Guide for

3D Modeling to Advance Utility Coordination in Projects Delivered Using Alternative Contracting Methods

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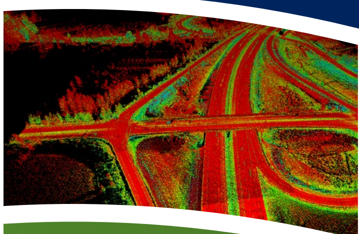



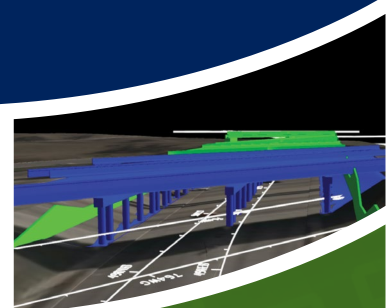

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models:

Schedule, Cost, and Post-Construction

*An **Every Day Counts** Innovation*

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Introduction

Effective utility coordination in projects delivered using alternative contracting methods (ACM) has one common theme: utility issues must be considered as early in the project development process as possible to permit the project delivery team as many options for resolving utility conflicts as practical. In the words of one author, "detection of utility conflicts as early as possible during the project development process can help identify the optimum application of strategies to resolve those conflicts."[1] The objective of optimizing utility strategies is *to avoid relocation where possible*. To achieve this goal, the agency needs to start the utility conflict identification and coordination process at a point where major design definition decisions like final alignment and geometry have not been locked in to the degree that redesigning to accommodate utility considerations is prohibitive. This creates a requirement to reduce uncertainty with respect to utility locations to an acceptable level.

The second Strategic Highway Research Program (SHRP 2) presents a full set of tools for identifying utility locations, including subsurface utility engineering (SUE), ground-penetrating radar (GPR), and radio frequency identification (RFID) tagging. These tools, while apparently reliable, are often insufficient, triggering the need to excavate test holes (commonly known as "pot-holing") to physically locate the utilities in question.[2] At that point, a contractor typically is needed to conduct the exploratory excavations to furnish physical utility location information to the designer. When early contractor design involvement is needed, ACMs provide a proven solution for procuring that capability in a manner that permits utility coordination risk sharing rather than contractual mechanisms designed to shed this ubiquitous risk. Since ACMs bring both design and construction resources to the table, three-dimensional (3D) engineered models can be used as the medium for communicating spatial information for the entire team and its external utility company stakeholders.

1 Quiroga, C., Kraus, E., Le, J., Scott, P., Anspach, J., Swafford, T., and Meis, P., Identification of Utility Conflicts and Solutions: Pilot Implementation of the SHRP 2 R15B Products at the Maryland State Highway Administration. (SHRP 2 Renewal Project R15C). Transportation Research Board, National Academies, Washington D.C. 2014.

2 Dwyre, E.M., Batchko, Z., and Castelli, R.J., "Geotechnical Baseline Reports for Foundation Projects," Proceedings, GeoFlorida 2010: Advances in Analysis, Modeling & Design (GSP 199), Orlando, Florida, 2010, pp. 1-10.

The Business Case for 3D Engineered Utility Models

Unlike other linear highway assets, there is a compelling case for creating and maintaining a 3D model-based information management system for utilities. Other linear assets such as roadways do not have the same amount of third-party project planning issues related to right of way (ROW) or impact on landowners and businesses, nor do they require the level of granularity necessary to detect clashes required by underground utilities. Therefore, in most cases, schemes based on geographic information systems (GIS) are more than adequate. However, managing utility location information in a 3D model is vital through all project phases — cradle to grave. To achieve this, asset information requirements should be clearly identified during procurement and articulated through the solicitation documents.

