Advanced Modeling Techniques for Enhanced Constructability Review, Phase II: A Survey of State Practice and Related Research

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The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

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Executive Summary

Background

In 2012, Caltrans' interest in learning how other state departments of transportation (DOTs) are employing 3-D modeling and other types of advanced modeling techniques on highway projects led to the March 1, 2012, Preliminary Investigation, Advanced Modeling Techniques for Enhanced Constructability Review: A Survey of State Practice and Related Research. In addition to examining national guidance and related domestic and international research, a significant portion of the 2012 project was devoted to surveying state DOTs about the state of the practice of using advanced modeling.

In the current investigation, Caltrans is seeking information that builds on the findings documented in the 2012 report to learn more about how DOTs use modeling, specifically within constructability reviews, to enhance the preconstruction process review. For this investigation, advanced modeling refers to the use of 3-D and 4-D engineered models.

In support of Caltrans' expanded inquiry, this Preliminary Investigation aims to gather high-level information about model use, staff responsibilities, data and file management, and the effects of modeling on agency workflows and efficiencies through a survey of and follow-up contacts with state DOTs. A literature search to identify recently completed research or projects in progress supplements these findings.

Summary of Findings

Survey of Current Practice and Case Studies

We conducted an online survey of a select group of state DOTs that use 3-D modeling. Of the 12 survey recipients, nine states responded: Florida, Iowa, Kentucky, Michigan, Missouri, New York, North Carolina, Pennsylvania and Wisconsin. We prepared case studies for six states (Florida, Iowa, Kentucky, Missouri, North Carolina and Wisconsin) by summarizing responses to the initial survey and follow-up contacts that examined the efficiencies gained and lessons learned from the states' experiences with modeling.

Constructability Reviews

Caltrans is particularly interested in knowing how other states are employing modeling in constructability reviews. None of the respondents has significant experience with using models during these reviews as a standard practice, though Wisconsin DOT has made limited use of modeling in constructability reviews for clash detection analysis. A new constructability review process is under development at Michigan DOT, and the agency is in the early stages of requiring models at every submittal milestone. A new Michigan DOT team, using checklists to assess quality and constructability, will oversee the constructability reviews.

Few respondents are using specialized software for constructability reviews. Florida DOT uses a proprietary application to track the entire review process for plan reviews and project submittals. Iowa DOT is considering the use of software to review deliverables to contractors for automated machine guidance (AMG), and Wisconsin DOT is using software for clash detection.

How Modeling is Used

Respondents use four primary modeling tools—GEOPAK, InRoads and MicroStation from Bentley Systems Inc., and Civil 3D from Autodesk Inc. Respondents use modeling most often during the design phase of preconstruction and are least likely to use modeling during the planning and right of way phases.

A few respondents provided details about the types of projects most likely to be subject to modeling. Iowa DOT models all projects where cross sections are developed (grade, grade and pave). In Kentucky, roadway projects are more likely to be modeled than structural projects, while Missouri DOT is focused on linear corridor modeling for expansion projects. Beginning this month, Wisconsin DOT will model all projects with earthwork included in the project scope.

Visualization is used by all respondents except Michigan and is most often used for high-profile or complex projects, often where the public is involved. Respondents find it difficult to estimate the cost to produce a visualization model, with most noting that costs are project-specific. Florida DOT is investigating the use of a new software—InfraWorks—to expedite its production of visualization models.

Three states reported using modeling for underground investigations. None of the agencies reported using modeling to prepare Plans, Specifications and Estimates (PS&E) packages, though some respondents expect modeling to be used for this purpose as modeling programs mature.

Staffing and Training

Typically, both state staff and consultants prepare 3-D and visualization models. Three respondents (Florida, Kentucky and North Carolina) reported outsourcing a significant portion of their design work, which reduces the volume of projects modeled by state staff in these agencies.

The type of state employee most often receiving modeling training is an engineer, with engineering technicians also frequently mentioned by respondents. Most respondents have well-developed training programs, with many offering online access to course materials and software downloads. Some states offer joint training for state staff and consultants, and others offer personal, one-on-one training. Respondents may have contracts to employ training professionals or topic area experts to deliver the training.

Data and File Management

Respondents produce a range of file types based on the tools used in their modeling programs. Some files are proprietary to the modeling tool (for example, an ALG file that is an InRoads geometry file), while other files appear to be more standard, such as Land XML files that use a standard ASCII format based on XML to specify engineering and survey data.

Modeling files are produced at varying points during the preconstruction process—from the very start of the project (Kentucky, Michigan, North Carolina and Wisconsin) to 50 percent completion (New York) to 100 percent design (Iowa).

More than half of respondents use ProjectWise, a Bentley Systems Inc. product, to store modeling files and share them with stakeholder groups. Florida DOT, now using another commercial document management application to store and share data, is considering a move to ProjectWise. Wisconsin DOT is also investigating an alternative to its current use of a Windows network to share files across the agency. External collaborators access files most

often through FTP access, and several respondents provide potential bidders and contractors with online access to modeling files as part of the letting process.

Impacts of Modeling

None of the respondents has formally quantified the benefits of modeling. However, all comment on savings or improvements identified anecdotally or expected as modeling programs mature.

Time savings. While in the early stages of transitioning from 2-D to 3-D modeling, an inexperienced modeler may take longer to complete a design. However an experienced modeler can save time in the overall preconstruction process. Other observations:

- Kentucky is not adding hours, but shifting them to earlier in the production cycle, and the cost of modeling is a fraction of what it would cost to reverse engineer plans.
- Wisconsin DOT reports that modeling does not noticeably increase workload and can reduce project rework and risk.

Cost savings. Respondents agree that modeling can reduce costs by identifying problem areas in a design earlier in the preconstruction process, though they may differ on where cost savings will be most significant.

A. Iowa DOT notes that the greater cost savings are not associated with the design but with the efficiencies gained in construction by eliminating the need for contractors to pay consultants to create 3-D models from 2-D plans, and money saved by AMG grading and paving.
B. Wisconsin DOT notes cost savings achieved through 3-D modeling can be greater in the general, drainage, structural and feature design categories than during earthwork and excavation.

Quality impacts. Iowa DOT reports that the design intent is clearer in 3-D than 2-D. While modeling is too new in Wisconsin to identify benefits to final design quality, the added detail associated with a 3-D model is expected to contribute to a higher quality design concept.

Future benefits. Several respondents reported that contractors are employing consultants to prepare models for use in AMG if the DOT is not supplying a 3-D model with bidding documents. These respondents prefer to deliver the models to contractors rather than have contractors rely on a consultant's interpretation of 2-D plans.

Lessons Learned

Respondents offered their experiences and recommendations for agencies preparing to transition to 3-D modeling.

Education and training. Several respondents noted that keeping training materials current can be difficult when software versions change so frequently. Offering modeling training while active projects are still in the final stages of completion using previous processes can be confusing to staff.

Software issues.

A. Several respondents noted that out-of-the-box modeling software can be challenging to use for certain applications, and some states are modifying modeling software to meet local needs. Florida DOT offers its customized software to interested parties through downloads available on the agency's web site.

B. One respondent noted that the move to 3-D modeling may be inevitable. As software companies stop updating 2-D processes, the tools will not be optimized to create the most efficient workflows when relying on older processes.

C. Large data sets from Light Detection and Ranging (LiDAR) can be difficult to manage, though new software releases may offer some relief.

System limitations. Poor network communications in remote areas and slow Internet access can require agencies to use physical media rather than online access to share data with external collaborators.

Resistance to change. All respondents noted resistance to change as an obstacle—in some cases, a significant obstacle. Communication, including a clear message about the importance of modeling to the agency, is often mentioned as critical to encouraging acceptance of new practices.

Collaboration. Respondents use several tools to encourage collaboration among stakeholders, including reviewing software such as Florida DOT's Electronic Review Comments (ERC), a database that tracks comments and responses for plan reviews and project submittals; Smart Boards; and web conferencing (GoToMeeting and Bridgit).

Signing and sealing digital documents. In Kentucky, consultants have expressed concern about digitally signing electronic plan packages. Florida DOT has developed an application to sign and seal documents stored electronically.

Related Research

We located several research reports and other publications from studies conducted since the first phase of this investigation was published in March 2012. In national guidance, an April 2013 NCHRP synthesis identifies the current state of the practice regarding the use of geospatial data and tools, including 3-D modeling. A series of Federal Highway Administration (FHWA) publications, webinars and web sites provides a wealth of training and educational opportunities, and a project in progress, expected to conclude in December 2014, will create a manual that outlines the benefits of 3-D modeling and how to generate accurate 3-D models.

Other recently published research includes two 2014 conference papers. The first paper proposed basing 3-D models on an open standard for model data; the second paper examined the use of 3-D modeling on a $2.6 billion reconstruction project in Texas. An October 2013 article describes a new quality control process tested in a Virginia DOT pilot program; an August 2013 article describes Connecticut DOT's use of modeling for a recent corridor improvement project.

Gaps in Findings

While most respondents have yet to make regular use of models during the constructability review process, some states are making inroads in this area, and it is likely modeling will become a more common feature of constructability reviews as modeling programs mature.

Even though modeling is clearly being integrated into mainstream workflows within the agencies we contacted for this investigation, its use is still relatively new to most agencies. The full impact of modeling has yet to be determined, particularly with regard to quantifiable impacts on time and cost savings, quality and accuracy. Data to support this type of evaluation will likely become more readily available as more projects move from 3-D design to completion of construction.

Next Steps

Caltrans might consider the following as it continues to evaluate the use of advanced modeling techniques during the preconstruction process:

- Following up with Michigan DOT to learn more about its new constructability review process that employs modeling and checklists.
- Consulting with agencies using or beginning to use modeling for underground investigations (Florida, Michigan and Wisconsin DOTs) to learn more about this practice.
- Examining the training materials offered by respondents to get a sense for how these agencies are preparing staff for modeling duties and the formats used to deliver training.
- Consulting with Florida DOT to learn more about ERC, its reviewing software.
- Engaging the agencies contacted for this Preliminary Investigation to initiate an informal community of practice to share ideas and experiences as each agency develops its modeling program.

Detailed Findings

Survey of Current Practice

Survey Approach

We conducted an online survey of a select group of state DOTs known to have experience with 3-D modeling. Recipients of the survey include:

- Florida.
- Iowa.
- Kentucky.
- Maryland.
- Michigan.
- Missouri.
- New York.
- North Carolina.
- Oregon.
- Pennsylvania.
- Washington.
- Wisconsin.

The survey consisted of the following questions:

1. Please describe your agency's constructability review process.
2. Please identify below the preconstruction phases for which advanced modeling is used. Please check all that apply.
    a. Environmental review.
    b. Preliminary engineering.
    c. Planning.
    d. Design.
    e. Right of way.
    f. Other.
3. Does your agency use visualization during the preconstruction phase of project development?
    3a. Is visualization limited to certain types of projects (bridges, Interstates, above a certain cost, etc.) within the preconstruction phases identified in question 2?
    3b. Please provide an estimate of the cost (in dollars or hours) to develop the visualization model.
4. Is your agency using advanced modeling to investigate a project's impact to underground utilities, soils, rocks, groundwater, environmental plumes, hazardous waste, archeology, etc.?
5. In addition to design software such as Civil 3D, InRoads or GEOPAK, are you using a reviewing software to perform constructability reviews?
6. Who develops the advanced model during the preconstruction phases of project development identified below?
    a. Environmental review.
    b. Preliminary engineering.
    c. Planning.
    d. Design.

e. Right of way.
f. Other; please describe below.

