TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

3D Engineered Models for Construction

CASE STUDY FOR POLICIES AND ORGANIZATIONAL CHANGES FOR IMPLEMENTATION: THE KENTUCKY CASE STUDY

ABSTRACT

This case study provides an example of how the Kentucky Transportation Cabinet was able to innovate and make better use of three-dimensional design data for construction applications. This seamless transition from design to bid to build has improved highway delivery for the State of Kentucky.

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Introduction

The building construction industry began using three dimensional (3D) engineered models in the 1980s because of the greater efficiency, reduced schedule, and reduced cost offered by this approach. Today, 3D modeling for building construction has become the standard for design and construction of commercial and industrial buildings. Known as Building Information Modeling (BIM), the concept goes beyond planning and design phases of the project and extends throughout the building life-cycle to support cost management, construction management, project management, and even facility operation. While lagging behind BIM, the use of 3D models for horizontal construction, also known as Civil Integrated Management, represents roadway construction in digital form and has been shown to accelerate construction operations, improve accuracy, reduce cost, and increase safety on jobsites.[1]

Highway construction contractors began using 3D modeling for transportation projects in the 1990s. Typically contractors would "reverse engineer" 2D plans developed by State agencies to use for automated machine guidance. Many State transportation agencies have developed the capability and resources to develop 3D models, with potential for use as legal and binding documentation. However, State specifications typically are not written to accommodate the nuances associated with the full application of 3D modeling for roadway construction.

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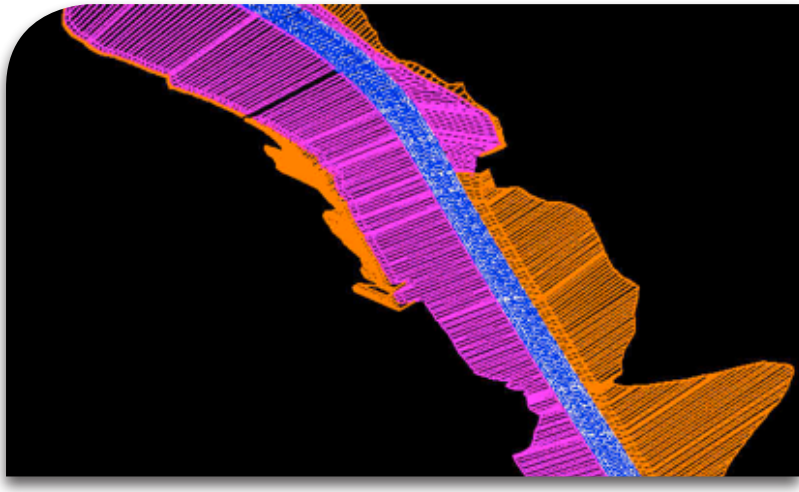
1 Washington DC, Federal Highway Administration: 3D Engineered Models for Construction – Implementation Plan, March 2013.

KENTUCKY'S APPLICATION OF 3D DATA FOR CONSTRUCTION

Like many transportation agencies across the nation, the Kentucky Transportation Cabinet (KYTC) has the capability to develop 3D models for designing roadway projects, but they had not used them to their full potential for bidding and construction until recently. In the past, KYTC staff or hired design consultants would develop a 3D model of the project that until recently would be translated to 2D plans for bidding and contract award. Following award, many contractors would then develop a 3D model, based on the 2D plan set, to use for construction and automated machine guidance. To eliminate these redundant conversions and to continue expanding their application of 3D modeling, KYTC piloted the use of an in-house 3D model as the final plan set to release for bidding. In the contract documents, KYTC still provided the contractors with a 2D plan set; however, the 3D plan set served as the record document and took precedence over the 2D set in any discrepancies identified. To facilitate the transition to using 3D models, the KYTC included several special notes in the plan set that superseded their standard specifications as indicated in the coordination of contract documents. These special notes provide a model by which other agencies can adjust specifications to accommodate the use of 3D modeling, increase efficiency, and reduce overall costs of roadway construction. For KYTC, the use of 3D design greatly increased accuracy and efficiency and also allows the designer to identify potential issues and conflicts prior to start of construction.