The agency should be prepared to request and receive this information, intending to *use* the final 3D model during asset operations and maintenance (O&M) rather than just a historical documentation of as-built conditions. This is a major concern because current workflows are not able to integrate this information back into the agency's asset maintenance, management, and future 4R (resurfacing, restoration, rehabilitation, and reconstruction) or capital improvement delivery projects. ACMs call for early contractor design involvement, giving the agency the ability to integrate utility information with other design and construction documentation in a manner that turns the post-construction 3D model into a life cycle asset management tool without the administrative issues found in traditional design-bid-build projects where the designer and the contractor have no contractual relationship.

Alternative Contracting Methods

Figure 1 shows the ACMs that were included in the Federal Highway Administration's (FHWA's) *Every Day Counts* program: Design-Bid-Build (D-B-B) with Alternative Technical Concepts (ATCs), Design-Build (D-B), and Construction Manager/General Contractor (CM/GC). The terminology can be confusing, so for the purposes of this guide, the following definitions are proposed based on FHWA usage:[3]

- Design-Bid-Build: D-B-B is a form of project delivery whereby the contracting agency either performs the design work in-house or negotiates with an engineering design firm to prepare drawings and specifications under a design services contract, and then separately contracts for at-risk construction by engaging a contractor through competitive bidding. Under this arrangement, the contracting agency warrants to the contractor that the drawings and specifications are complete and free from error (contracting agency takes the risk).
- Alternative Technical Concepts: The use of ATCs gives contractors the opportunity to propose innovative, cost-effective solutions that are equal to or better than the contracting agency's design and construction criteria for a project. This contracting approach promotes competition and enables highway agencies to choose design and construction solutions that offer the best value.
- Design-Build: The D-B project delivery method combines a project's design and construction phases in one contract, allowing the contractor flexibility to choose design, materials, and construction methods while assuming the risk and responsibility for both design and construction. This can accelerate project delivery, lower costs, and improve quality.

3 FHWA Every Day Counts website at: *https://www.fhwa.dot.gov/innovation/everydaycounts/edc_innovation.cfm*

- Construction Manager/General Contractor: In the CM/GC project delivery process, the project owner hires a contractor to provide feedback during the design phase on issues such as innovation use, cost and time savings, and constructability. This helps the project owner make better decisions and manage projects with accelerated construction schedules and greater cost certainty.

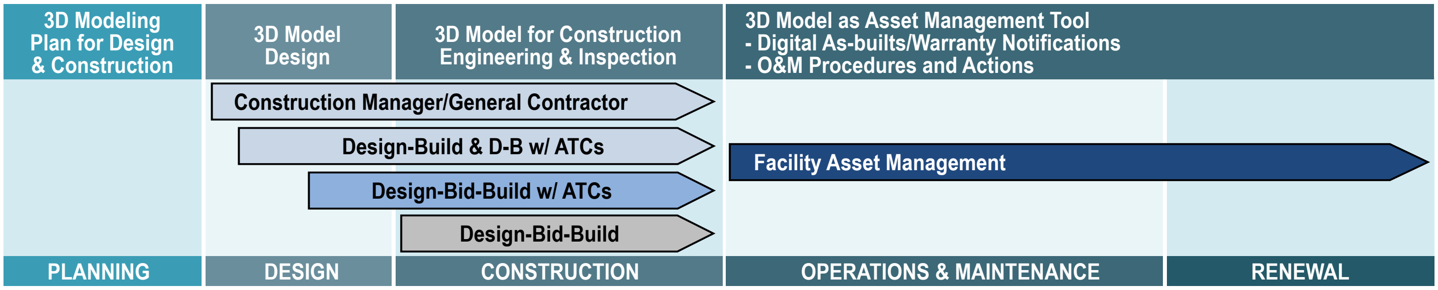


Figure 1: Relating Alternative Contracting Methods with 3D Engineered Models to the Asset Life Cycle

In each of the ACMs, contractor design involvement is provided to the degree established in the specific contract. The amount of contractor design input can range from merely proposing ATCs on a D-B-B project to being fully responsible and liable for both design and construction on a D-B project. When specifically related to utility coordination, the same spectrum applies, from a contractor proposing to change the utility work in a D-B-B ATC, to the contractor being assigned the responsibility for utility coordination in CM/GC, to the design-builder developing the project utility strategy in D-B.

