Guide for

Creating and Maintaining 4D Models

Fall 2016

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models:

Schedule, Cost, and Post-Construction

*An **Every Day Counts** Innovation*

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Creating and Maintaining 4D Models

Introduction

Using four-dimensional (4D) models for construction project management is not a new concept. However, 4D models may be used differently in traditional delivery methods, in which there is no contractual relationship between the designer and the contractor, verses how they are used by a design-build team, which works collaboratively to develop the design to support the contractor's specific means and methods.

To create a 4D model, which is done in commercial off-the-shelf (COTS) 4D simulation software such as that shown in Figure 1, each work item in the schedule must be connected to discrete three-dimensional (3D) objects. The process of creating the 4D model in the COTS software is relatively straightforward. However, the person performing these connections must be able to navigate through 3D models and read construction schedules.

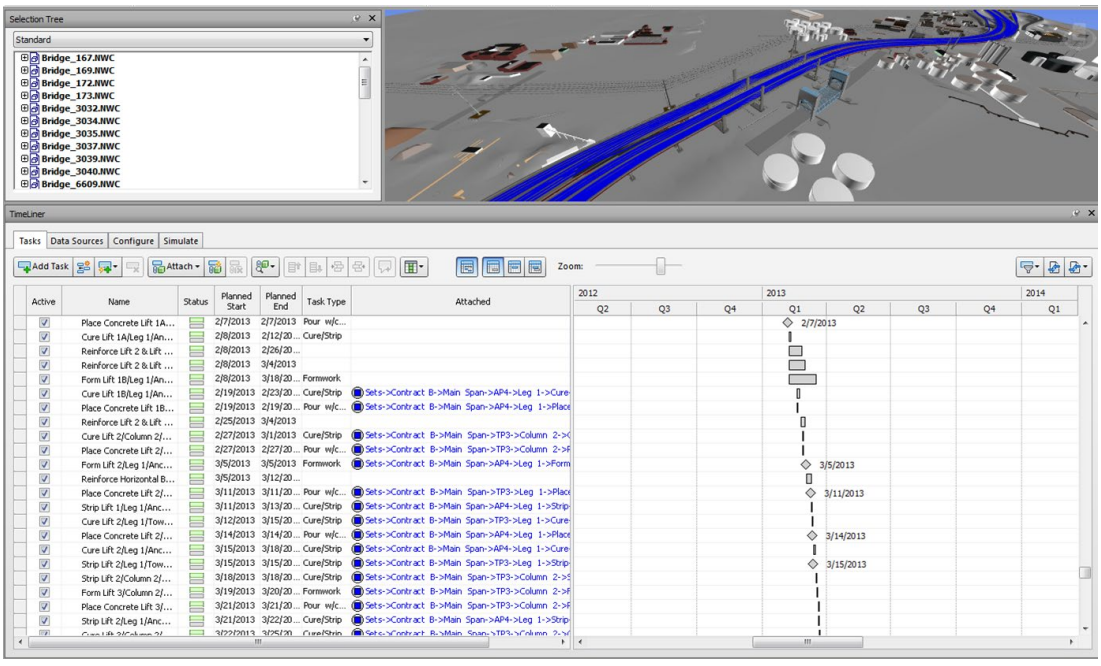


Figure 1: A screenshot of a 4D model in COTS software[1]

1 Image courtesy of WSP | Parsons Brinckerhoff

Many state transportation agencies (STAs) have already established practices for producing designs and schedules that can be incorporated into the process for developing 4D models. A 4D model should be planned in advance of developing both the 3D model and the critical path method (CPM) schedule so that the two can be aligned in detail to the extent necessary to fit the purpose of the model. The level of detail, visual quality, and engineering precision in both the 3D model and the CPM schedule will differ depending on the purpose of the 4D model.