7. If your agency uses visualization during the preconstruction phase of project development, who develops this model?
   7a. Does the complexity of a project determine who develops the visualization model?
8. Please describe the types of state employee (by classification or functional area) receiving training in advanced modeling within your agency.
9. Please describe the types of files that are produced in your advanced modeling program.
10. At what stage of a project or percent of project completion are modeling-related electronic files prepared and used?
11. Please describe the types of electronic files associated with modeling that are shared and how these files are shared in the instances below.
    - Across the agency.
    - Within the project development team.
    - With consultants.
    - With potential bidders.
    - With contractors.
12. How does your agency store the large amounts of data associated with your advanced modeling program?
13. How do employees in remote locations access data related to your advanced modeling program?
14. Please provide details on any of your answers above, or additional comments.

We received responses from nine state DOTs:

- Florida.
- Iowa.
- Kentucky.
- Michigan.
- Missouri.
- New York.
- North Carolina.
- Pennsylvania.
- Wisconsin.

See **Appendix A: Survey Results** beginning on page 37 for the full text of all survey responses.

Survey Results

The survey gathered information in six topic areas related to the use of advanced modeling:

1. Constructability review processes.
   - Using special software for constructability reviews.
2. Modeling tools.
3. Using modeling in preconstruction phases.
   - Using modeling for underground investigations.
4. Using visualization.

5. Staffing issues.
    - Training staff.
6. Data and file management.
    - File types.
    - When modeling files are produced.
    - Sharing modeling files.
    - Storing data and providing remote access.

Below is a summary of key findings in each of these topic areas.

1) Constructability Review Processes

Respondents reported a range of approaches to constructability review, from in-field or final plan inspections (North Carolina) to constructability checklist development (Michigan) to a highly detailed constructability review process (Pennsylvania). None of the respondents reported the standard use of models during constructability reviews, however:

- In Kentucky, constructability reviews are sometimes conducted in a special meeting where the 3-D model is displayed on a screen and meeting attendees examine the model for discrepancies.
- Michigan DOT is developing its constructability review process. A recently hired land surveyor and engineer work as a team to review the 3-D model produced by MDOT designers. The new team is developing a quality assurance checklist and other review checklists for constructability.
- In Wisconsin, models are not part of the standard constructability review process. For complicated design projects, Navisworks, an Autodesk Inc. project review software (see http://www.autodesk.com/products/autodesk-navisworks-family/overview), has been used for clash detection analysis. Over the next few years, Wisconsin DOT expects to use models in constructability reviews more often as surface model development becomes more common.

Using Special Software for Constructability Reviews

Three states—Florida, Iowa and Wisconsin—are using or considering the use of specialized software for constructability reviews.

- Florida DOT uses Adobe Acrobat (see http://www.adobe.com/products/acrobatpro.html) and Bluebeam Revu (see http://www.bluebeam.com/us/products/revu/) for collaborative review of documents. Florida also uses ERC, an application used to track the entire review process for plan reviews and project submittals. See http://www.dot.state.fl.us/officeofdesign/ProjectReview/ERC/ for more information about ERC.
- Iowa DOT is investigating Agtek Earthwork 4D to review its deliverables to contractors for AMG. See http://www.agtek.com/transportation.asp for more information.
- Wisconsin DOT has used Navisworks in a limited number of projects for clash detection analysis.

2) Modeling Tools

The table below identifies the tools used by respondents to generate modeling files.

Modeling Tools Used by Respondents		
Product/Vendor	**State**	**Vendor Web Site**
Civil 3D Autodesk Inc.	Florida, Wisconsin	http://www.autodesk.com/products/autodesk-autocad-civil-3d/overview
GEOPAK Bentley Systems Inc.	Florida, Iowa, Missouri, North Carolina	http://www.bentley.com/en-US/Products/GEOPAK+Civil+Engineering+Suite/
InRoads Bentley Systems Inc.	Kentucky, New York, Pennsylvania	http://www.bentley.com/en-US/Products/InRoads+Suite/
MicroStation Bentley Systems Inc.	Florida, Iowa, Missouri, New York, Pennsylvania	http://www.bentley.com/en-US/Products/microstation+product+line/

3) Using Modeling in Preconstruction Phases

We asked respondents to identify when 3-D modeling is used during the various phases of preconstruction. All survey respondents use 3-D modeling in the design phase. The fewest number of respondents reported using 3-D modeling during the planning and right of way phases. The table below summarizes survey responses.

Modeling Used in Preconstruction Phases		
Preconstruction Phase	**State**	**Notes**
Environmental review	Michigan, Missouri, North Carolina, Pennsylvania, Wisconsin	*Missouri*. GIS modeling is done for environmental review.
Preliminary engineering	Iowa, Kentucky, Michigan, New York, North Carolina, Pennsylvania, Wisconsin	
Planning	Kentucky, Michigan, North Carolina, Wisconsin	

Modeling Used in Preconstruction Phases		
Preconstruction Phase	**State**	**Notes**
Design	Florida, Iowa, Kentucky, Michigan, Missouri, North Carolina, New York, Pennsylvania, Wisconsin	*Florida*. Most 3-D modeling is done for design-build projects. On some design-bid-build projects, the contractor will develop 3-D models from FDOT-supplied CADD (computer-aided drafting and design) and engineering data (usually LandXML or cross sections). *Missouri*. Partial 3-D modeling is completed as part of the roadway design process for corridor projects involving earthwork.
Right of way	Iowa, Michigan, North Carolina, Wisconsin	

Using Modeling for Underground Investigations

Only three states reported using modeling to investigate a project's impact on underground utilities, soils, rocks, groundwater, environmental plumes, hazardous waste or archeology.

- In Florida, statewide contracts for tomography and subsurface utility engineering are in place, and modeling has been used on a few projects where utility conflicts were suspected.
- Michigan DOT is just starting to use models to investigate the impact on underground utilities.
- For its most complex projects, Wisconsin DOT will locate underground utilities using ground penetrating radar, hydrojet excavation or Spar—an Optimal Ranging Inc. product to survey and map underground utilities (see http://www.optimalranging.com/products/spar-300). Utility data is imported into a Navisworks model for clash detection.

4) Using Visualization

Michigan is the only respondent not using visualization. All respondents except Pennsylvania note that visualization is selectively used, with all but Florida and Pennsylvania DOTs indicating that visualization is used for high-profile or complex projects, often where public outreach, education or involvement is needed. Specific examples of visualization use:

- Iowa: Public input on roundabouts and a proposed J-turn.
- Kentucky: Interchanges, major intersection design, urban widening and roundabouts.
- Missouri DOT: A diverging diamond interchange or roundabout.
- New York: Projects in heavily congested areas.

Respondents noted that it is difficult to estimate the cost of visualization, with cost tending to vary by project. Only two respondents provided details:

- A simple project for Iowa DOT could take 40 hours to develop a highly detailed rendering. The respondent noted that basic wireframe models are developed on all projects and are simply part of the tools used to design.
- In North Carolina, large projects can take a few months, while smaller projects may take one or two weeks.

Typically, both state and consultant staff members prepare visualization models for survey respondents. Only Iowa DOT indicated that visualization models are prepared by state staff alone. In Pennsylvania and Wisconsin, only consultants prepare visualization models. Florida DOT is reviewing InfraWorks (see http://www.autodesk.com/products/infraworks-family/overview) to expedite preparation of visualization models given the limited number of staff now able to do 3-D rendering using MicroStation.

5) Staffing Issues

We asked respondents whether consultants or state staff members develop models and whether circumstances dictate who takes responsibility for model development. The table below summarizes responsibility for 3-D model development by construction phase.

Responsibility for Developing the 3-D Model by Preconstruction Phase

State	Preconstruction Phase				
	Environmental Review	Preliminary Engineering	Planning	Design	Right of Way
Florida				Both state and consultant staff	
Iowa		Both state and consultant staff		Both state and consultant staff	Both state and consultant staff
Kentucky		Both state and consultant staff	Consultant staff	Both state and consultant staff	
Michigan	Both state and consultant staff	Both state and consultant staff	Both state and consultant staff	Both state and consultant staff	Both state and consultant staff
Missouri	Both state and consultant staff			Both state and consultant staff	
New York		Both state and consultant staff		Both state and consultant staff	
North Carolina	Consultant staff	Both state and consultant staff	Consultant staff	Both state and consultant staff	Both state and consultant staff
Pennsylvania	Consultant staff	Consultant staff		Consultant staff	
Wisconsin	Both state and consultant staff	Both state and consultant staff	Both state and consultant staff	Both state and consultant staff	Both state and consultant staff

Training Staff

The type of state employee who most often receives modeling training is an engineer, with engineering technicians also frequently mentioned by respondents as potential modeling trainees. The table below summarizes survey responses.

Type of State Employee Receiving Advanced Modeling Training	
State	**Type of State Staff**
Florida	• Engineering technicians. • Engineers. • Construction management staff. • Project managers.
Iowa	• All road design technicians. • All nonmanagerial engineers. • One visualization technician.
Kentucky	• Engineering technicians. • Engineers.
Michigan	• Engineers (road and bridge).
Missouri	• Some senior design technicians. • Highway designers.
New York	• Engineering technicians. • Engineers. • Limited regional construction CADD coordinators.
North Carolina	• Roadway engineers. • Hydraulic design engineers.
Pennsylvania	• Project management staff. • System management staff (information technology).
Wisconsin	• Roadway design staff

6) Data and File Management

File Types

Respondents provided a range of detail about the types of files produced in their advanced modeling programs, including vendors and tools. Below are definitions of the file types listed in the table summarizing survey responses.

File Format	Definition
ALG	InRoads geometry file
AMG	Automated machine guidance; links design software with construction equipment to direct the equipment's operation
ArcGIS	Geographic information system product used with maps and geographic material
CSV	Comma separated values file
DC	Data Collector file format used in Trimble Survey Controller
DGN	MicroStation drawing files
DTM	Digital terrain model or surface model
DWG	Native file format of AutoCAD
DXF	Data eXchange File, a file format used to transfer 2-D and 3-D information
GPK	GEOPAK coordinate geometry database file
IRD	InRoads roadway definition file
LandXML	ASCII format based on XML used to specify civil engineering and surveying data
TIN	Triangulated Irregular Network

Types of Files Produced in an Agency's Advanced Modeling Program

State	File Type
Florida	• 2-D and 3-D MicroStation files. • 3-D AutoCAD Civil 3D files. • LandXML.
Iowa	• MicroStation files using GEOPAK tools. • AMG in LandXML format (native GEOPAK for surfaces). • 3-D breakline line string files in MicroStation DGN and Autodesk DXF formats.
Kentucky	• InRoads DTM and LandXML files for the existing and design surfaces (finished grade and subgrade). • InRoads ALG and LandXML files for the geometry. • Trimble DC files and CSV files for coordinate control. • Existing and proposed manuscript files in DXF format for upload into Survey Controller.
Michigan	• 3-D line string files. • Triangle files.