Regardless of the ACM, the salient issue becomes how to relate geospatial information for both preconstruction and post-construction utilities to the ACM project's design. 3D engineered models furnish the flexibility to both describe the utility work during design and construction and archive the completed utility-related data for use in post-construction operations, maintenance, and underground asset management applications.

Defining 3D Utility Coordination Strategies Applicable to ACMs

Much has been written on the topic of utility coordination and conflict resolution on traditional D-B-B projects. However, little, if any, guidance is available for using 3D models as the vehicle within the context of ACM projects. According to a Transportation Research Board SHRP 2 report (S2-R15B-RW-1: *Identification of Utility Conflicts and Solutions*), the strategies noted in the following paragraph can address utility conflicts. Definitions are provided as follows:

- Protect utility in place: Implement an engineering (protect-in-place) countermeasure that does not involve utility relocation or changes to the transportation project alignment.[4]
- Abandon utility in place: Remove the utility from service without physically removing it.
- Relocate before construction: Change the given utility's location on the project site before the construction contractor is given notice to proceed with work.
- Relocate during construction: Change the given utility's location on the project site after the construction contractor is given notice to proceed with work.

4 Quiroga, C., Kraus, E., Scott, P., Swafford, T., and Meis, P., *Identification of Utility Conflicts and Solutions*. Transportation Research Board, National Academies, Washington D.C., 2012.

- Accept an exception to policy: Resolve the utility conflict by permitting a solution that is not within the state's utility accommodation policy.[5]
- Change the horizontal or vertical alignment of the proposed transportation facility: Modify the project's design in a manner that minimizes utility conflicts.

With the exception of relocation, each strategy requires that the decision be made to evaluate the specific viable options at a point early in the design process. The literature cites a number of barriers to making those decisions, including inaccurate location data, reliability of utility information sources, and increasingly congested ROW.[6] In the D-B-B context, the owner supplies an implicit warranty of the quality of the construction documents, which also applies to the utility information displayed in the plans and contained in the project's specifications. The issue is further complicated by the myriad state statutes regarding utility markings for construction safety. Lastly, the impact on traffic when an excavation on a public road begins further exacerbates the pressure felt by state department of transportation (DOT) utility engineers to get the construction completed and the traffic control measures removed.

D-B-B is a linear process, and so integration of various stakeholders during the project planning and design process is minimal. ACMs are a mechanism to gain increasing levels of stakeholder integration and collaboration with regard to project utility coordination requirements.[7] The SHRP 2 R15 Renewal Project titled *Integrating the Priorities of Transportation Agencies and Utility Companies*[8] indicated increasing the level of integration during project development and delivery as a desired outcome for the research. Taking the ACM focus on integration together with the expressed SHRP 2 R15 need to increase integration among DOTs and utility companies provides the fundamental motivation for leveraging the benefits of 3D modeling of utility works using ACMs.

Developing Life Cycle 3D Models for Underground Asset Management

Figure 2 presents a flow chart that illustrates the use of 3D modeling along with ACM delivery (in this case D-B) to develop a life cycle tool for managing underground assets. The chart shows that the process must start in planning. Research has shown that to gain the greatest benefit from ACM delivery, the agency must make the project delivery method selection decision before the project is advanced into the environmental clearance phase. Doing so forces planners to look past the National Environmental Policy Act (NEPA) clearance and out to how the project will be designed and built. The National Cooperative Highway Research Program (NCHRP) Synthesis 455: *Alternative Technical Concepts*[9] found that failure to consider potential means and methods during the environmental permitting process often unintentionally excludes options that could potentially accrue great time and cost savings. The SHRP 2 R10 *Project Management Strategies for Complex Projects* final report[10] found that making the ACM selection decision after preliminary engineering has commenced often results in the project's design being advanced further than optimum for delivery using

5 Quiroga, C., et al. *Identification of Utility Conflicts and Solutions*. Transportation Research Board. 2012.

6 Sterling, R.L., Anspach, J., Allouche, E., Simicevic, J., Rogers, C.D.F., Weston, K., and Hayes, K., "*Encouraging Innovation in Locating and Characterizing Underground Utilities*," SHRP 2 Report S2-R01-RW, Transportation Research Board, National Academies, Washington D.C., 2009.

