3D Engineered Models:
Schedule, Cost and Post-Construction

PROGRAM CASE STUDY

This case study highlights the approach taken by the NYSDOT for establishing request for proposal requirements for the Kosciuszko Bridge project to incorporate 4D and 5D modeling for tracking the progress of activities and issuing payments during the construction phase.

"We can use this technology to streamline and improve a lot of the things we do. The models improve the constructability of the plans, so we get better bids from the contractors. We can also finish projects quicker and with fewer problems, which saves money."

– Craig Ruyle, P.E., NYSDOT Regional Construction Engineer

4D and 5D Modeling: *NYSDOT's Approach to Optimizing Resources*

State transportation agencies (STAs) are tasked to provide a safe transportation system that moves people and goods within the state's jurisdiction. However, the aging infrastructure and continued crisis of limited funding create a challenge that requires STAs to look for better ways to avoid schedule delays, minimize risk, and control cost through the project delivery process. Agencies can benefit from an approach to better manage transportation projects using data models that incorporate schedule and cost information into a visual simulation of the construction phase. This approach uses the three-dimensional (3D) design model along with the project schedule and cost to create four-dimensional (4D) and five-dimensional (5D) models, respectively.

The New York State Department of Transportation (NYSDOT) has made beneficial use of 4D models in large and complex projects in the New York City area and recently established 5D model requirements for the Kosciuszko Bridge project.

Project Overview

The Kosciuszko Bridge project is a complex design-build project in the NYSDOT's New York City Region (Region 11). The project will replace the original 1939 truss bridge connecting the Brooklyn and Queens boroughs in New York City. The construction of the project will be completed in two phases under two different contracts. The contract for Phase 1, which is the focus of this case study, includes design and construction of the following:

- The eastbound main span and approaches at each end of the structure
- The eastbound and westbound connectors, including an interchange with the Long Island Expressway
- A new pedestrian bridge
- A portion of the Meeker Avenue Viaduct
- The demolition and removal of the existing bridge, approaches, connectors and portion of the Meeker Avenue Viaduct
- The preliminary design of the westbound main span and approaches

The contract notice to proceed (NTP) was issued on May 23, 2014, and has a completion date of December 30, 2017. The project is running ahead of schedule, and it is anticipated to have a substantial completion date of November 22, 2017, when the public will have unrestricted use of the bridge. The project scoping documents, photographs of the construction site, current project status, schedule, and construction costs to-date can be accessed through the Kosciuszko Bridge project web page[1].