Types of Files Produced in an Agency's Advanced Modeling Program	
State	**File Type**
Missouri	• ArcGIS files. • MicroStation and GEOPAK files (IRD, TIN, GPK, LandXML of geometry and terrain models, DGN).
New York	• MicroStation design files (DGN). • InRoads to produce digital terrain models (DTM and LandXML), alignments (ALG and LandXML). • InRoads Storm and Sanitary for drainage designs.
North Carolina	• 3-D design file, proposed DTM, alignment files and LandXML format files.
Wisconsin	• Surface models in Civil 3D DWG files.

When Modeling Files are Produced

Modeling files are produced at varying points during the preconstruction process—from the very start of the project (Kentucky, Michigan, North Carolina and Wisconsin) to 50 percent completion (New York) to 100 percent design (Iowa). Other highlights from survey responses:

- While modeling is done throughout the design process in Iowa, final surfaces for AMG are not developed until 100 percent design.
- Kentucky produces DTM and ALG files from the beginning of the preconstruction process. Other file types are produced at the end of the process, after the design is finalized and files are submitted for letting.
- Modeling-related electronic files are packaged and delivered with Missouri DOT's PS&E documents. ArcGIS files are prepared as part of the normal design process to screen for environmental and archeological sites but are not delivered with the PS&E package.
- In North Carolina, all new projects are prepared in 3-D design from the beginning; these files are provided to contractors when the projects are advertised.
- In Wisconsin, models are developed throughout the roadway design process. Final models for distribution to contractors are prepared at design completion.

Sharing Modeling Files

Respondents were asked to describe the types of files shared with specific stakeholder groups and how that sharing takes place. ProjectWise from Bentley Systems Inc. (see http://www.bentley.com/en-US/Products/projectwise+project+team+collaboration/) and internal servers are common file sharing mechanisms for internal staff, while FTP is often used to provide access to external collaborators. Respondents share similar files with potential bidders and contractors, with several respondents providing online access to electronic files along with other data needed to prepare bids.

Storing Data and Providing Remote Access

Five of the nine respondents—Iowa, Kentucky, Michigan, Missouri, New York—use ProjectWise to store data. Other storage practices:

- Florida DOT shares data using TIMS3 (see http://www.tims3.com/TIMS3), a document management application for the engineering community, and stores data on internally managed web and file servers. Florida is considering cloud storage if it moves to ProjectWise.
- Pennsylvania DOT loads its modeling files into its Engineering and Construction Management System.
- Wisconsin DOT's current practice is to archive the entire Civil 3D project data set in its native format. The agency is developing a data management and archival strategy to replace this approach.

The respondents using ProjectWise to store data reported that remote access to this data is made available through ProjectWise; however, slow Internet connections in remote areas can require agencies to use physical media to share data. Florida DOT provides remote access via the Internet. Wisconsin DOT provides Internet access via a virtual private network.

Case Studies

We contacted six of the nine survey respondents to follow up on initial survey responses and ask additional questions about agency workflows and efficiencies:

1. Florida DOT.
2. Iowa DOT.
3. Kentucky Transportation Cabinet.
4. Missouri DOT.
5. North Carolina DOT.
6. Wisconsin DOT.

The following case studies summarize the responses to the initial survey questions and are supplemented by the follow-up phone interviews or email inquiries. The case studies are organized according to the following topic areas:

- Use of 3-D modeling.
- Staff responsibilities.
- Education and training.
- Data and files.
- Impacts of modeling.
- Lessons learned.
- Related documents.
- Contact.

1) Florida Department of Transportation

Use of 3-D Modeling

Florida DOT uses both MicroStation GEOPAK and Civil 3D to produce models in the design phase of preconstruction. Most projects are completed using GEOPAK, though use of Civil 3D is starting to take off, with several dozen projects in the pipeline. Florida is the only state among survey respondents to report such limited use of modeling during the phases of preconstruction. It is also one of three survey respondents using modeling to investigate utilities. Subsurface utility engineering has been used on a few projects where utility conflicts were suspected. A May 2014 conference paper described "the technologies, processes, and risk management aspects of 3-D mapping of non-visible assets, and results so far of the successful project deliverables for the Florida DOT." See **Related Documents** for more information.

One of the few respondents to use reviewing software, Florida DOT uses Adobe Acrobat and Bluebeam Revu for collaborative document review. The agency also uses ERC, a proprietary database application that tracks the entire review process, including comments and responses, for plan reviews and project submittals. See **Related Documents** for more information about these reviewing tools. Collaboration with staff and consultants in remote locations is encouraged through the use of GoToMeeting and Smart Boards.

The agency is not using modeling to prepare its PS&E packages, though respondents believe using models could contribute to the development of more appropriate bid estimates for materials and supplies.

Staff Responsibilities

Consultants perform 95 percent or more of Florida's design work, so while both state staff and consultants develop advanced models, consultants complete more of the modeling work and tend to work on more complex projects. For Design-Build projects, the Florida DOT designer-contractor team develops the 3-D model. On some Design-Bid-Build projects, the contractor develops a 3-D model from Florida DOT-supplied CADD and engineering data, which is usually LandXML or cross sections. Visualization models are prepared for relatively few projects and used only for public presentation. Both state and consultant staff may prepare the visualization model. With only a few Florida DOT staff capable of 3-D rendering in MicroStation, the agency is reviewing InfraWorks, an Autodesk Inc. product, to expedite visualization projects.

Education and Training

Florida DOT offers extensive training to its engineering technicians, professional engineers, construction management staff and project managers. In addition to contracts to provide two-week training classes in the essential activities of GEOPAK and Civil 3D modeling platforms, the agency's CADD office can also provide face-to-face training to staff. Links to presentations, training manuals and downloads are given in **Related Documents**.

Florida DOT provides training support within its own agency and to other DOTs through customized software downloads and training materials accessible to internal and external users. Presentations from an annual Design Expo are made available to the public through the agency's web site, offering the latest on the use and impact of modeling in the agency. Additional training opportunities are provided through annual meetings of the Florida Local User Group; these presentations are also available to the public.

The agency also provides access to an rGuide library (see http://apwcts.rguidelibrary.com/) for fully indexed, video-based Civil 3D training. FDOT develops the rGuide training modules that are then hosted on the APW-CTS web site.

Data and Files

Florida DOT uses both MicroStation GEOPAK and Civil 3D modeling tools. Files are produced in 2-D, 3-D and LandXML formats. Files are produced during the design phase of preconstruction, though for a few design-bid-build projects, contractors have produced 3-D files after the project letting.

Files within the agency are shared via TIMS3, a CADDware electronic file management system. The agency is investigating the use of ProjectWise and has two archival systems in use. External project collaborators gain access to files via email, physical media or an FTP site. Potential bidders and contractors can subscribe to Bid Express (http://www.dot.state.fl.us/cc-admin/Expedite/prime.shtml), the agency's online bidding exchange, to download files.

Modeling data is stored on the agency's web and file servers. The agency will consider cloud storage if it moves forward with ProjectWise. Staff in remote locations and external collaborators gain access to files stored centrally via the Internet.

Impacts of Modeling

While the agency has yet to formally quantify the benefits of modeling, some anecdotal evidence indicates time savings associated with it. For example, in the first modeling project undertaken by Florida DOT, a three-mile reconstruction project in Fort Lauderdale, the overall design schedule was longer than programmed, but the actual hours spent on the project were less than estimated. Florida DOT attributes the longer design time to two complete turnovers of the design squad. Even with this, the amount billed for the project design was less than estimated.

Another example that illustrates the speed with which modeling can be accomplished: For the same reconstruction project in Fort Lauderdale, after the project design was completed, it took the agency about eight hours to develop a 3-D video animation that highlighted drainage, underground utilities and intersections.

While not the focus of this investigation, Florida DOT noted that contractors benefit when modeling is used. Recognizing these benefits, contractors have invested in their own models to perform AMG if a Florida DOT model is not supplied during the bidding process.

Lessons Learned

- *Education and training*. It can be challenging to ensure updates to training materials are made in concert with software changes.
- *Software and hardware*. Software and hardware have not been an issue for Florida DOT as it focuses more of its efforts on modeling. The hardware needed to run modeling is affordable and includes a standard flat-panel monitor and an affordable gaming card to perform the CADD functions. Software is updated as needed, with the 2014 version of Civil 3D in place and deployment of the most recent version of MicroStation—SS3—to begin in August.

  As 2-D production tools transition to 3-D processes (as GEOPAK's SS4 is expected to), resistance to modeling may become moot. Up-to-date, full-featured tools used for 2-D processes will simply not be available or will not provide the automation associated with 3-D modeling. While design work could still be done in 2-D with the upgraded tools, the tools will not be optimized to create the most effective workflows.
- *System issues*. Costs for the servers and storage needed for 3-D modeling has increased as information technology has been centralized statewide.
- *Resistance to change*. The agency recognizes that the way business has been done will have to change as transportation agencies embrace the principles of civil integrated management, which addresses more than simply 3-D modeling.

  The primary obstacle is resistance from the agency's own internal designers on design-bid-build projects. As a "siloed" organization, it can be difficult to coordinate the activities of disparate divisions or units. While areas such as surveying and mapping, construction and CADD are progressive when it comes to employing technology such as modeling, the Office of Design and the Roadway Design Office tend to focus more on policy and procedure, and are less involved in pushing technology out to roadway designers.

Related Documents

"Advances in 3D Modeling of Existing Subsurface Utilities," Carlo Pilia, James H. Anspach, *Proceedings of the Second Transportation & Development Institute Congress*, May 2014. Citation at http://dx.doi.org/10.1061/9780784413586.055
From the abstract: 3D design for highway and other transportation projects is ramping up in a significant way. However, almost all projects using this new technology still rely upon 2D mapping and occasional cross-sections or point locations for the depictions of existing underground utilities. The reason for this is simple; there has been no 3D utility information consistently and comprehensively available. … Florida DOT has instigated a trial program to utilize these technologies and concepts on a variety of highway projects. This paper will detail the technologies, processes, and risk management aspects of 3D mapping of non-visible assets, and results so far of the successful project deliverables for the Florida DOT. It will discuss remaining challenges and issues, and the potential to leverage clash detection programs based upon good data versus bad.

Bluebeam Revu, Bluebeam Software Inc. 2014.
http://www.bluebeam.com/us/products/revu/
From the web site: Bluebeam Revu combines powerful PDF editing, markup and collaboration technology with reliable file creation.

Conferences, Events, & Presentations, Engineering/CADD Systems Office, Florida Department of Transportation, 2014.
http://www.dot.state.fl.us/ecso/main/Events.shtm
From the web site: The ECSO staff gives presentations on the use of the FDOT CADD software and standards at meetings and conferences throughout the state where users may be present. We understand that it is not possible to attend all sessions so this is a place to download those presentations. … Find links here to presentations from sessions of the Florida Local User Group**,** the state's annual Design Expo, and a 2013 Civil 3D Symposium. Sessions are organized by product type.