7 Blanchard, B., "*Design-Build Lessons Learned Florida DOT*," Proceedings, Louisiana Transportation Engineering Conference, Baton Rouge, Louisiana, February, 2007, p. 6-14.

8 Ellis, R., Venner, M., Paulsen, C., Anspach, J., Adams, G., and Vanderbergh, K., *Integrating the Priorities of Transportation Agencies and Utility Companies,* SHRP 2 Report S2-R15-RW, Transportation Research Board, National Academies, Washington D.C., 2009.

9 Gransberg, D.D., Loulakis, M.C., and Gad, G.M., *Alternative Technical Concepts for Contract Delivery Methods*, NCHRP Synthesis 455, Transportation Research Board, National Academies, Washington D.C., 2014.

10 SHRP 2 R10 *Project Management Strategies for Complex Projects* research report (2014): http://www.trb.org/Main/Blurbs/167481.aspx

CM/GC, D-B, and ATCs. The result was wasted design effort and the constraint of potential innovations that would save both time and money. Therefore, to maximize the benefits associated with both 3D models and ACM project delivery, the process must be kicked off knowing that both approaches will be used as the benchmark for decision-making throughout the project's life cycle.

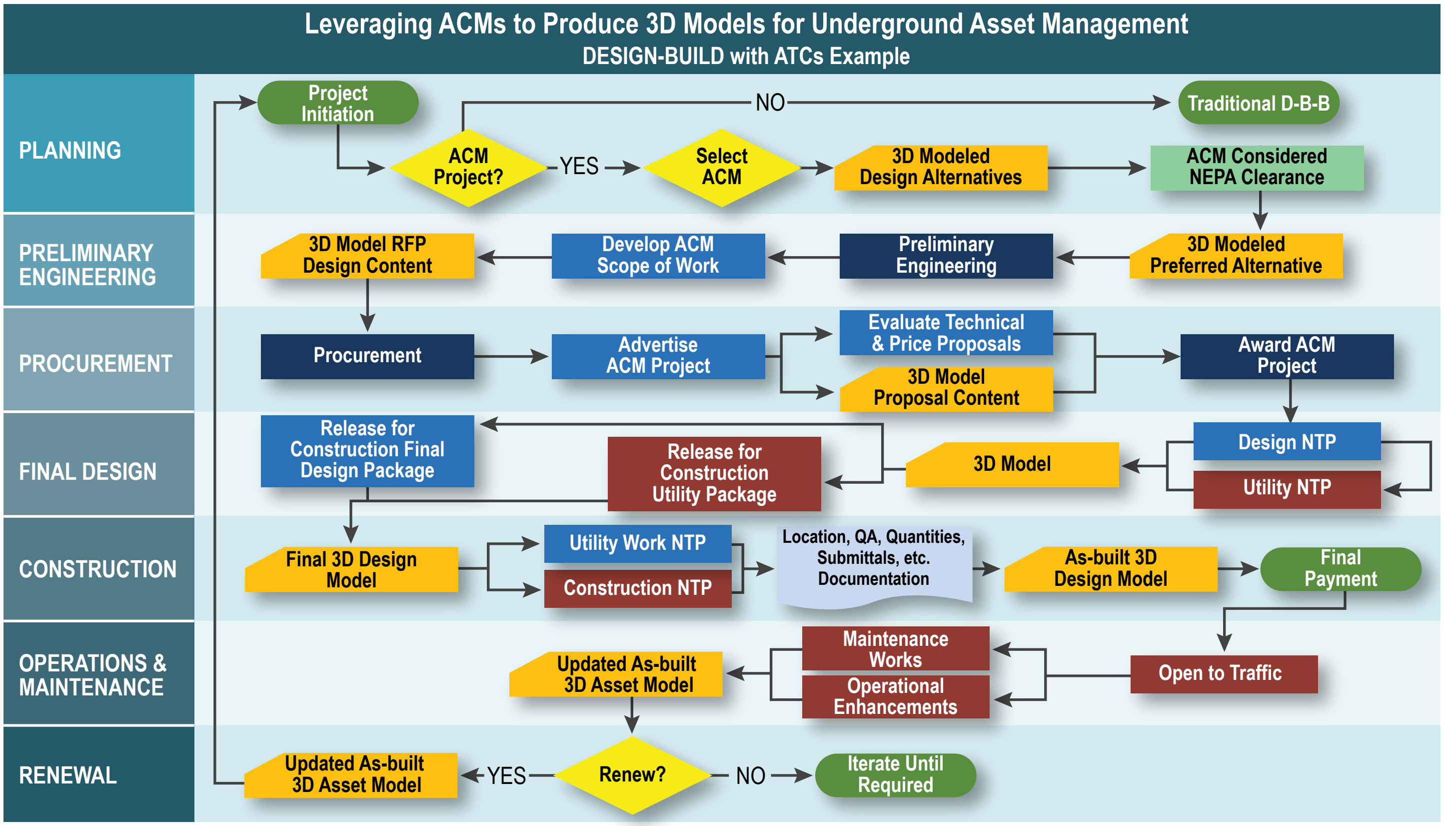


Figure 2: 3D Engineered Models for Utility Coordination in Design-Build Project Delivery

Project Development

It is important to remember that the classic project development process was created assuming D-B-B project delivery. Therefore, that assumption is the first one that must be tested in all projects' cases. If the project is a good candidate for both 3D modeling and alternative delivery, then an ACM should be selected and environmental impact statement development should begin using 3D design tools. Various alternatives are then modeled in 3D and the application is submitted based on 3D design products. Additionally, when ROW and utility coordination are approached in developing the NEPA clearance application, the geospatial relationships associated with each can be input in the model. The result is that once a preferred alternative is selected, it is already portrayed in three dimensions.