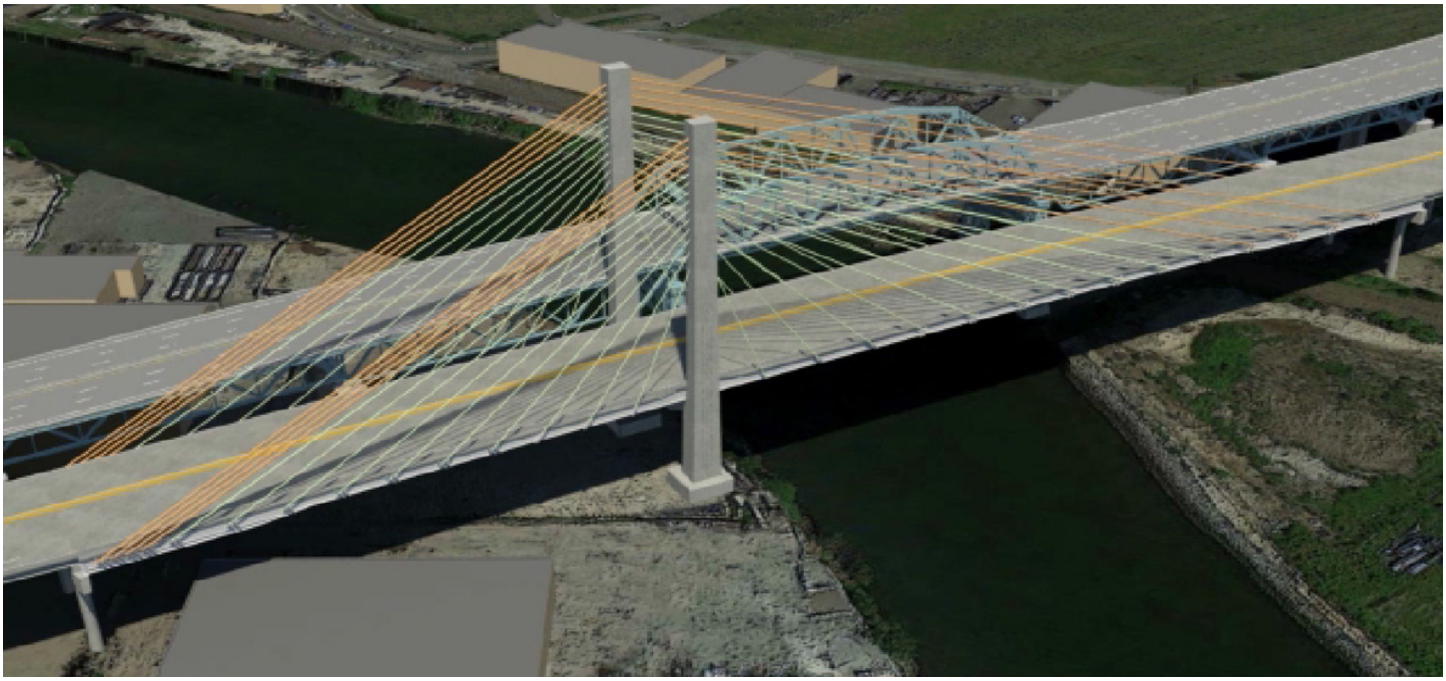

Figure 1: Kosciuszko Bridge Animation[2]

Developing Requirement Specifications for 4D and 5D Modeling

The NYSDOT standard construction contracts for all projects include scheduling requirements to ensure the work will be completed in accordance with the contract timeline by closely tracking progress and performance. The goals for implementing scheduling requirements are to reduce delays and claims and to aid staff in the successful delivery of construction contracts.

The scheduling requirements are defined by contract value and complexity as either Type 1 or Type 2 progress schedules. Type 1 progress schedules are considered to be a generic bar chart with logic, while Type 2 are required to be developed in Primavera® P6 scheduling software using a critical path method (CPM).

Type 2 schedules are further subdivided into 2A, 2B, and 2C. Type 2A schedules are a basic CPM with no resource loading and, together with Type 1, make up about 95% of NYSDOT projects. Type 2B schedules introduce a high-level resource loading (e.g., crews and heavy equipment) and are used for projects exceeding $100 million. Type 2C schedules require full resource loading for the entire project and have a specified work breakdown structure (WBS) that could be used for managing payments in design-build projects. Type 2C schedule requirements are used for "mega projects" ($200-$300 million).

The NYSDOT WBS has six standard levels for CPM progress schedules (shown in Figure 2).

1 *https://www.dot.ny.gov/kbridge*

2 Image courtesy of NYSDOT

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Project Level	Pre-Construction Activities Construction Activities Post-Construction Activities	Pre-Construction Activities by Geographic Areas	Areas of Work	Stages of Work	Highway Features
		Submittals, Shop Drawings Activities, Procurement, Fabrication Activities	Sub-Nodes for Stages of Work	Sub-Nodes for Highway Features (e.g., Bridges)	Components (e.g., Highway Segments: pavement, drainage, etc.)

Figure 2: NYSDOT Work Breakdown Structure for Progress Schedules

The RFP for the Kosciuszko Bridge included 4D and 5D modeling requirements (Type 2C CPM schedule). The project requirements included a cost-loading component to the CPM schedule, making it the first bridge project to require the contractor to provide a 5D model.

The modeling requirements were created for the purpose of tracking progress and, more importantly, for issuing interim payments toward the number of aggregate lump sum payment items. In addition, the visualization models provide a way to evaluate and monitor the planned construction activities after contract award. Specifically, the Kosciuszko Bridge project requirements called for the development of a 3D design model to support 4D and 5D models of key elements or construction activities.