Creating and Updating a 4D Model

Figure 2: This 4D model communicates traffic staging and necessarily includes the whole project.[2]

The decision to create or impose a requirement for a 4D model on a project will be generated in the context of a specific purpose. The purpose will provide necessary information regarding the target audience, construction activities that need to be simulated, geometric accuracy for the 3D model, and the types of products to be output from the 4D model. Some 4D models, such as the 4D model used to communicate traffic staging in Figure 2, may cover both the full extent of the project limits and the full duration of construction.

A 4D model for activities during a short full closure, for example during accelerated bridge replacement (Figure 3), would only need to include those specific activities. These are likely a subset of a larger CPM schedule and 3D model. The next step is to establish the requirements for both the 3D model and the schedule.

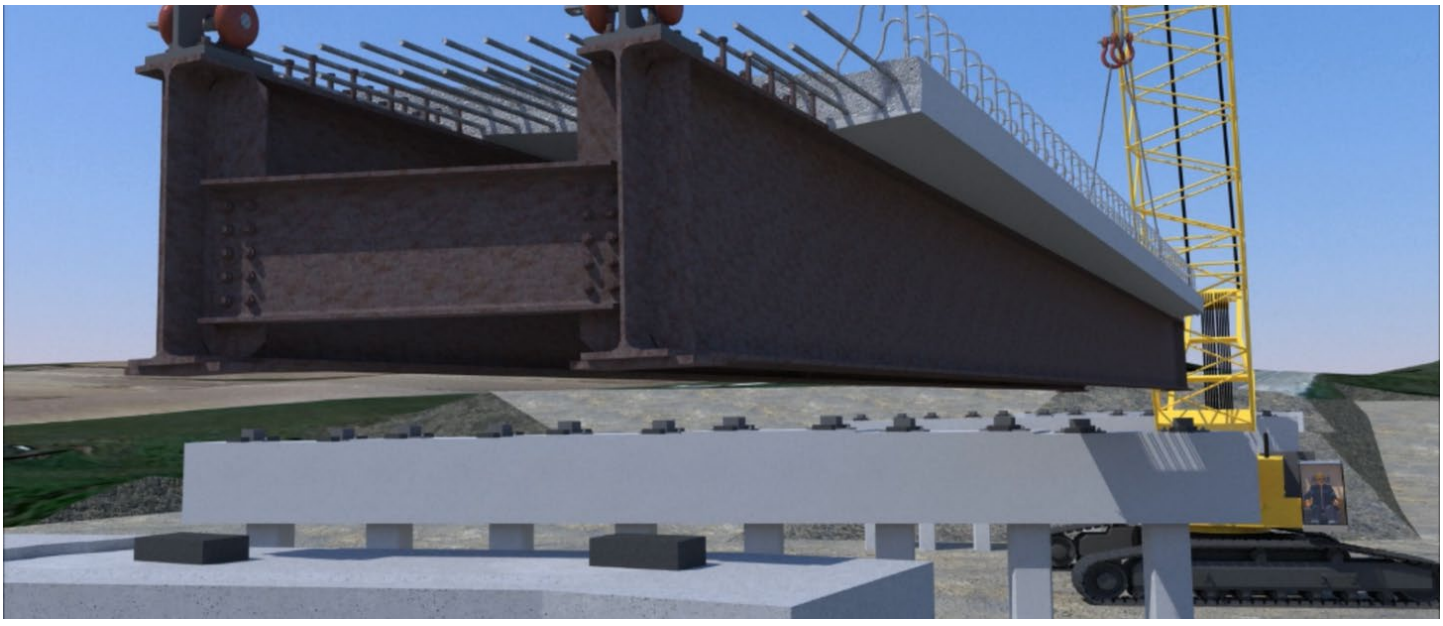


Figure 3: This 4D model has more detail, but only includes the bridge work area.[3]

2, 3 Image courtesy of WSP | Parsons Brinckerhoff

Developing the Schedule

The schedule is normally created by the construction contractor, so any requirements for task naming or work breakdown structure (WBS) organization need to be clearly communicated in the bid documents. Schedule requirements are often defined by the level of detail tied to a particular WBS, but schedule organization can be important for 4D modeling. Many STAs already have established CPM scheduling processes with multi-level, hierarchal WBS requirements that can be used for creating a 4D model, but guidance for WBS organization may need to be added. A standard WBS used in transportation projects is illustrated in Figure 4.