FDOT CADD Training, Engineering/CADD Systems Office, Florida Department of Transportation, 2014.
http://www.dot.state.fl.us/ecso/main/FDOTCaddTraining.shtm
From the web site: FDOT CADD Training Manuals Engineering/CADD Systems Office (ECSO) provides a full line of training for the various customization of the Florida Department of Transportation (FDOT) Computer Aided Drafting & Design (CADD) Software suite delivered to assist the CADD users in the design process of FDOT projects. The following are the training manuals for use within the course or to use in self help for the individual user. They are complete with data sets for immediate use.

Downloads, Engineering/CADD Systems Office, Florida Department of Transportation, 2014.
http://www.dot.state.fl.us/ecso/downloads/software/software.shtm
Complete software downloads are available from this web site, including Florida DOT's 2014 version of customized Civil 3D CADD Software; SS2 CADD Software (MicroStation); and PEDDS, an application developed by Florida DOT used to sign and seal documents stored electronically.

Electronic Review Comment (ERC) System, Florida Department of Transportation, 2014.
http://www.dot.state.fl.us/officeofdesign/ProjectReview/ERC/
From the web site: Electronic Review Comments (ERC) is an application used to track the entire review process (comments and responses) for plan reviews and project submittals in a database. All comments and responses reside in one location allowing any user easy access to all or partial review data on demand. The system allows Project Managers to easily track all comments and responses from all Reviewers and Consultants at anytime during the process

TIMS3 (Technical Information Management System 3), The Ingenium Group, 2014.
http://www.tims3.com/TIMS3
From the web site: TIMS3 (Technical Information Management System) is a leading document management application for the engineering community. By providing an easy to-use interface and extranet connectivity, TIMS3 removes traditional business boundaries and connects users to a powerful network of information resources. With TIMS3, engineering firms can achieve operational efficiencies, enhanced productivity and have a high degree of control over their business critical documents.

Contact

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2) Iowa Department of Transportation

Use of 3-D Modeling

Using GEOPAK Corridor Modeler, Iowa DOT employs modeling in three preconstruction phases: preliminary engineering, design and right of way. While the agency does not have a formal constructability review process because Iowa DOT models all projects where cross sections are developed (grade as well as grade and pave) in 3-D, constructability issues can be easily identified throughout the design process. With modeling as part of the typical design workflow, additional efforts are not necessary to encourage collaboration. Regular team meetings are scheduled for most projects, and most communication is done via email or face-to-face communication.

While basic wireframe models are produced for every project, Iowa DOT also uses visualization, most typically on projects that include something new to the public or may be politically sensitive. Recent examples of visualization use to gather public input include designs for a roundabout and a proposed J-turn. The cost to produce a visualization model is project-dependent, with a simple project perhaps taking 40 hours to develop a highly detailed rendering.

The agency is not currently employing a reviewing software, though it is investigating Agtek Earthwork 4D, a product that could aid in reviewing the agency's deliverables to contractors for AMG.

Staff Responsibilities

The agency uses both state and consultant staff to prepare models during the preliminary engineering, design and right of way phases of preconstruction. Only state staff members are charged with preparing visualization models, with one design technician in the Office of Design tasked with developing advanced rendering of models.

Education and Training

All road design technicians and nonmanagerial engineers are trained in modeling techniques, but only one design technician has the knowledge and skills to perform the advanced visualization techniques when producing models.

Data and Files

Iowa DOT uses MicroStation GEOPAK to create 3-D models. Models are prepared in LandXML format as well as the native GEOPAK formats for the surfaces. The agency also prepares 3-D breakline strings in MicroStation DGN and Autodesk DXF formats. While modeling is done throughout the design process, final surfaces for AMG are not developed until the design is complete.

Files are made available to staff across the agency through project directories in ProjectWise. These files are also shared with consultants, typically using an FTP site. A project is underway to begin sharing files with consultants using ProjectWise. Files for potential bidders and contractors are made available online through Bid Express. Electronic files are supplied for information only at this time, though the agency has received positive feedback from contractors in Iowa. All AMG files are supplied pre-bid, which has contributed to submission of more favorable bids for work types that allow for GPS-controlled AMG.

The recent move of project-related data to ProjectWise is expected to resolve storage issues associated with the former Windows-based storage system. Employees in remote locations are able to access the data in ProjectWise.

Impacts of Modeling

- *Time savings*. Once designers become proficient in 3-D modeling, the process of creating a set of AMG-related files for contractor use is much faster than the previous 2-D approach.
- *Cost savings*. Cost savings are not as readily identified in the design phase of a project as they are in the efficiencies gained in construction. Developing models in the design phase has reduced costs by not requiring contractors to pay consultants to construct models from 2-D plans. Producing models that can be used for AMG grading and paving also saves money by reducing the number of stakes needed for construction surveys.
- *Quality*. Design intent is preserved when Iowa DOT develops models in the design phase. Consultants working with contractors no longer need to develop models using data from 2-D plans, which introduces the possibility that the intent of the designer could be misinterpreted.
- *Accuracy*. Modeling of projects has helped identify staging plans that were developed in 2-D that will not work when fully realized in 3-D.

Lessons Learned

- *Education and training*. Initiating modeling training while designers are still using 2-D processes proved to be challenging. Iowa DOT chose to start modeling on new projects and projects at a certain point in predesign development to limit potential confusion.
- *Software*. The GEOPAK software used by Iowa DOT was developed to design straight corridors, which makes it challenging to design structures like bridge berms, dikes and channels. Effective communication with the software developer is crucial to address areas of concern like this challenge.
- *Resistance to change*. The importance of modeling needs to be stressed to encourage some staff members to adopt the new technology. Some designers may not be comfortable with or understand 3-D design.

Contact

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3) Kentucky Transportation Cabinet

Use of 3-D Modeling

Using InRoads, Kentucky Transportation Cabinet (KYTC) prepares models in three preconstruction phases: preliminary engineering, planning and design. Visualization is used most typically for public involvement on more complex projects such as interchanges, major intersection design, urban widening and roundabouts. One staff person is trained in visualization, and consultants also provide visualization models. Cost estimates are not available, and project complexity does not determine who prepares a visualization model.

Internal reviews of project plans tend to follow more traditional practices, reviewing a set of plans sheet by sheet. Sometimes the agency conducts constructability reviews in a special meeting, sometimes as a standard joint inspection. The designers display the InRoads model on a screen and meeting attendees examine the model for discrepancies. (At this time, KYTC has yet to employ a 4-D model that includes the time factor, so construction staff is not typically included in these reviews.)

Staff Responsibilities

Approximately 5 percent of design is completed in-house, with the balance completed by consultants. While both state staff and consultants prepare models in the preliminary engineering and design phases, only consultant staff prepares planning models. Given the concentration of design work outside of the agency, most modeling for design phases is completed by consultants. That said, KYTC has found that its internal staff has readily embraced 3-D modeling, while its consultants tend to be less enthusiastic about the use of advanced modeling techniques.

Education and Training

KYTC engineering technicians and engineers are trained in 3-D modeling using InRoads software. The agency has established a joint training program in which KYTC staff and consultants participate together in training sessions conducted by the Kentucky chapter of the National Society of Professional Engineers. This collaborative approach to training has been in place for 20 years, with KYTC contracting with outside agencies and vendor experts to deliver the specialized training.

Data and Files

KYTC produces InRoads DTM and LandXML files for the existing and design surfaces (finished grade and subgrade), as well as InRoads ALG and LandXML files for the geometry. Files are also prepared for coordinate control. InRoads DTM and ALG files are prepared from the beginning of the project. Other files are prepared at the end of the project, after the design is finalized and files are submitted for letting the project.

ProjectWise is used to store and share files across the agency. Employees in remote locations access data through ProjectWise if Internet connections permit. For those in more remote locations where Internet access is less reliable, files are supplied on a DVD. Files are also shared with consultants, as needed, and with potential bidders through the agency's Electronic Plan Room. If information was not available pre-bid, the agency will work with the winning contractor to obtain the data needed.

Impacts of Modeling

Internally, KYTC designs in 3-D to catch things that would not typically be seen in paper plans (for example, things that fall between cross sections). For its pilot 3-D project, the agency used InRoads to color slope gradients. In preparing the model, designers readily identified a 50-foot flat area that required regrading. Designers could quickly complete the regrade in the model, saving valuable time that could have been lost had the issue not been identified until the construction phase.

The agency is still piloting the use of 3-D modeling, and quantifiable benefits have yet to be determined. The first pilot project's design is complete, with construction stalled because of permitting issues. By next summer KYTC expects to have additional information about whether this project will move into the construction phase. The second pilot—a major roadway between Lexington and Nicholasville—is planned. Roadway projects are more likely to be considered for 3-D modeling than structural projects.

KYTC is not taking full advantage of InRoads Quantity Manager, instead entering quantities into an estimator using a MicroStation macro that automates creation of the plan summary sheet. The greatest advantage of using modeling has been improved accuracy of volumes needed for earthwork.

From KYTC's perspective, modeling is not outside the agency's traditional workflow, and the cost of modeling is a fraction of what it would cost to reverse engineer plans. Having a staff person well-trained in modeling practices allows KYTC to develop models quickly. In this environment, KYTC is not adding a step to its processes and is not generating much more in extra costs. Instead, the agency (or its design consultant) is shifting hours to the front end of the production cycle.

Lessons Learned

- *Education and training*. The collaborative training sessions for KYTC designers and consultant staff have been effective. While designers tend to embrace the new technology and are being trained to use it, construction engineers in general are less conversant on the new technology and some may be resistant.

Software limitations. KYTC works with large LiDAR files that are "packed in" on the InRoads software.

- *System limitations*. KYTC uses ProjectWise to manage its modeling files, with servers in each of the 12 districts and central office sharing data. Rural districts using a slow DSL Internet connection can find it challenging to download large files.
- *Resistance to change*. This is KYTC's biggest challenge. Effective integration of 3-D modeling starts with an agency's leadership. Another area of concern is emphasizing and building into contracts the requirement to use the agency's electronic data rather than having a contractor scrap the KYTC data and develop its own.
- *Other concerns*. Concerns about signing and sealing plans have been raised by consultants concerned about the possibility of increased liability associated with digitally signing electronic plan packages. Contracts with consultants may need to be revised to retain the consultant on an as-needed basis during the life cycle of the project (until construction is complete). Typically, when a consultant completes a design, the contract with the consultant is closed after letting the project.

Related Documents

"KYTC's Electronic Data and 3D Models," Jeff Jasper, Division of Highway Design, Kentucky Transportation Cabinet, *AASHTO Subcommittee on Design Annual Meeting*, 2013.
http://design.transportation.org/Documents/SCOD%202013%20Meeting/KYTC%27s%20Electronic%20Data%20and%203D%20Modeling-Jeff%20Jasper%20(session2).pdf
This presentation addresses KYTC's history with 3-D modeling, an overview of the current policy, and a discussion of challenges and plans for the future.

3D Engineered Models for Construction—Case Study for Policies and Organizational Changes for Implementation: The Kentucky Case Study, Christopher Schneider, Jason Littleton, Federal Highway Administration, Publication No. FHWA-HIF-13-049, undated.
http://www.fhwa.dot.gov/construction/pubs/hif13049.pdf
This case study discusses KYTC's pilot project (relocation of approximately five miles of two-lane rural roadway on KY 7) for which 3-D models are developed for the proposed top surface and subgrade. The publication notes that "[t]he 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."