Additionally, if the potential means and methods that would benefit the project have been properly considered based on the selected ACM, the commitments made in the permit will not prevent their employment. As the primary objective of utility coordination is to avoid relocation, the preferred alternative will theoretically minimize the potential impact on the existing utilities. It should also have optimized the post-construction locations for new utility work that will be built during the project.

Preliminary Engineering

During preliminary engineering, ROW acquisition will be quantified as will the requirements for third-party utility coordination. These requirements, as well as a detailed design concept, will be developed in the 3D model. Depending on the ACM selected for the project, the information will be included in the scope of work that will be articulated in the project's solicitation documents. Competing teams will be required to furnish technical proposals in a digital format that is compatible with the agency's 3D model requirements. Provisions are made for integrating those submittals during the proposal evaluation period. If utility-specific ATCs are desired, the 3D model will be prepared to permit the evaluation panel to assess the impacts of any ATCs on the project's ROW and technical design aspects. The final product is a request for proposals (RFP) that includes arrangements for importing various technical proposals into the 3D model during proposal evaluation.

Procurement

As previously stated, the traditional procurement procedure will need to be modified to accommodate using the 3D model in the evaluation of ATCs and the technical and price proposals. The Missouri DOT found that to implement ATCs on D-B-B projects, it needed to post the 60 percent plans and begin the ATC proposal-evaluation-approval process as much as 12 months before the scheduled letting. The strength of extending the procurement period is that it increases the level of competition due to advertising the project earlier than traditional projects, which in turn allows more time for industry to form partnerships and collect detailed information about the project site that would be impossible during the normal 30-day letting period.