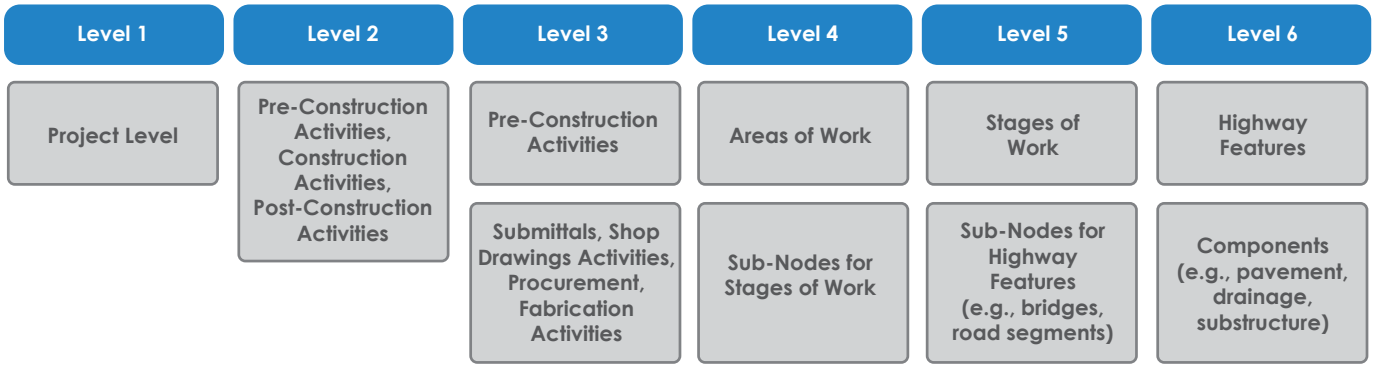


Figure 4: Example of Standard WBS Used in Transportation Projects

Schedule organization may be important for several reasons. One is that tasks must be uniquely and consistently named. This is especially important for automating updates as construction progresses and the schedule is updated routinely. Another reason is if the schedule will be tied to contract payments. Often, bid items used for contract payments reflect several discrete construction activities in the WBS. If there is a need for a five-dimensional (5D) model that has meaningful correlation with contract payments, then the contractor may need guidance to develop a WBS that aligns to these bid items.

Developing the 3D Model

The level of detail should be defined based on the purpose of the 4D model, and it can range in complexity to meet agency needs. The design model can be a significant source of 3D model content, but the contractor may need to furnish additional 3D model content reflecting interim staging, falsework, and equipment.

There may also be a need for a 3D context model. This is a model of landmarks and the nearby area outside of the project limits that enables viewers to orient themselves. Context models are more common when the public is the target audience for the 4D model.

Figure 5 illustrates the key considerations for determining levels of detail for the 3D model, including visualization needs and schedule details. It is important to note that the level of detail in the 3D model should be developed closely in concert with the scheduling detail that needs to be determined early in the process. The level of detail and geometric accuracy needs may vary for different components of the 3D model. For instance, the context model does not normally need to have high accuracy or detail.

Levels of Detail	Modeling Considerations: Basis of Design	Visualization Needs	Schedule Details
Level 1	• 2D CADD Drawings + Aerial Photos	• Communication for Public Involvement (non-technical) • Communication for Contract Review	• Major Milestones + High Level WBS
Level 2	• Low Density/Low Detail 3D Corridor Model	• Communication for Public Involvement (non-technical) • Preliminary Technical Review (Project Delivery Team)	• Major Milestones + High Level WBS
Level 3	• High Density/High Detail 3D Corridor Model	• Communication for Public Involvement (non-technical) • Project Technical Review (Project Delivery Team)	• CPM Multi-level WBS for Specific Activities
Level 4	• High Density/High Detail 3D Corridor Model • Pre-fabrication and Shop Models • 3D Bridge Models	• Communication for Public Involvement (non-technical) • Constructability Technical Review (Construction Team)	• CPM Multi-level WBS for Entire Project
Level 5	• Pre-fabrication and Shop Models • 3D Bridge Models	• Communication for Public Involvement (non-technical) • Constructability Technical Review (Construction Team)	• Cost Loaded CPM Multi-level WBS for Entire Project (5D)