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4) Missouri Department of Transportation

Use of 3-D Modeling

The agency uses MicroStation GEOPAK to create models in two preconstruction phases: environmental review and design. GIS modeling is done for environmental review; partial 3-D modeling is completed as part of the roadway design process for corridor projects involving earthwork. Visualization is used for very high-profile projects or projects that require additional public outreach or education, such as a diverging diamond interchange or roundabout. While visualization is now possible for every project, it is rarely used.

The preliminary design includes 50- or 100-foot template drops. The final design includes 10-foot intervals and critical point sections, and 1-foot intervals for critical areas such as gore areas and intersections. The designer creates the DTM file from the final design, with the top of surface and alternate grading surface in LandXML.

The agency is focusing on linear corridor modeling for expansion projects and has yet to see any modeled projects in construction. While the agency is using corridor modeling tools, quantities are still based on area method calculations. Design teams are encouraged to deliver models when designing large projects, but limited funding for expansion projects has curtailed the amount of modeling the agency currently does.

Staff Responsibilities

Both state staff and consultants are responsible for modeling. In Missouri, highway designers are primarily responsible for the modeling work, though a senior design technician may also perform modeling duties.

Education and Training

Missouri DOT is launching a training and education program as part of the implementation of the SS3 Power GEOPAK software planned for later this fall. The change to new software will be implemented on an aggressive district-by-district schedule, beginning with the first district at the end of September 2014 and finishing with the last district by the end of April 2015.

Data and Files

In addition to ArcGIS files, Missouri DOT produces files using MicroStation GEOPAK, including IRD, TIN, GPK, LandXML (for both geometry and terrain) and DGN files. Modeling-related electronic files are part of the roadway design process and are packaged and delivered with the PS&E documents. While not delivered as part of the PS&E package, ArcGIS files are prepared as part of the normal design process to screen for environmental issues and archaeological sites.

Missouri DOT's mapping unit provides mapping files such as LiDAR, topographic geometry and TIN models to district roadway designers. The roadway design team shares TIN and CADD data with the Bridge Division for use in stream hydraulic analysis for bridges. The design team also shares CADD data with the right of way group to import land boundaries in ArcGIS. Construction staff receives the electronic data produced as part of the roadway design process to do contract administration and payment of quantities.

Potential bidders and contractors have access to files through Missouri DOT's web site at http://www.modot.org/business/contractor_resources/OpenLetting.shtml. Electronic deliverables such as alignment and profile data, TIN models, MicroStation geometry and any surfaces generated as a result of the design process in native and LandXML formats are made available.

Modeling files are stored in and accessed through ProjectWise. The ProjectWise database is centralized; each district has its own data source for ProjectWise. LiDAR data is stored in dedicated servers that are available only to district staff.

Impacts of Modeling

In 2011, Missouri implemented a 3-D design policy. Among the impacts of modeling identified thus far:

- *Time savings*. When staff has developed a proficiency with 3-D modeling, time savings are expected. At this time, it takes longer to design a project using the modeling tools.
- *Future benefits*. Design models are available for some projects, but construction staff is not yet conducting 3-D-based construction inspections. Using engineering models for inspection is a goal the agency is moving toward in the next year.

Lessons Learned

- *Software limitations.*
    - Current tools still have limitations with modeling and handling large data sets from LiDAR. The limitations associated with creating large digital terrain models from LiDAR are expected to be positively impacted by the launch of SS3 Power GEOPAK later this fall.
    - Sharing large data sets such as imagery and LiDAR point clouds across the network can be problematic. To address this, later this fall Missouri DOT will implement a management system for large data—a web-based application that will house large imagery and LiDAR data sets in a central location, but give users access to it as needed. Users can view only the areas of interest by selecting a fence for a geographical area.
    - Missouri DOT is implementing new tools that are expected to improve the modeler's experience. For example, the agency is standardizing configuration settings for its CADD unit and creating a process to transfer data that alleviates any added burden for the user. The agency is also introducing methodology that will reduce the amount of effort to design intersections, roundabouts, crossovers, etc. Moving to the new technology is expected to increase designers' satisfaction and lessen any resistance to the new methods.
- *System limitations*. Network communications in remote areas, where a fiber connection is not available, is a significant infrastructure limitation that cannot be addressed without major expansion of communication lines.
- *Other concerns*. Missouri DOT is working with FHWA to bring in experts to help create guidance to ensure that the models Missouri DOT designers develop will address what is needed for construction.

- *Recommendations*. States beginning to use 3-D technology are advised to:
  - Complete a few high-profile pilot projects before implementing modeling on all projects.
  - Streamline LiDAR data going to designers.

Related Documents

3D Project Development Workflows for DOT Projects, Alexa Mitchell, Missouri Department of Transportation, March 2014.
http://prezi.com/esichijty3jh/3d-project-development-workflows-for-dot-projects/
This online presentation provides timelines and information about Missouri DOT's use of 3-D modeling.

"Virtual Design & Construction: More Than 3D Modeling," Alexa Mitchell, Missouri Department of Transportation, *2013 Transportation Engineers Association of Missouri Conference,* 2013.
http://www.teamconference.org/2013/Virtual_Design_and_Construction.pdf.pdf
This conference presentation addresses roles, technology and data acquisition, and provides an update on Missouri DOT's use of 3-D modeling.

"237.14, Electronic Design Data Delivery," *Engineering Policy Guide*, Missouri Department of Transportation, January 9, 2013.
http://epg.modot.mo.gov/index.php?title=237.14_Electronic_Design_Data_Delivery
This is an interim rule providing temporary guidance with regard to electronic data. Missouri DOT plans to finalize the rule when the agency moves to the SS3 version of PowerGEOPAK later this fall. *From the rule:*

> MoDOT uses MicroStation for highway and bridge design and drafting. Highway design surveys and road design computations are achieved by using Bentley GEOPAK software. All department drawings are available to the consultant in a Microstation DGN format only. GEOPAK deliverable requirements pertain to road design, preliminary design, and survey projects only. Bridge design projects do not require GEOPAK deliverables.

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5) North Carolina Department of Transportation

Use of 3-D Modeling

Up until about five years ago, North Carolina DOT had little experience with modeling. At that time, modeling experience was limited to a visualization group within the agency using Photoshop to create a rendering. Today, all new projects in highway design use 3-D design practices from the beginning of the project. North Carolina initiated modeling with bridge replacement projects completed in 2010 and started providing modeled TINs on 2011 bridge projects for bid advertisement.

Using MicroStation GEOPAK Corridor Modeler software that has been modified to meet specific agency needs, North Carolina DOT prepares models during all phases of preconstruction, with the heaviest users of modeling software in the central office. There is currently no requirement for districts to use modeling software. A legislative mandate that 65 percent of projects employ consultants means that the agency's contractors are modeling, too.

Visualization is used for certain high-profile projects. In these cases, the visualization model is prepared during the preliminary design phase for use at public meetings. Typically, consultants prepare these models.

The 3-D models are not used in a formal constructability review process. The current constructability review process includes in-field inspections during which staff members with design and construction expertise discuss the project and review hard-copy plans for feasibility.

The agency has found that preparing its own models for the pre-bid process eliminates the need for contractors to obtain post-bid modeling to develop files needed for AMG. Contractors had been paying consultants to prepare 3-D models for AMG based on data provided by North Carolina DOT in its letting documents. By providing electronic surface files to contractors wishing to use AMG, the agency may see the impact of modeling in more favorable bids.

Staff Responsibilities

Consultants are responsible for preparing models for environmental review and planning phases; both state staff and consultants prepare models during preliminary engineering, design and right of way phases of preconstruction.

Education and Training

Training is provided to both staff and consultants. Staff in the Roadway and Hydraulic Design areas began receiving training in fall 2009. A wealth of training materials is provided via the North Carolina DOT web site; see **Related Documents** for more information.

Data and Files

Files produced in connection with North Carolina DOT's modeling program include the 3-D design file, proposed DTM and alignment files, and LandXML files. All design files are shared on a project server segregated by discipline (structures, geotechnical, roadway, surveys and hydraulic). The same files are made available to consultants via an FTP site; contractors are provided with these files via Bid Express.

Impacts of Modeling

- *Time savings*. While designers now take more time to prepare 3-D models than when preparing 2-D models, once staff is comfortable with the software, time savings are expected when making changes and updating quantities with greater ease.
- *Cost savings*. Modeling is relatively new to the agency, and it takes time to complete the transition. Savings will likely be realized when staff has surpassed the learning curve and modeling is considered a standard practice.
- *Quality*. The agency has not completed enough projects to know how the model is used in the field. There is simply not enough data yet to measure quality impacts.
- *Accuracy*. Quantities are still determined using older methods. Quantities may be more accurate when modeling is used.

Lessons Learned

- *Education and training*. The agency has developed its own training classes, customized to meet the needs of internal designers and consultants.
- *Software*. Software continues to change, with regular releases of new versions of software. This creates a training challenge. Out-of-the-box software cannot be used without making changes to meet the needs of the specific user, so while software tools are advanced, making them work for a specific environment takes time and attention.
- *Resistance to change*. Building in time for learning into early modeling projects can reduce anxiety among staff members who are reluctant to embrace the new technology. Identifying the return on the investment for the additional time required on early modeling projects can be helpful for those who may be resistant to the use of new technology. Management support is also critical to encourage staff to adopt new practices.

Related Documents

Corridor Modeling: Roadway Design Training for Corridor Modeling, North Carolina Department of Transportation, undated.
https://connect.ncdot.gov/projects/roadway/pages/corridor-modeling.aspx
This web site provides a wealth of training materials, including illustrated questions and answers about various topics, basic template fundamentals, training exercises and a template library.

Contact

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6) Wisconsin Department of Transportation

Use of 3-D Modeling

Roadway design staff develops surface models in Civil 3D as part of the standard roadway design workflow. Beginning this month, all new Wisconsin DOT design projects with earthwork included in the project scope will be required to deliver surface models.

Modeling is used in all five preconstruction phases. While models are not part of the agency's standard constructability review process, the agency's most complicated design projects have employed Navisworks for clash detection analysis. On the few projects using clash detection, the agency identified numerous design issues that could be corrected during the design phase of the project. As surface model development becomes more common within Wisconsin DOT, the agency expects to use models more frequently during constructability review.

Project staff determines when a visualization model will be produced, and these models are typically limited to more complex projects with larger budgets. Consultants are responsible for developing the visualization models. The cost for a visualization model is specific to the quality and detail expected for the project.

Staff Responsibilities

Both state staff and consultants are involved in developing models during all five preconstruction phases. Staff uses Microsoft SharePoint, Bridgit web conferencing (see http://www.smarttech.com/bridgited) and Smart Boards to communicate and collaborate.

Data and Files

Wisconsin DOT develops surface models using Civil 3D DWG files. A Windows network is used to share files across the agency and within the project development team. Consultants gain access to the DWG files via FTP. Potential bidders and contractors have access to LandXML, DWG and CSV files. While the agency currently archives the entire Civil 3D project data set in its native format, a project is underway to develop a data management and archival strategy.