Proposal evaluation using the 3D model allows the agency the ability to assess the impacts on work sequence and schedule in a way that is impossible with 2D documents. If the agency integrates a cost estimating and scheduling feature with the 3D design model, it can use the evaluation as a series of simulations and select the best value on a basis of what is best for the project. The result of the evaluation is a winning proposal that has been vetted by the 3D model that was developed in planning and modified during preliminary engineering.

Final Design

The focus shifts to splitting the project from a series of functional features of work to design and construction work packages during the final design phase. Depending on the ACM in use, construction can overlap design if desired to accelerate the project delivery period. To facilitate an early start of construction, the underground features of work must be advanced to final design level first. To accommodate this, a separate notice to proceed (NTP) can be issued to permit the contractor to begin exploratory excavations and test holes to physically locate existing utilities and quantify the geotechnical character of the subsurface. Information from the test holes and exploratory excavations is then fed into the 3D model to govern the spatial constraints in which the final design must be compatible.

Construction

Once the design progresses to development of the final utility strategy, an early release for construction package can be issued, permitting the contractor and utility companies to get moving on the preparatory utility work. Additionally, the same package could include the 3D design information necessary to commence the drainage structure, storm sewerage, and other underground assets that are new to the project site. During this phase, data must be collected on all underground assets within the ROW. Not only is spatial and location data collected, but material submittal information can be input in the 3D model in preparation for commissioning and hand over to operations and maintenance when construction is complete.

This process results in a detailed as-built 3D model that is loaded with material source, type, and warranty information. The model also provides the archive for any RFID tagging schemes and, if developed properly, can be used to furnish updated data for existing SUE databases in the project area. In theory, the 3D model can be configured to issue electronic messages to O&M personnel when material warranties are about to expire, giving them advance notice to schedule field inspections of seals, joints, etc. and make claims for those materials that failed to live up to their promised service lives.

Operations and Maintenance

This is the longest period and the point where internal standard operating procedures must be developed to include using the 3D model as part of the underground asset management program and updates to the model as assets and appurtenances are modified, moved, or replaced. The model can also be used to notify agency personnel when preventive and routine maintenance and services of the underground assets are due. If connected to the financial information system, the model can be used to track maintenance cost and time. That data can then be used in determining when an underground asset has reached its economic service life and should be scheduled for renewal or replacement.

Renewal

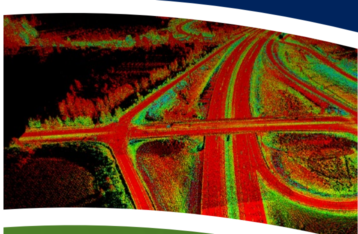
If the decision is made to renew or replace the asset, the updated as-built 3D model is transferred to the planning group for use in developing the project to replace the old asset with a new one. Thus, the 3D model is an integral tool that records the progression of a given project's life cycle from cradle to grave and back again.

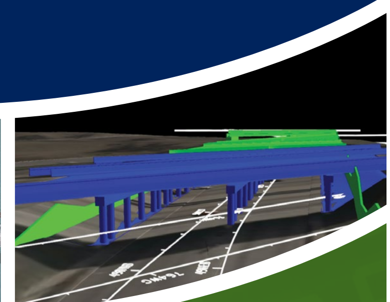
Summary

The combination of 3D engineered models, ACMs, and asset management creates a much higher level of synergy than is currently available in the traditional D-B-B 2D documentation environment. The previous discussion has identified a number of benefits of implementing 3D modeling in conjunction with alternative delivery. The FHWA *Every Day Counts* program challenged the nation's public transportation agencies to "pursue better, faster, and *smarter ways of doing business*."[11] Combining the tools that have proven to be valuable in EDC rounds 1 and 2 with EDC-3's 3D engineered modeling is indeed a *smarter way of doing business*.

11 Mendez, V., "Every Day Counts: Innovation Initiative," Federal Highway Administration, Washington D.C., 2010, p.1-2.

***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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