Figure 5: Considerations for Determining Level of Detail for 4D Models

Creating the 4D Model

Once the design and the schedule are developed, they can be merged. The CADD (computer-aided design and drafting) geometry should be mapped to the schedule tasks using rule-based automation to allow dynamic synchronization with later schedule updates. Generally, it is recommended that geometry selection sets be built that align with the relevant schedule task names, followed by configuration of the automated rule-based mapping to selection set names. Naturally, this works best when the scheduler maintains structure and discipline when setting task names. Once the task names are set, they should not be modified as such changes break the mapping relationships, requiring significant rework to restore. Figure 6 illustrates the workflow for creating a 4D model.

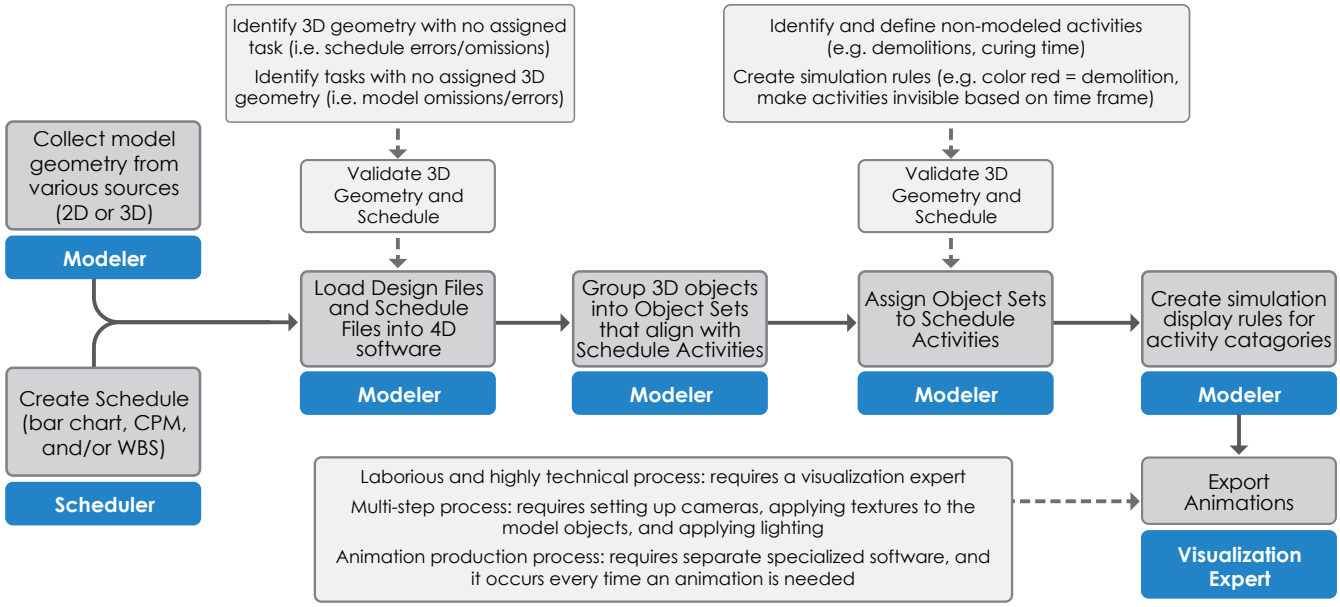


Figure 6: Workflow for Creating a 4D Model

Updating the Models

Model updates are like any other task in the contract administration of a project. Therefore, it is critical to set specifications for creating and maintaining models throughout the construction phase. The model's creator is typically the party responsible for its maintenance, but it is necessary to establish specifications defining the responsibilities and roles of all involved parties. Setting clear standards for schedule organization and task naming will help automate the process of updating the 4D model as construction proceeds. Also, there needs to be facility for potential design changes and for changes in the contractor's planned means and methods. Some of these means and methods may only be developed as construction progresses, so the updates may involve adding more tasks in the WBS as well as new 3D content.