> *Note*: We culled the input reflected in **Impacts of Modeling** and **Lessons Learned** from the Wisconsin DOT response to the current survey and presentations appearing in **Related Documents**.

Impacts of Modeling

Wisconsin DOT has not attempted to quantify modeling's benefits, but has identified efficiencies, including:

- *Time savings*. When workflows are focused on building 3-D deliverables, adding them to existing deliverables does not noticeably increase total workload. Modeling can reduce project rework and risk and enhance improvements to cost and schedule.
- *Cost savings*. Cost gains achieved through the use of 3-D modeling can be more significant during general, drainage, structural and feature design categories than during earthwork and excavation alone.
- *Quality*. Modeling is too new for the agency to identify benefits to final design quality. That said, compared to 2-D design, 3-D design incorporates a higher level of detail into

the final design, and the added detail is expected to contribute to a higher quality design concept.

- *Other impacts*. Modeling improves communication with stakeholders, especially with nonengineers.

Lessons Learned

- *Resistance to change*. While most staff members are not excited about changes to their tools and work processes, communication can be critical in helping them accept significant change in a short time.
- *Communication*. Increasing communication, coordination and collaboration between all project planning, design, construction, ad hoc, maintenance, operations and oversight staffs is important.
- *Workflow and efficiencies*.
  - A methodology and workflow for sharing, editing and approving 3-D model files are critical to success.
  - The goal of an effective design workflow is to develop construction-ready surface models during the design process.
  - Designing in Civil 3D and producing sheets in MicroStation is not an optimal workflow.
  - Surfaces, which are the key output of modeling, must be built early and built well.
  - The 3-D surface model output must be synchronized with plan sheets.

Related Documents

Implementing a Model Based Approach to Design and Construction at Wisconsin DOT, Eric Arneson, Methods Development, Wisconsin Department of Transportation, July 11, 2013.
ftp://wydot-ftp.dot.state.wy.us/PhotosSurveys/TRBpresentations/2013-07-11-WisDOT-Model-Implementation.pptx
This presentation covers Wisconsin DOT's current AMG and model practices; changes to design to deliver 3-D models; the agency's model-centric approach to design; and implementation status (lessons learned).

CIM-Civil Integrated Management: Best Practices & Lessons Learned; WisDOT SE Freeways—Focus on Design & Construction, Bob Gutierrez, William Mohr, Mike Paddock, Lance Parve, Kurt Flierl, Wisconsin Department of Transportation, August 23, 2012.
http://www.efl.fhwa.dot.gov/files/technology/3d-modeling/Thursday_Meeting/Lance-Parve.pdf
This presentation accompanied an August 2012 Focus on Design and Construction meeting.

3D Engineered Models for Construction—Understanding the Benefits of 3D Modeling in Construction: The Wisconsin Case Study, Lance Parve, Federal Highway Administration, FHWA-HIF-13-050, undated.
http://www.fhwa.dot.gov/construction/pubs/hif13050.pdf
This case study of Wisconsin DOT's experience with 3-D modeling on its $1.7 billion Zoo Interchange project includes lessons learned.

Contact

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Related Research

The publications below offer national guidance, training opportunities and recent published and in-progress research on the subject of 3-D modeling by transportation agencies.

National Guidance

NCHRP Synthesis 446: Use of Advanced Geospatial Data, Tools, Technologies, and Information in Department of Transportation Projects, Michael J. Olsen, John D. Raugust, Gene V. Roe, April 2013.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_446.pdf
This report presents the current state of the practice about the development, documentation, and introduction of advanced geospatial technologies within the transportation agencies. Highlights of the report include:

Page 12 of the report (page 21 of the PDF) presents tables that show the percentage of DOTs using 3-D modeling and the project phases to which 3-D modeling is applied. Relevant excerpts from these tables appear below.

State DOT Level of Usage or of Interest in 3-D Model-Based Design

Level of usage/interest	Percentage
Standard operating procedure	29%
Implementing	23%
Investigating	19%
Researching	10%
Not using	15%
No interest	2%
Not sure	2%

State DOT Level of Usage of 3-D Model-Based Design by Project Phase

Application	Percentage
Planning	28%
Right of way	14%
Design	72%
Construction	38%
Operations	14%
Other	12%
Not using	16%
Not sure	8%

Page 44 of the report (page 53 of the PDF) begins a discussion of 3-D model-based design, noting its strengths and weaknesses (see Table 19 on page 45 of the report) and examples of current uses in state DOTs.

3D, 4D, and 5D Engineered Models for Construction; Executive Summary, Christopher Schneider, Federal Highway Administration, Publication No. FHWA-HIF-13-048, March 2013.
http://www.fhwa.dot.gov/construction/pubs/hif13048.pdf
From the abstract: This Technical Brief provides an overview of 3D modeling, including technology applications during design and construction, benefits to stakeholders, resource requirements, current state-of-the practice, and advanced applications such as adding 4D and 5D components.

Page 3 of the PDF provides this estimate of cost savings associated with the use of 3-D models:

> Once built, the model can be utilized throughout the full lifecycle of a facility and by various agencies, for example during infrastructure maintenance, operations, and asset management work.
>
> - 66% savings for grade checking
> - Up to 85% for reduction of stakes
> - 3% to 6% by volume for improved material yields, and
> - 30% to 50% for uninterrupted earthmoving production.
>
> These results can equate to a savings of 4% to 6% of total project costs by using 3-D models. Contractors often claim 15% to 25% increased efficiency in earthmoving alone. One project had an 8-month schedule reduction and another project reported increases in productivity ranging from 40% to 50%.

3D Engineered Models Webinar Series, Federal Highway Administration, May 29, 2014.
http://www.fhwa.dot.gov/construction/3d/webinars.cfm
From the web site: A series of eight webinars have been developed to assist the FHWA's transportation partners in adopting this proven technology. The webinars are given in a "cradle to grave" sequence. Participants will hear how contractors incorporate 3D engineered models in their workflow of bidding and preparing to execute construction.

Recorded Webinars

- **Overview of 3D Engineered Models for Construction**, Federal Highway Administration, November 20, 2013.
  http://www.fhwa.dot.gov/construction/3d/webinars/webinar01.pdf
- **Creating 3D Engineered Models**, Federal Highway Administration, January 8, 2014.
  http://www.fhwa.dot.gov/construction/3d/webinars/webinar02.pdf
- **Applications of 3D Models in the Construction Office**, Federal Highway Administration, February 19, 2014.
  http://www.fhwa.dot.gov/construction/3d/webinars/webinar03.pdf
- **Applications of 3D Models on the Construction Site**, Federal Highway Administration, April 2, 2014.
  http://www.fhwa.dot.gov/construction/3d/webinars/webinar04.pdf

- **Managing and Sharing 3D Models for Construction**, Federal Highway Administration, May 7, 2014.
  http://www.fhwa.dot.gov/construction/3d/webinars/webinar05.pdf

Future sessions include:

- **Overcoming Challenges to Using 3D Engineered Models for Construction**, scheduled for September 10, 2014; register at https://www.nhi.fhwa.dot.gov/resources/webconference/viewconference.aspx?webconfid=27666.
- **Steps to Requiring 3D Engineered Models for Construction**, scheduled for October 15, 2014.
- **The Future: Adding Time, Cost and Other Information to 3D Models**, scheduled for November 19, 2014.

3D Engineered Models, Federal Highway Administration, January 16, 2014.
http://www.fhwa.dot.gov/construction/3d/design.cfm
This web site provides links to resources in the following topic areas:

- Design.
- Design visualization.
- Electronic data, geometrical drafting.
- Mechanistic analysis.
- U.S. specifications/standards.
- International specifications/standards.

Related Resources:

Education/Training, 3D Engineered Models, Federal Highway Administration, January 16, 2014.
http://www.fhwa.dot.gov/construction/3d/training.cfm
Find links to online and classroom-based training, including free Civil 3D training provided by Wisconsin DOT.

Resources/Technical Reports, 3D Engineered Models, Federal Highway Administration, January 14, 2014.
http://www.fhwa.dot.gov/construction/3d/resources.cfm
Among the resources available here are FHWA case studies on the use of 3-D modeling and AMG and select training materials.

In-Progress National Research

Implementation Manual for 3D Engineered Models for Construction, Iowa State University, Ames, project in progress, expected completion date: December 31, 2014.
Abstract at http://trid.trb.org/view/2014/P/1307300
From the abstract: As part of its Every Day Counts initiative, the Federal Highway Administration (FHWA) has an implementation plan to support the widespread use of 3D Engineered Models for Construction. … FHWA has requested the Iowa Department of Transportation to develop a manual for owner agencies, designers, and contractors that outlines the benefits of 3D modeling and how to properly generate accurate 3D models for downstream uses. The Institute for Transportation (InTrans) at Iowa State University and Snyder & Associates, Inc. is already

involved in two other aspects of the FHWA's implementation plan: The development of Technical Service Call Centers and the development of web-based training modules. Sponsor: Iowa Department of Transportation.

Recently Published Research

"Object-Based 3D Intelligent Model for Construction Planning/Simulation in a Highway Construction," Zhenhua Shen, Kevin Orr, Wonsik Choi, Namgon Kim, Hyunjoo Kim, *Construction Research Congress*, May 2014.
Citation at http://dx.doi.org/10.1061/9780784413517.027
From the abstract: This study proposes a three dimensional (3D) visualization model in highway design/construction that electronically represents information of highway projects. The 3D model will be based on the Standard for the Exchange of Product (STEP) model data, which is an open standard, so it can be used as data structures. Because the design model includes integrated resources to represent 3D geometric shape and project management information of the infrastructure, the built visualization model will allow end users to extract the necessary data from the object-based 3D intelligent model. This integrated data model is expected to provide practical engineering information to improve the design/construction process.

"Improving Transparency of Construction Projects Using Visualization Technology," Nabeel Khwaja, Cameron Schmeits, *TRB 93rd Annual Meeting Compendium of Papers*, Paper # 14-4694, 2014.
http://docs.trb.org/prp/14-4694.pdf
This conference paper discussed the use of 3-D modeling to develop and present complex spatial and temporal engineering information to project stakeholders in a user-friendly format. The paper presents a case study of the successful use of this technology on the $2.6 billion Lyndon B. Johnson Freeway reconstruction project in Dallas.

"Ensuring Design-Build Quality in a 3D World," Mo Harmon, Mark Lemieux, Matt Simon, *CE News*, Vol. 25, Issue 9, pages 28-30, October 2013.
http://www.cenews.com/magazine-article-cenews.com-10-2013-ensuring_design_build_quality_in_a_3d_world-9495.html
This article describes a new quality assurance and quality control process that has been developed to help design-build teams with the transition from 2-D to 3-D. The new process was tested in a pilot program by Virginia Department of Transportation. The authors note that the quality management system helped identify conflicts in the design, shortened the review and validation time, and reduced the amount of rework necessary.

"Virtual Design and Construction of Transportation Projects," Kevin Gilson, Brian Mercure, *CE News*, Vol. 25, Issue 7, pages 44-46, August 2013.
http://www.cenews.com/magazine-article-cenews.com-8-2013-virtual_design_and_construction_of_transportation_projects-9398.html
Connecticut Department of Transportation's use of 3-D and 4-D modeling for the I-95 New Haven Harbor Crossing Corridor Improvement Program is highlighted in this article. The 3-D and 4-D models (the latter combine design elements with construction activities to show progress on the project over time) are used for technical analysis, to communicate ideas and to provide visualization to help the public understand the project.