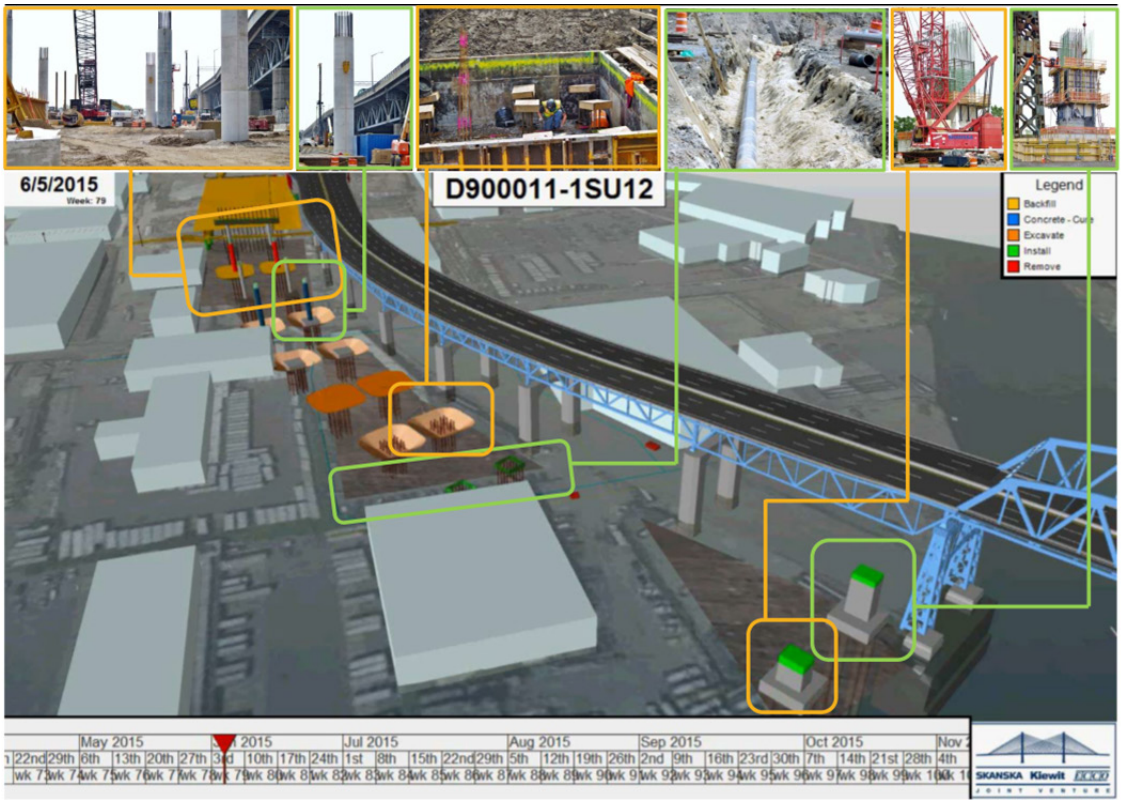

Figure 3: Comparison of an As-Built 4D Model and Site Photographs on a Specified Day[3]

The 3D model was defined as a virtual model containing the representation of physical objects in 3D (x, y, and z) as surfaces or solids. The requirements also included the use of 3D animations and 4D schedule simulations as visual aids to be used during the proposal evaluation process. These visualization models helped the owner

3 Image courtesy of NYSDOT, Skanska-Kiewit Joint Venture, FHWA, and WSP | Parsons Brinckerhoff

understand the design intent and construction methods and sequence of activities. This made it much easier for the NYSDOT team to review each proposal, as opposed to flipping through hundreds of plan-sheets and large-format Gantt chart plots. In addition, the submitted 3D animations and 4D simulations would also be used for public outreach.

All progress payments will be generated from the 3D model and cost-loaded CPM schedule (4/5D models), thus requiring the design-builder to also develop and maintain the 5D model. The agency's intent for this design-build approach was to use the models as part of the design process and update them as the project was constructed.

Other requirements for the development of the models included the type of software to be used for the 3D model elements and cost-loaded schedule. The contract required the design-builder to use the following software packages:

- Bentley® MicroStation® dgn format for developing the 3D models to support the 4/5D models
- Oracle® Primavera® P6 format for developing and maintaining the cost-loaded progress schedule
- Synchro® Professional or Autodesk Navisworks® or approved equivalent for developing the 4/5D models and 4D schedule simulations
- SpringBoard data and software hosting cloud-based project management service

In addition, the design-builder was required to use the agency's computer-aided design drafting (CADD) standards. The NYSDOT also required any software packages not already owned by the agency to be made available for the duration of the contract, with concurrent access to the current models. Because the agency already owned and used Bentley MicroStation and Oracle Primavera software packages for everyday operations, only Synchro Professional needed to be provided.

Data Management and Training Requirements

The agency required the design-builder to provide a model management plan and a designated CADD/model manager, because the models were complex and the 5D models were to be the basis for processing payments. The purpose of the model management plan was to establish a strategy for creating and maintaining the models, keeping track of the software being used, managing change while keeping models current with the project activities and milestones, providing quality control and assurance for all models, and defining the roles and responsibilities for the modeling team. The CADD/model manager's responsibilities were to manage, direct, and review all project CADD production, modeling, animation, and schedule simulation activities and serve as the point of contact for all modeling and simulation-related activities.

The contract also had requirements for the contractor to host 4D and 5D model workshops to review the logic and understand how to work with the data. Delivery of a digital, 3D as-built model for the project was also a requirement.

3D and 4D Modeling Approach

All schedule activities from the 4D and 5D models needed to be uploaded into SiteManager® to process the payments through the agency's official construction management system. In order to manage the payment items, the project was divided into seven major items for high-level payments, which then would be broken into categories and subcategories of activities. The seven major items are listed below:

- Design-build design services
- Design-build construction inspection services
- Design-build quality control services
- Design-build force account work
- Design-build site mobilization
- Design-build construction work
- Design-build partnering workshop

The construction inspection services category was further divided into 34 different payment items. The design-builder was required to produce a monthly report of all the completed activities using the payment items in the 4D/5D model, which then would be loaded into SiteManager for payment.