Additionally, for the 4D model to be useful, it must be updated frequently while maintaining a balance between level of effort and benefits. In the design phase, design changes drive the 4D model updates more, whereas in the construction phase the schedule changes become the larger driver.

The 4D modeling specifications should include a model management plan that outlines the strategy for keeping models up-to-date with construction progress and submittal of progress documents. This management plan should include the following components:

Responsibilities and roles – specifies who is responsible for updating the model and outlines the requirements for the modeling team. The team should include, at minimum, a scheduler and a 3D modeler with experience developing models using the specified software packages.

Hardware/software – defines the specific types and versions of the software to be used for creating and updating CADD data, 3D and 4D models, and the progress schedule including the desired file formats. These requirements should also include accessibility to editing the models behind the agency's firewall or methods for submitting external data.

Schedule submittal – determines the frequency of submittals, which should coincide with specified progress schedule documentation. It is recommended that a routine for periodic updates be defined to prevent ad hoc updates to the model. The contractor and the agency should mutually agree on the interval for updating the model. Certainly, particular project urgencies must guide the decision.

Product deliverables – describes the types of products to be delivered to the agency for interim and final milestones in the project.

Quality control (QC) and quality assurance (QA) plan – defines the strategy for auditing changes to 3D and 4D models and defines the roles and responsibilities of the modeling team.

Updating 4D Models during Design

Updating a 4D model during design should take place at minimum at design milestones, and it may be used to identify higher-level schedule problems. A status 4D model should be prepared for periodic project design coordination meetings. The update period may tighten in the last phases of design in the heightened urgency to correct any classes prior to advertisement. The agency can use the 4D model to communicate design intent, means and methods, and sequencing of work to subcontractors in pre-bid meetings.

Updating 4D Models during Construction

After an award has been made, the model takes on greater complexity and thus deserves closer scrutiny as the contractor has more clarity about temporary structures, laydown areas, exclusion zones and equipment, and overall means and methods. Thus, the updating of the 4D model is likely driven by new factors, for example the need to generate look-ahead schedules. Project teams might update the design model and schedule regularly and run the 4D simulations each week to create 14-day and 42-day look-ahead views of currently planned activities.

It is recommended that 4D model meetings be held at predetermined intervals to better manage processes during construction. The meeting should be led by the party responsible for creating the 4D model, and all subcontractors' field supervisors whose tradesmen will work that month should address the projected period of work. Also, there may be new opportunities to add 3D model content sourced from the subcontractors' scope of work. In the event one or more subcontractors may prepare 3D models for their own execution of work, the content should be incorporated into the coordinated design model. It is important to note that any additional subcontractor models should be reviewed by the agency to ensure consistency with the contract requirements. Figure 7 illustrates the workflow for updating a 4D model during construction.