Appendix A: Survey Results

The full text of each survey response is provided below. For reference, we have included an abbreviated version of each question before the response; for the full question text, please see page seven of this Preliminary Investigation.

Florida

Contact: Bruce Dana, Statewide CADD Coordinator, Florida Department of Transportation, 850-414-4720, bruce.dana@dot.state.fl.us.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** Diverse multidiscipline team reviews the plans in hardcopy or electronically (PDF) at 90% submittal or before.
2. **Modeling is used in these preconstruction phases:**
   - Design
3. **Visualization used during preconstruction phase?** [No response.]

3a. **Limits on visualization?** [No response.]

3b. **Estimate of visualization cost:** [No response.]

4. **Using modeling to investigate utilities, soils, etc.?** Yes. Tomography and SUE [subsurface utility engineering] for two statewide contracts in place. Has been used on a few other projects where utility conflicts were suspected.
5. **Using reviewing software?** Yes. Adobe Acrobat and Bluebeam Revu. [See http://www.bluebeam.com/us/products/revu/]. We also use a collaborative review and comment system called ERC. [See http://www.dot.state.fl.us/officeofdesign/ProjectReview/ERC/ for more information.]

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Design – both state and consultant staff
   - Other – consultant staff. [See below for details.]

   In Design-Build projects the design-contractor team develops their 3-D models. Also on some Design-Bid-Build projects the contractor will develop 3-D models from FDOT-supplied CADD and engineering data (usually LandXML or cross sections).
7. **Responsibility for developing visualization model:** Both state and consultant staff. Only for public presentation, and on few projects. We are looking at tools like InfraWorks [see http://www.autodesk.com/products/infraworks-family/overview] to help speed this along, but we have only a few staff capable of 3-D rendering in MicroStation.

   State staff classification or functional area: [No response.]

7a. **Project complexity determines who develops visualization model?** Yes. Also depends on who is doing the design. Consultants perform 95% or more of the design for FDOT presently, and we tend to consult the more complex projects now.

8. **Type of state employee receiving advanced modeling training:** Engineering technicians, professional engineers, construction management staff, project managers.

All have attended training (examples posted on the FDOT CADD Office website).

Data and File Management

9. **Types of files produced:** 2-D and 3-D MicroStation files, 3-D AutoCAD Civil 3D files, Land XML. See: http://www.dot.state.fl.us/ecso/downloads/presentations/Files/DesignExpo2014/AutodeskCivil3D.shtm and http://www.dot.state.fl.us/ecso/downloads/presentations/Files/DesignExpo2014/BentleyMicroStationGEOPAK.shtm

10. **When (stage or project completion) electronic files are used:** During design when they are done, although for Design-Bid-Build projects the contractors have developed them post-let.

11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** All files shared with a CADDware electronic file management system called TIMS (http://www.tims3.com/). We are investigating Bentley ProjectWise. We have an archival system called PEDDS-DB and an EDMS System (Hummingbird) too.
    - **Within the project development team.** See 11a. for in-house projects; external collaboration by email, FTP and physical media.
    - **With consultants.** External collaboration by email, FTP and physical media.
    - **With potential bidders.** We have a website where bidders and contractors download the files; see http://www.dot.state.fl.us/cc-admin/Expedite/prime.shtml.
    - **With contractors.** We have a website where bidders and contractors download the files; see http://www.dot.state.fl.us/cc-admin/Expedite/prime.shtml.

12. **Storing large amounts of data:** On internally managed Web and file servers. Considering cloud if the move to ProjectWise happens.

13. **Data access for employees in remote locations:** Internet.

14. **Details and additional comments:** Please call me after July 1 for additional information you might need.

Iowa

Contact: Thomas Hamski, Automation Engineer, Office of Design, Iowa Department of Transportation, 515-239-1836, thomas.hamski@dot.iowa.gov.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** We do not have an official constructability process, however, by modeling all of our projects in 3-D we can easily identify constructability issues throughout the design process.
2. **Modeling is used in these preconstruction phases:**
   - Preliminary engineering
   - Design
   - Right of way
3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** Yes. High-detailed rendered visualization is generally done on projects where something is being done that is sensitive politically or is something new for the public. Two examples Iowa has done so far for public input are roundabouts and a proposed J-turn.

3b. **Estimate of visualization cost:** It is difficult to estimate as every model is different. A simple project could take 40 hours to develop a high-detailed rendering. Basic wireframe models are developed on all projects and are simply part of the tools we use to design.

4. **Using modeling to investigate utilities, soils, etc.?** No.
5. **Using reviewing software?** Yes. We have started to look into Agtek Earthwork 4D [see http://www.agtek.com/] to review our deliverables to contractors for automated machine guidance. We have not committed to a specific software yet, but Agtek's software package looks very promising.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Preliminary engineering – both state and consultant staff
   - Design – both state and consultant staff
   - Right of way – both state and consultant staff
7. **Responsibility for developing visualization model:** State staff.

   State staff classification or functional area: The Office of Design has one design technician who has the knowledge for advanced rendering of models.

7a. **Project complexity determines who develops visualization model?** No.

8. **Type of state employee receiving advanced modeling training:** All road design technicians and nonmanagerial engineers are trained in modeling techniques, where only one technician has the knowledge in advanced visualization of the models.

Data and File Management

9. **Types of files produced:** All of the modeling that the Office of Design produces are in MicroStation using GEOPAK tools to create the 3-D models. When we deliver models to contractors for automated machine guidance, we offer the models in LandXML format; we

also supply the native GEOPAK formats for the surfaces. We also supply 3-D breakline line strings in MicroStation DGN and Autodesk DXF formats.

10. **When (stage or project completion) electronic files are used:** Modeling is done all throughout the design process in Iowa. Final surfaces for automated machine guidance are not developed until 100% design.
11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** All project-related files are available to any staff in the project directories.
    - **Within the project development team.** [No response.]
    - **With consultants.** Typically, all project-related files in a project directory are shared with a consultant to ensure they can develop a design properly. In the past, we have used FTP to share this information with consultants, but we are in the process of sharing through ProjectWise.
    - **With potential bidders.** All MicroStation DGN files that contain alignment and profile information. LandXML and native GEOPAK format of surfaces for grading, 3-D breaklines in DGN and DXF format. All electronic data that is available is shared with the project [and] is listed online with the bid order pre-letting.
    - **With contractors.** All MicroStation DGN files that contain alignment and profile information. LandXML and native GEOPAK format of surfaces for grading, 3-D breaklines in DGN and DXF format. All electronic data that is available is shared with the project [and] is listed online with the bid order pre-letting.
12. **Storing large amounts of data:** Iowa recently moved our project-related data into Bentley System's ProjectWise document management system to alleviate our storage issues with a Windows-based storage system.
13. **Data access for employees in remote locations:** Through our ProjectWise document management system.
14. **Details and additional comments:** [No response.]

Kentucky

Contact: Kevin Martin, Transportation Engineering Branch Manager, Kentucky Transportation Cabinet, 502-782-4899, kevin.martin@ky.gov .

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** Some projects have a formal plan review process while others cover it in our final plan inspection meeting. The decision on how to best handle constructability review is project-specific mainly based on the complexity of the traffic control scheme.
2. **Modeling is used in these preconstruction phases:**
    - Preliminary engineering
    - Planning
    - Design
3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** Mainly for public involvement on more complex projects (interchanges, major intersection design, urban widening, roundabouts, etc.).

3b. **Estimate of visualization cost:** We don't have a good estimate, as this is not a standard item when negotiating consultant contracts. We have an in-house visualization person, but he is not available to comment for this survey at this time.

4. **Using modeling to investigate utilities, soils, etc.?** No.

5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Preliminary engineering – both state and consultant staff
   - Planning – consultant staff
   - Design – both state and consultant staff

7. **Responsibility for developing visualization model:** Both state and consultant staff.
   State staff classification or functional area: [No response.]

7a. **Project complexity determines who develops visualization model?** No.

8. **Type of state employee receiving advanced modeling training:** Engineering technicians and engineers.

Data and File Management

9. **Types of files produced:** InRoads DTM and LandXML files for the existing and design surfaces (finished grade and subgrade). InRoads ALG and LandXML files for the geometry. Trimble DC files and CSV files for coordinate control. Existing and proposed manuscript files in DXF format for upload into the Survey Controller.

10. **When (stage or project completion) electronic files are used:** DTM and ALG files from the beginning. The others come at the very end, after the design is finalized and we submit the files for the letting.

11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** All files are shared. We use ProjectWise across our agency.
    - **Within the project development team.** All files are shared. We use ProjectWise across our agency.
    - **With consultants.** All files are shared if needed. Consultant submits the required electronic files before the letting.
    - **With potential bidders.** All electronic files submitted as supplemental data prior to the letting are distributed through our Electronic Plan Room pre-bid.
    - **With contractors.** We will work with our winning contractor to get the data they need if it was not submitted pre-bid.

12. **Storing large amounts of data:** ProjectWise.

13. **Data access for employees in remote locations:** ProjectWise, but many county construction field offices have DSL or slower Internet connections, so we supply a DVD with the electronic data if necessary.

14. **Details and additional comments:** KY is doing a few pilot projects that require the use of our 3-D model for construction and inspection services over our plan set and the model will be the as-built record "plans." We have presented on this topic for FHWA as part of the EDC2 initiative.

Michigan

Contact: David LaCross, Construction Survey Specialist, Michigan Department of Transportation, 517-331-6062, lacrossd@michigan.gov.

Note: Michigan DOT responded to additional questions about agency workflows and efficiencies; see questions 14 through 20.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** We are currently in the process of developing a constructability review process.
2. **Modeling is used in these preconstruction phases:**
   - Environmental review
   - Preliminary engineering
   - Planning
   - Design
   - Right of way
3. **Visualization used during preconstruction phase?** No.

3a. **Limits on visualization?** N/A

3b. **Estimate of visualization cost:** N/A

4. **Using modeling to investigate utilities, soils, etc.?** Yes. We are just starting to implement the use of models to investigate the impact to underground utilities. We do not have any examples at this time.
5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Environmental review – both state and consultant staff
   - Preliminary engineering – both state and consultant staff
   - Planning – both state and consultant staff
   - Design – both state and consultant staff
   - Right of way – both state and consultant staff
7. **Responsibility for developing visualization model:** N/A
   State staff classification or functional area: N/A

7a. **Project complexity determines who develops visualization model?** N/A

8. **Type of state employee receiving advanced modeling training:** Road and bridge engineers.

Data and File Management

9. **Types of files produced:** 3-D line string files, triangle files.
10. **When (stage or project completion) electronic files are used:** We are currently in the pilot stage of requiring a model at each of the submittal milestones for review.
11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** DGN files; LandXML files; DXF files; and GPK files.
    - **Within the project development team.** DGN files; LandXML files; DXF files; and GPK files.
    - **With consultants.** DGN files; LandXML files; DXF files; and GPK files.
    - **With potential bidders.** DGN files; LandXML files; DXF files; and GPK files.
    - **With contractors.** DGN files; LandXML files; DXF files; and GPK files.
12. **Storing large amounts of data:** We have the files stored on a server with access to the files through ProjectWise.
13. **Data access for employees in remote locations:** We have the files stored on a server with access to the files through ProjectWise and by using a vpn [virtual private network] login to the server.