Leading up to the letting and project award, KYTC gathered input from the Kentucky Association of Highway Contractors on issues associated with using KYTC models for construction and AMG. Contractors and cabinet staff discussed and resolved issues with file formats, size, accuracy, and such required elements as cross sections.

PROJECT DESCRIPTION: The pilot project is located in eastern Kentucky in Elliot County. The scope includes relocation of approximately 5 miles of two-lane rural roadway on KY 7, north of the City of Sandy Hook. The project required excavation of approximately 3 million cubic yards of material. The primary purpose of the project is to improve both the safety and capacity of KY 7 by correcting geometric deficiencies and improving traffic flow, while minimizing possible environmental impacts on the surrounding area.



KYTC will develop and use 3D models for the proposed top surface and sub grade. The ultimate purpose of this process is to refine the way designers create the construction model so that it is more useful for contractors. The goals of this pilot project, as seen by KYTC, are to: 1) determine the best modeling practices for design, so better models can be provided to contractors in the future; and 2) set new policy to require better 3D models from design.

SPECIAL PROVISIONS: To accommodate the pilot, given existing construction standards, KYTC developed special notes or provisions to include in the advertised plan set for the project. The special provisions mitigated conflicts and discrepancies that could arise between traditional 2D plans and 3D electronic files.

USE OF 3D DESIGN MODEL: A special note that superseded section 109.01.01 of KYTC construction standards specified that contractors should use the 3D terrain model for construction and automated machine guidance. This special note is at the very core of the changes made to accommodate use of 3D modeling, and eliminates the possibility that contractors redevelop a model, as they have in the past. This special note also indicated that inspectors will use the 3D model as the basis for inspecting contractor's work.

> *3D terrain models of the proposed finished and sub grade surfaces have been provided ... The contractor shall use the provided surface model for the construction of the project using GPS machine guidance ... KYTC shall use the same model to inspect the contractor's work.*
> (Special Note for Use of a 3D Design Model)

HIERARCHY OF CONTRACT DOCUMENTS:
A special note that superseded Section 105.05 of KYTC Standard Specifications adjusted the ranking of documents that a contractor and DOT staff will defer to in cases where a conflict is present. This is important to establish so that all parties are able to agree on adjustments or corrections made during the construction process. To accommodate 3D modeling, KYTC inserted the 3D surface model above traditional 2D plans. KYTC felt this provision would not only require the use of the model, but also instill a sense of confidence in the accuracy of the model designed by KYTC staff.

KYTC Standard Specifications (Section 105.05) Project Documentation Hierarchy

1. Questions/Answers
2. CAP Report
3. Special Notes
4. Special Provisions
5. 3D Surface Model
6. Plans
7. Standard Drawings
8. Supplemental Specs
9. Standard Specs

MEASUREMENT OF QUANTITIES: A special note that superseded Section 204.04.02 of the existing standards accommodated the change in using end-area volumes from cross sections to using quantities calculated by a 3D software, Bentley InRoads, that triangulates irregular network volumes. Because surfaces between cross sections are directly modeled instead of estimated, using the digital terrain model for quantifying earthwork is more accurate than the traditional method of end-area volumes.

CORRECTIONS TO SURFACE MODEL: The KYTC recognizes there could be errors within the 3D model. To address such errors, a special note allowed KYTC engineers a minimum of three days to correct any errors or omissions once identified. The note also allows contractors to provide value engineering suggestions to decrease costs, and if accepted by KYTC, provides the contractor with half of the savings. Value engineering (VE) proposals are reviewed within 5 days of submittal.