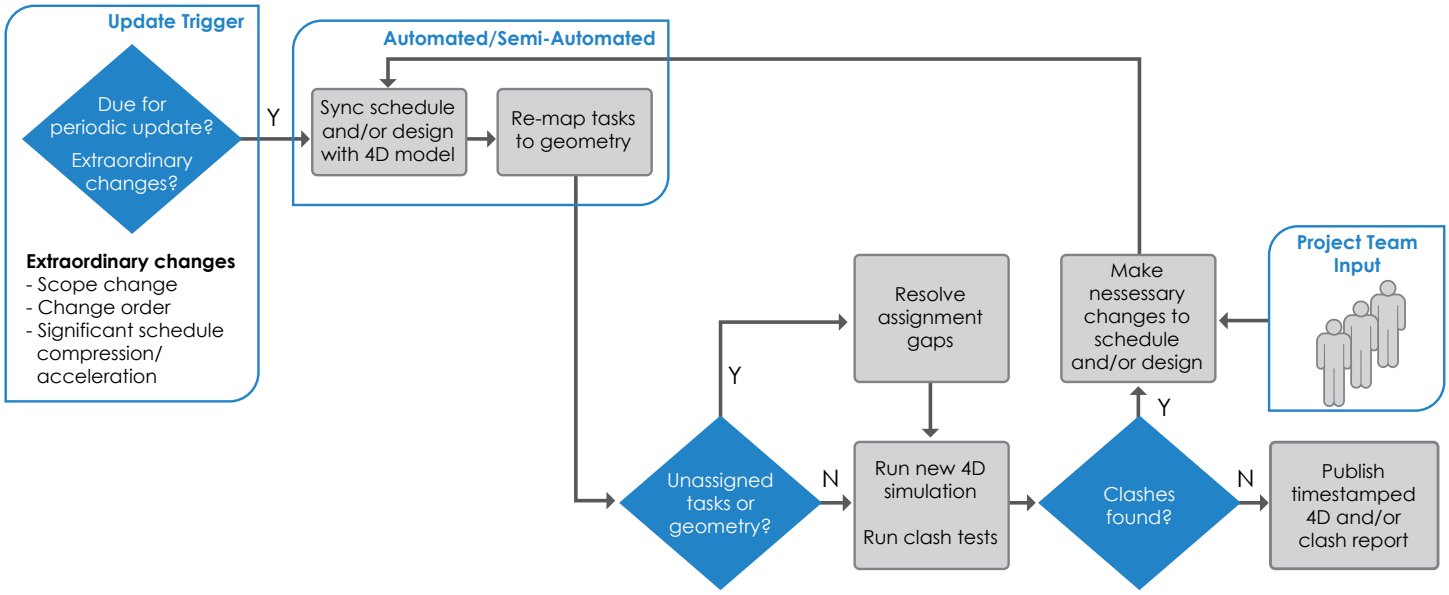


Figure 7: Workflow for Updating a 4D Model during Construction

Using the Models

The versatility of 4D models gives project stakeholders many ways to use them. Examples include constructability review, testing "what-if" scenarios for a particular activity (e.g., equipment mobilization), and validating completed work (Figure 8) through different types of outputs (e.g., videos or static 3D graphics). This flexibility, however, requires skilled visualization staff to prepare the different desired outputs.