The schedule organization drove the development of the 4D model and was most critical to the success of the 5D modeling exercise. As such, the detail of components in the 3D model needed to match the schedule activities. The designer created 2D CADD drawings that then needed to be converted to 3D model elements. In the meantime, the scheduling team created the cost-loaded CPM schedule. The process to create the 4D schedule simulation is described in Figure 4.

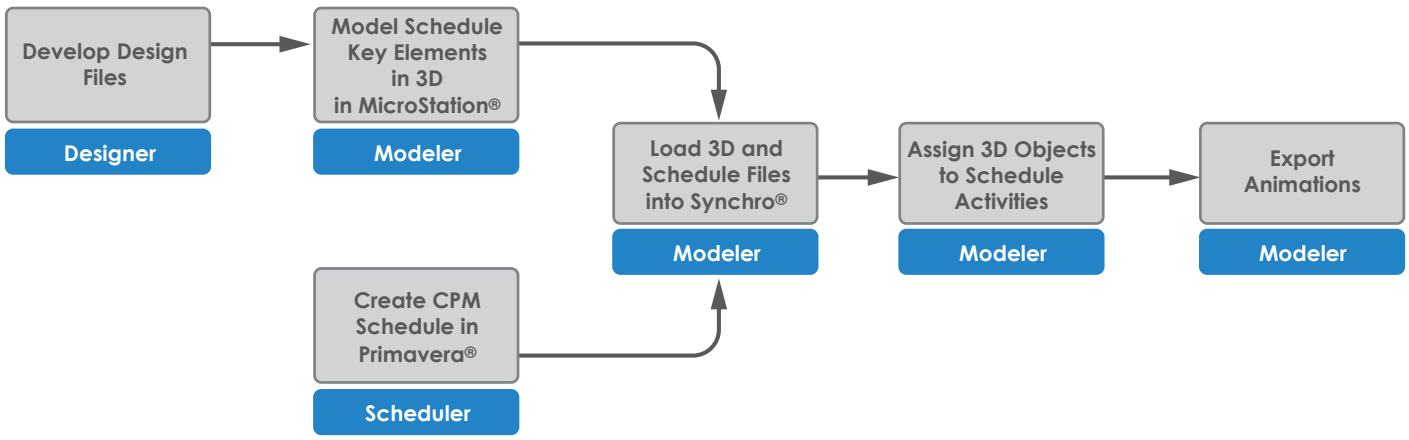

Figure 4: Overview of the 4D Modeling Process for the Kosciuszko Bridge Project

Challenges and Lessons Learned

Both the design-builder and the NYSDOT had to overcome a few challenges during the design-build process. The first challenge was associated with meeting the requirement to store and update all modeling files through the project's SpringBoard server. All software packages used in developing and updating the 4D/5D models had to be loaded on the server. The size of the Synchro files and software system requirements exceeded the capacity and bandwidth of the server. In addition, when a software update was required for Synchro, the update had to be completed by the service running on the server. Furthermore, when the SpringBoard server encountered technical issues, the team had to wait until the issue was resolved to continue working. The solution to the problem was to run Synchro from a local machine, update the files to the SpringBoard server on a weekly or bi-weekly basis, and provide 4D animations on a monthly basis.

The second issue was the assumption that the design would be developed using 3D models. The designer had to use a variety of software packages to develop the design, and the contract documents were created from 2D drawings, which was a missed opportunity for creating efficiencies in the design process.

Following are the lessons learned identified as part of the challenges and processes during the project:

- Provide timely and appropriate training to team members.
- Have dedicated staff with strong technical skills to build and maintain the models.
- Establish the 3D design components early on to meet the needs of the 4D model.
- Understand all the initial investments required to develop the skills and the infrastructure to support 4D and 5D models.
- The contractor is the appropriate party to maintain the 4D and 5D models for a design-build project.
- It is important to keep a full time scheduler on site for a project of this size and complexity.

Summary

The NYSDOT has set the goal of using 3D engineered models as part of the construction process as a standard enterprise practice, and 4D models have been a requirement for a number of projects. The use of 4D and 5D modeling on the Kosciuszko Bridge was based on the desire for developing a process to optimize human and financial resources while being transparent. The NYSDOT developed this set of specifications to guide the process from the beginning of the project using already established 3D modeling CADD standards and practices for developing CPM schedules for creating 4D models. The extra step to add a cost-loaded schedule for creating 5D models has proven to be a transparent approach for controlling cost and issuing interim contract payments for a design-build project.

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