efficiency throughout the life of this complex, multi-contract program. The production and use of digital modeling was only possible through the construction partnering process in which the agency authorized the process, the program manager developed the models, and the contractors provided detailed schedules on a monthly basis to help develop the 4D models.

> "Once we realized the value of 3D and 4D models, we decided to share our models for information purposes during the advertisement phase to show bidders our design intent. We want to incorporate more modeling in future projects to identify conflicts and reduce risk, which ultimately result in cost savings. The long term goal is to provide it as a contract document instead of for information only."
>
> *– Domenic A. LaRosa, P.E., District Engineer, Construction District 3 and 3A, CTDOT*

Modeling Approach

Because there were no 3D modeling requirements in the original design contract, the program manager had to use the 2D plans to create a 3D model that would facilitate technical analysis, project communication, visualization of construction sequences, and illustration for public information. The fourth dimension was added to the model by including the schedule information.

- Several commercial off-the-shelf software (COTS) packages were used to develop the 3D and 4D models, specifically: Bentley® MicroStation and DesCartes
- AutoCAD® Civil 3D® (C3D) for 3D modeling
- Autodesk® 3ds Max Design for photo-realistic rendering and animation
- Autodesk® Navisworks® Manage for 4D modeling
- ORACLE® Primavera P6

The 3D models were created to simulate the construction process as accurately as possible. The program manager modeling team used the survey data (including laser scans and digital terrain models) to create the existing infrastructure, then added proposed project elements from the conventional 2D drawings developed in MicroStation into AutoCAD C3D. Once the C3D model was created, it was imported into 3ds Max Design for creating a photo-realistic rendering and animation. Because this model was intended for public information, the modeling team added surrounding context (e.g., vehicles, signs, landscaping).

A construction planning scheduler developed a master program by combining all individual contract schedules. This process provided the foundation for the sequence of construction activities to simulate in the 4D model. Initially, the 3D model was not properly segmented to tie to a schedule. Thus, a lot of time was spent breaking up 3D elements to fit within standard construction activities.

Once the 3D model and the schedule were completed, they were imported into Navisworks Manage to add the fourth dimension (time). Geospatial 3D data (i.e., LiDAR[4] point cloud) was also used in the 3D and 4D models.

An illustration of the workflow for creating the 4D model animations is shown in Figure 3.