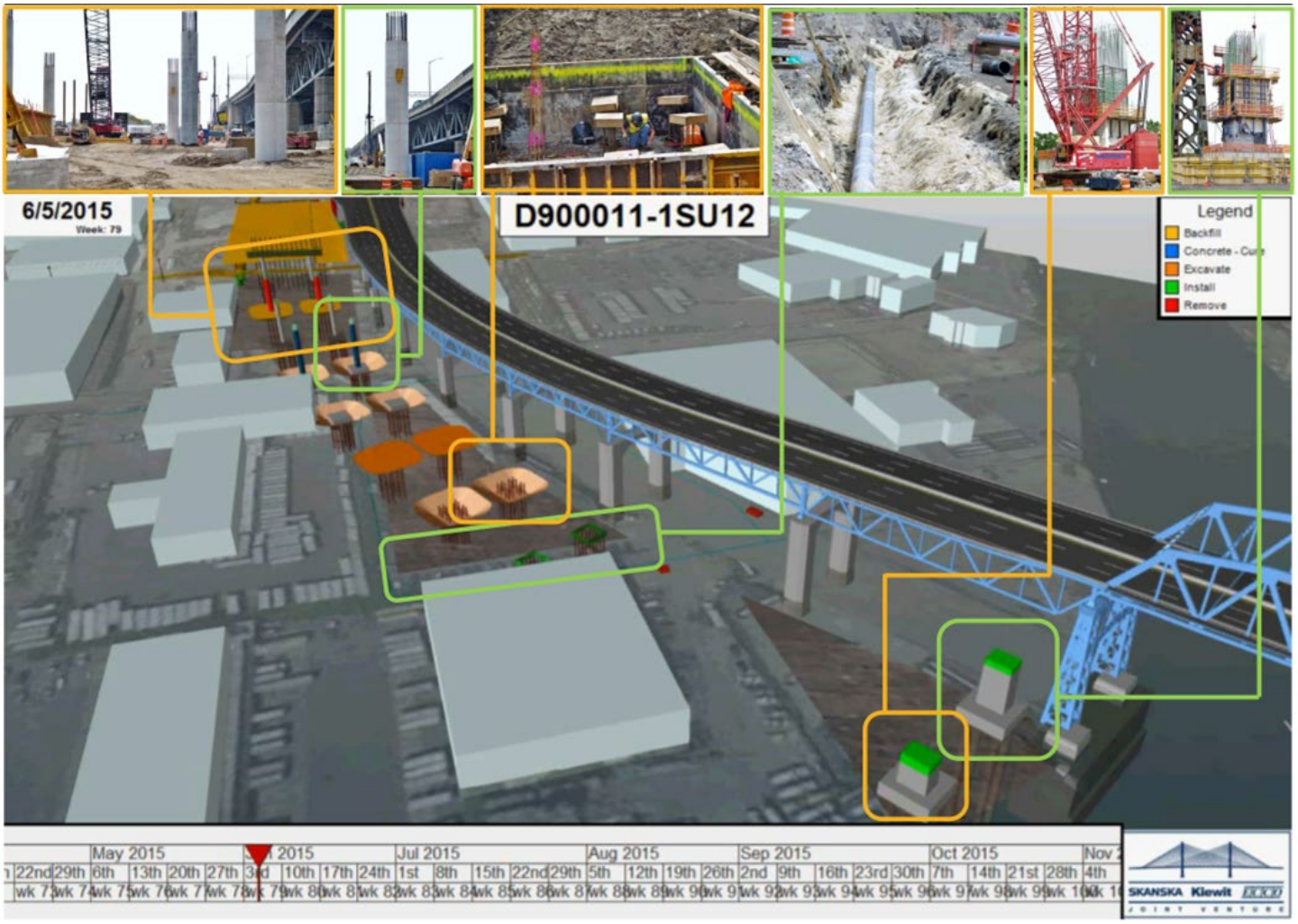


Figure 8: Comparison of an As-Built 4D Model and Site Photographs on Specified Day[4]

Conclusion

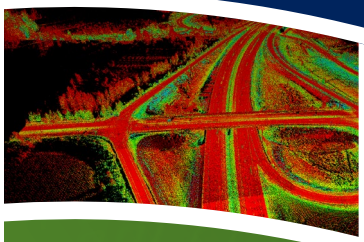
4D modeling specifications should focus on three pilars: schedule development, 3D model development, and 4D model updates. 4D models can serve as another project management tool to help manage risk, enhance efficiencies and safety, and foster collaboration. While challenges may still exist, creating requirements for developing and updating 4D models does not have to be a daunting task when using existing scheduling practices and 3D design methods.[5]

The use of 4D models offers STAs a better way to manage risk and resources. It increases communication with all project stakeholders, and in doing so, it promotes transparency and accountability. The benefits of 4D models not only add value to projects making use of alternative delivery methods, but also enhance project performance when using more traditional means of project delivery.

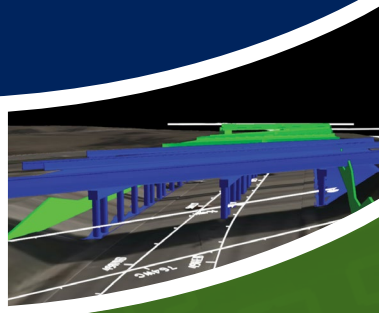
4 Image courtesy of Skanska-Kiewit Joint Venture, NYSDOT, FHWA, and WSP | Parsons Brinckerhoff

5 The New York State and Minnesota Departments of Transportation are two agencies that have developed 4D schedule requirements that can be used for references.

***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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