> *Any changes to the initial 3D surface model due to errors or omissions shall require a minimum of 72 hours to complete at the discretion of KYTC. All requests shall be sent to the Engineer, who will coordinate with the Division of Highway Design to investigate and correct.*
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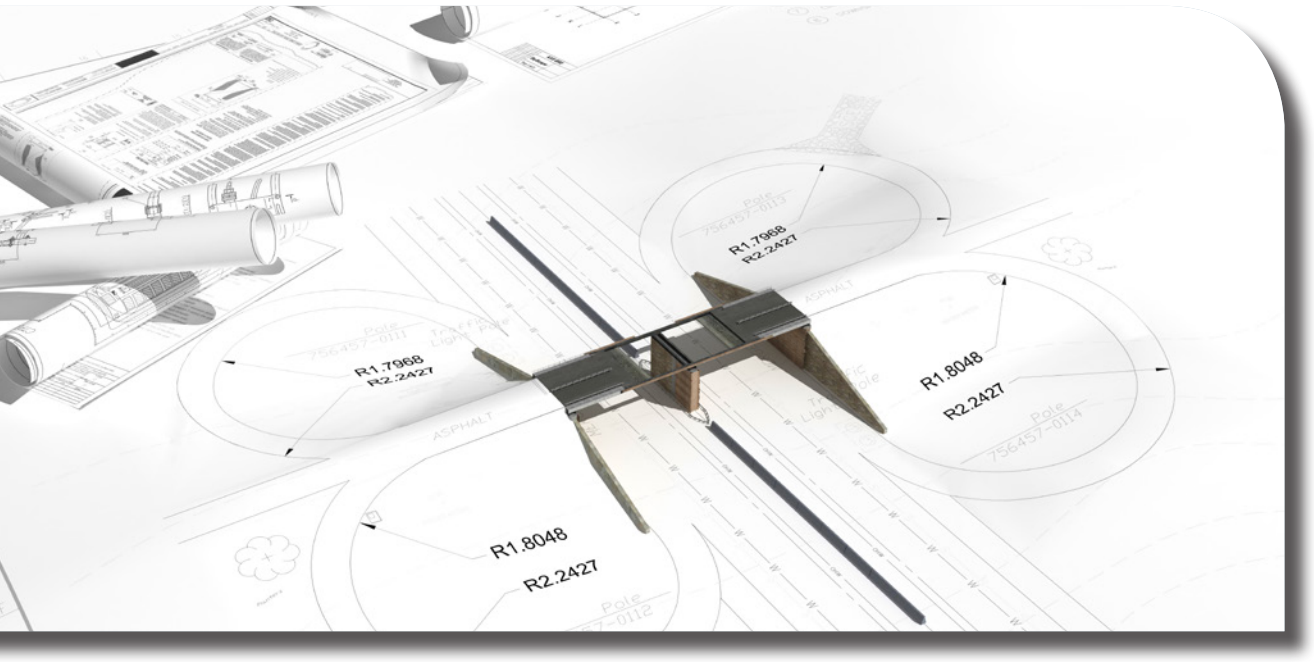
> *Any value engineering proposal that requires edits to the initially furnished 3D surface model shall be processed within 5 working days after the Cabinet approves the requested VE Proposal.*
> (Special Note for Corrections to 3D Surface Model)



PROGRESS MEETINGS: Given that this is a pilot project, KYTC included a note within contract provisions that the contractor schedule a mandatory progress meeting with central office staff, the field engineer, and the district construction crew. These meetings allow contractors and the KYTC staff to exchange feedback on use of the 3D surface model.

> *The contractor shall schedule meetings with the KYTC representatives including, but not limited to Central Office Design, Central Office Construction Field Engineer, and District Construction Crew. The purpose of these meetings is to receive feedback on the use of 3D surface model for the construction of the project. The meetings shall be coordinated at milestones determined by the engineer.* (Special Note for Mandatory Progress Meetings)

CONCLUSIONS

This case study provides an example of how an agency was able to make better use of 3D design data for construction applications. 3D modeling for vertical construction has been effectively used for many years and is now being increasingly applied to horizontal construction for roadway projects in order to take advantage of cost savings and improved efficiency. While state transportation agencies have traditionally lagged behind contractors in terms of capability to develop accurate and functional models, they are now becoming more proficient and are delivering models that contractors can use.

State construction specifications need to better accommodate development and use of 3D models as formal contract documents. The KYTC is one of many State transportation agencies that are piloting projects where agency-developed models will eventually supersede traditional plans during procurement and execution of civil construction projects. Just as the capability to develop 3D models has emerged within transportation agencies, so must policies and specifications so that the full potential of model data is achieved. Early State experiences will continue to facilitate change and increase the use of 3D modeling for roadway construction across the country for more effective and efficient use of limited resources.

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