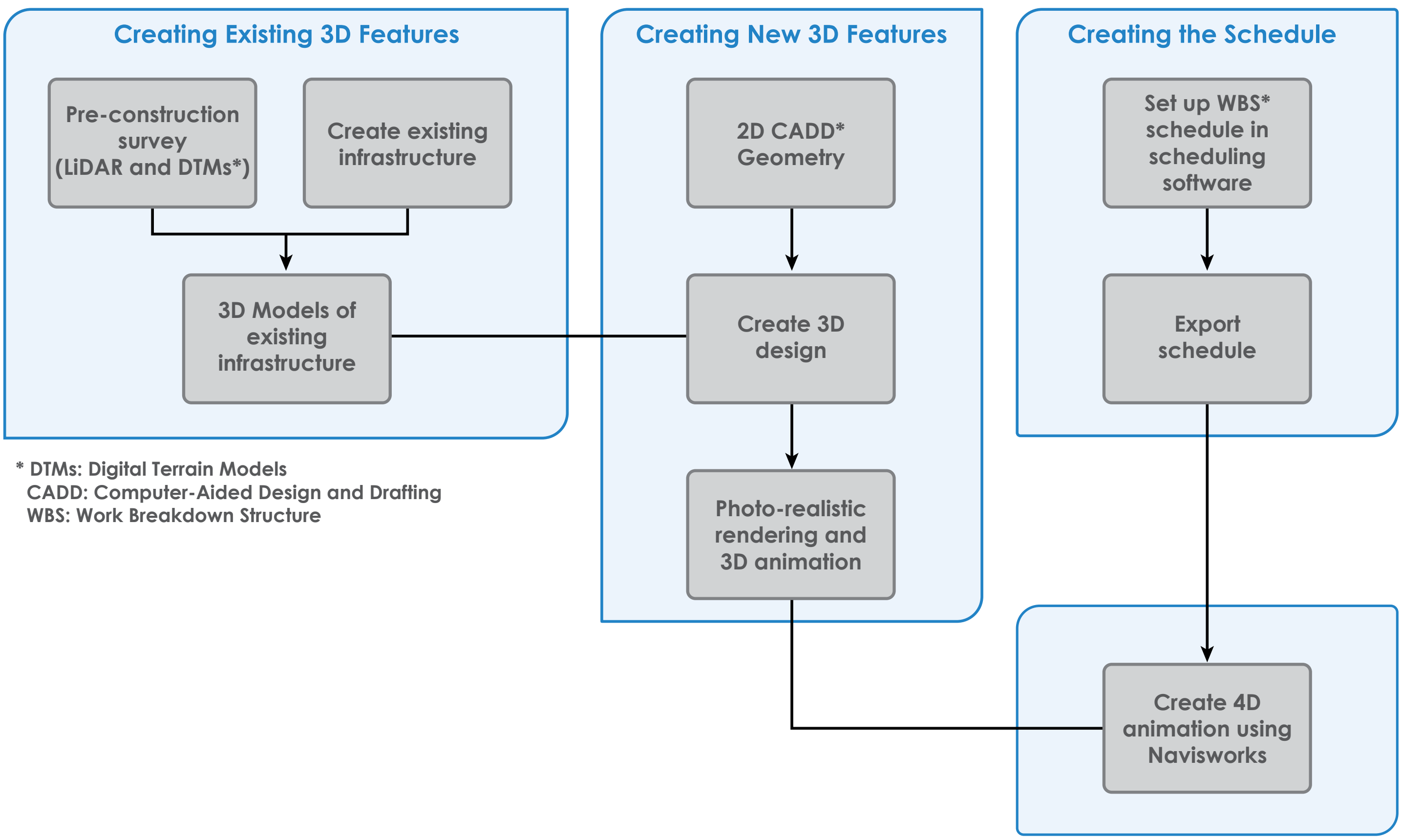


Figure 3: Workflow Used to Create 4D Model Animations

The initial level of detail used for the development of the 4D model was not very refined, but as the project moved from procurement to construction, the program management team collaborated with the contractor to refine the model using the resource and cost-loaded schedules developed precisely using the means and methods planned for construction.

4 Light Detection And Ranging

Challenges and Lessons Learned

The most notable challenge was the need to create the 3D model after the design was completed. If the design plans had originally been 3D-driven, it would have been much simpler to tie the individual components to the schedule activities. In the future, the CTDOT is moving forward with designing in a 3D environment from the beginning in order to realize all the benefits associated with this design method, such as 4D modeling, more accurate calculation of quantities, and class detection.

The CTDOT learned through the process that Global Positioning System (GPS) technology was a tool that enabled the use of 3D models for field use, so a provision in the contract to allow the GPS technology for construction engineering and inspection (CE&I) was added.

> "We are huge proponents of digital modeling (3D/4D) because it provides many benefits. In the design phase, digital modeling is used to communicate design intent, validate schedule logic, coordinate between multiple contract schedules, evaluate constructability, calculate more accurate quantities, etc. For the contractor, models are valuable tools they can use to determine their means and methods, identify conflicts, coordinate materials and equipment, and create a safety plan."
>
> *– Joe D'Agostino, P.E., Deputy Program Manager*
> *WSP | Parsons Brinckerhoff*

Summary

Risk management is a significant component of the project delivery process and an onerous task. Now, transportation professionals have tools at their disposal to make that task less difficult. The successful use of 4D models on large, complex projects is paving the way for the adoption of this technology as a standard risk management practice. Although the practice is nascent in the transportation industry, the CTDOT has demonstrated it is a proven and effective way to reduce risk, which translates into cost savings and ultimately delivering projects on time and within budget.

For additional information about this EDC Initiative, please contact:

Domenic LaRosa, P.E.
District Engineer, Construction District 3 and 3A New Haven
Connecticut DOT
Email: *Domenic.LaRosa@ct.gov*

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 Mgmt Eng
FHWA Resource Center — Atlanta
Phone: (404) 562-3669
Email: *David.Unkefer@dot.gov*

Every Day Counts (EDC), a State-based initiative of FHWA's Center for Accelerating Innovation, works with State, local and private sector partners to encourage the adoption of proven technologies and innovations aimed at shortening and enhancing project delivery.

U.S. Department of Transportation
Federal Highway Administration

FHWA-HIF-17-025