Agency Workflows and Efficiencies

14. **Encouraging project team members to communicate, coordinate and collaborate: [**No response.]
15. **Has modeling improved constructability reviews?** We recently hired a land surveyor and an engineer to work as a team to review the 3-D model produced by our designers. They are in the process of developing a QA checklist and other review checklists for constructability.

    By allowing the reviewers to check that the project will tie in with the existing roadway before the project is let has helped a lot. And to be able to check the grades and slopes in key areas such as gores and super transitions match the plans and will be constructible has helped the contractor and MDOT in constructability reviews.
16. **Has modeling improved development of PS&E bid packages?** I haven't seen any numbers regarding this yet. But I assume that they will improve as we start to require the 3-D model on projects.
17. **Quantifiable benefits:** We are still in the process of quantifying the benefits of 3-D models. At this time we anticipate the pilot stage to be complete by the end of the summer and hope to begin implementing the requirement after we review the results from our pilot phase.
18. **Efficiencies gained and benefits realized:** We are gaining efficiencies in streamlining the design data to the field. We currently have three construction projects utilizing 3-D models. Our inspectors have been using modern survey equipment with the model data to check the contractor during construction. By utilizing the survey equipment we have not required to have the contractor place stakes for grade checking of the roadway.

19. **Deployment barriers or obstacles:**

    Education and training. Yes, we have created some training material to train our in-house design staff to create the 3-D models.

    Software limitations. We are in the process of exploring the limits of our design software and survey software to create and consume 3-D data.

20. **Details and additional comments:** [No response.]

Missouri

Contact: Alexa Mitchell, CADD Services Engineer, Missouri Department of Transportation, 573-751-6591, alexa.mitchell@modot.mo.gov.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** Core team meetings are held throughout the life of a design project to identify potential issues as the project is being developed. This can include reviewing plan sheets or electronic data depending on the project.
2. **Modeling is used in these preconstruction phases:**
    - Environmental review
    - Design
    - GIS modeling is done for environmental review, partial 3-D modeling is completed as part of the roadway design process for corridor projects involving earthwork. For very high-profile projects, 3-D visualization will be utilized.
3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** Yes. High-profile projects or projects that require additional public outreach and education. For example, new diverging diamond interchange or roundabout.

3b. **Estimate of visualization cost:** Unknown.

4. **Using modeling to investigate utilities, soils, etc.?** No.
5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
    - Environmental review – both state and consultant staff
    - Design – both state and consultant staff
    - Other – both state and consultant staff

    MoDOT highway designers are responsible for developing any project modeling or the design consultant hired to do the work.

7. **Responsibility for developing visualization model:** Both state and consultant staff.

    State staff classification or functional area: Highway designers.

7a. **Project complexity determines who develops visualization model?** Yes. Again, only certain projects will have a visualization model. The modeling highway designers develop is the actual design model for construction.

8. **Type of state employee receiving advanced modeling training:** Highway designers, and sometimes senior design technicians.

Data and File Management

9. **Types of files produced:** ArcGIS files MicroStation and GEOPAK files (IRD, TIN, GPK, LandXML of geometry and terrain models, DGN).
10. **When (stage or project completion) electronic files are used:** Modeling-related electronic files are part of the roadway design process, and they are packaged and delivered with the PS&E documents. ArcGIS files are not delivered, but are prepared as part of the normal design process to screen for environmental and archeological sites.
11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** Mapping unit provides mapping files such as LiDAR, topographic geometry and TIN models to the district roadway designers. The roadway design team shares TIN and CADD data with the Bridge Division for use in stream hydraulic analysis for bridges. Also, the design team shares CADD data with the Right of Way group to import land boundaries in ArcGIS. Construction staff receives the electronic data produced as part of the roadway design process to do contract administration and payment of quantities.
    - **Within the project development team.** Only the design team working on the project uses the files produced as part of the normal design process for roadway projects
    - **With consultants.** Mapping files such as LiDAR, topographic geometry, and TIN models if available.
    - **With potential bidders.** Electronic deliverables such as alignment/profile data, TIN models, MicroStation geometry, and any surfaces generated as a result of the design process in native and LandXML format.
    - **With contractors.** Electronic deliverables such as alignment/profile data, TIN models, MicroStation geometry, and any surfaces generated as a result of the design process in native and LandXML format.
12. **Storing large amounts of data:** LiDAR data is stored in dedicated servers that are read only for district staff. Other design data is stored in our engineering document management system Bentley ProjectWise.
13. **Data access for employees in remote locations:** Roadway design is decentralized and each district has their own data source for ProjectWise. The ProjectWise database is centralized, but the actual data storage servers reside in each of the seven districts.
14. **Details and additional comments:** [No response.]

New York

Contacts: Meredith Little, Design/Construction, New York State Department of Transportation, 518-457-8557, meredith.little@dot.ny.gov; John Izzo, Design/Construction, New York State Department of Transportation, 518-457-9539, john.izzo@dot.ny.gov.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** NYSDOT performs a formal constructability review by all stakeholders, including Design and Construction, when project plans are 90% complete.
2. **Modeling is used in these preconstruction phases:**
   - Preliminary engineering
   - Design
3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** Yes. Visualization tends to be limited to our more complex projects and projects in heavily congested areas where public involvement may be greater.

3b. **Estimate of visualization cost:** We will provide this information within a follow-up email. [Not provided.]

4. **Using modeling to investigate utilities, soils, etc.?** No.
5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Preliminary engineering – both state and consultant staff
   - Design – both state and consultant staff
7. **Responsibility for developing visualization model:** Both state and consultant staff.

   State staff classification or functional area: Actual designers in many cases; however, we also have a visualization specialist within our Department.

7a. **Project complexity determines who develops visualization model?** Yes. More advanced visualizations (i.e., development of a traffic simulation) we would likely have our visualization specialist unit do this work.

8. **Type of state employee receiving advanced modeling training:** Design: engineers and technicians; construction: limited Regional Construction CADD Coordinators.

Data and File Management

9. **Types of files produced:** NYSDOT utilizes MicroStation design files (DGN), InRoads to produce Digital Terrain Models (DTM and XML), alignments (ALG and XML), Storm & Sanitary for drainage designs.
10. **When (stage or project completion) electronic files are used:** For most projects, designers are developing models at 50% project completion.
11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** For bridge/structures, project files (DGN, DTM and ALG files)

are shared between Highway and Structures design. Design shares final model files with Construction to be utilized during Construction phase.

- **Within the project development team.** Within the Project Development Team all design files are being continuously shared as the project progresses.
- **With consultants.** If stipulated in a consultant agreement, all final design files are provided as a deliverable.
- **With potential bidders.** The Department is providing electronic files on some projects as supplemental information for bidders.
- **With contractors.** Upon request, electronic design files are provided to contractors for their use.

12. **Storing large amounts of data:** NYSDOT utilizes ProjectWise to store design files.
13. **Data access for employees in remote locations:** ProjectWise access.
14. **Details and additional comments:** [No response.]

North Carolina

Contact: James McMellon, Roadway Design Project Engineer, North Carolina Department of Transportation, 919-707-6282, jmcmellon@ncdot.gov.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** During a project's design schedule, two field inspections are held in the field with all design and construction folks to discuss the project and provide feedback on its constructability.
2. **Modeling is used in these preconstruction phases:**
   - Design
   - Right of way
3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** Yes. Only certain high-profile projects might require visualization during the preliminary phase for use in showing the public.

3b. **Estimate of visualization cost:** Large projects can take a few months, with smaller projects taking just a week or two.

4. **Using modeling to investigate utilities, soils, etc.?** No.
5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Environmental review – consultant staff
   - Preliminary engineering – both state and consultant staff
   - Planning – consultant staff
   - Design – both state and consultant staff
   - Right of way – both state and consultant staff

7. **Responsibility for developing visualization model:** N/A

   State staff classification or functional area: [No response.]

7a. **Project complexity determines who develops visualization model?** Yes. As mentioned above, we use visualization on larger projects during the preliminary design for public meetings. Usually our planning department will use consultant staffing on larger projects that will require the use of visualization.

8. **Type of state employee receiving advanced modeling training:** Currently we are providing it for our Roadway and Hydraulic design folks. This would include the central offices, field design offices and private engineering firms that provide this type of design for the department.

Data and File Management

9. **Types of files produced:** 3-D design file, proposed DTM, alignment files, and XML format files.

10. **When (stage or project completion) electronic files are used:** Well, all new projects are prepared in 3-D design from the very beginning and these files are then provided to contractors during the advertisement of these projects.

11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** All design files are shared on a project server split into the many disciplines (structures, geotechnical, roadway, surveys, hydraulic). These are shared by all of DOT.
    - **Within the project development team.** Same as above.
    - **With consultants.** Same as above but have to be sent via FTP as they do not have access to our internal server.
    - **With potential bidders.** [No response.]
    - **With contractors.** 3-D design file, proposed DTM, alignment files, and XML format files.

12. **Storing large amounts of data:** On Microsoft servers with access controlled to different groups who need access. After award, they are moved to a team construction site that is available to the contractor also.

13. **Data access for employees in remote locations:** Through our network and websites. Remote locations are hindered by network speed, however.

14. **Details and additional comments:** We are very interested in how other states are also "growing" with the constant change of technology. We would love to see any results you might generate from this survey and also discuss other issues as we all move forward.

Pennsylvania

Contact: David J. Azzato, Chief, Highway Design and Technology Section, PennDOT Bureau of Project Delivery, Pennsylvania Department of Transportation, 717-787-5023, dazzato@pa.gov

Note: PennDOT responded to additional questions about agency workflows and efficiencies; see questions 14 through 20.

Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** See link below to Publication 10X, Design Manual 1X, Appendix N - Constructability Review Procedures for Highway and Bridge Projects, ftp://ftp.dot.state.pa.us/public/Bureaus/design/PUB10/PUB10X/Pub10X_Cover.pdf. [See page 207 of the PDF.]
2. **Modeling is used in these preconstruction phases:**
   - Environmental review
   - Preliminary engineering
   - Design
3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** No.

3b. **Estimate of visualization cost:** Not available.

4. **Using modeling to investigate utilities, soils, etc.?** No.
5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
   - Environmental review – consultant staff
   - Preliminary engineering – consultant staff
   - Design – consultant staff
7. **Responsibility for developing visualization model:** Consultant staff.
   State staff classification or functional area: N/A

7a. **Project complexity determines who develops visualization model?** N/A

8. **Type of state employee receiving advanced modeling training:** Project management staff and system management (IT) staff involved in 3-D modeling efforts.

Data and File Management

9. **Types of files produced:** See additional files (policy letters emailed separately) including: Strike-off Letter (Policy Letter) 481-13-01 dated February 11, 2013, Design Files Available in ECMS Pre-Bid Strike-off Letter 481-13-04, dated December 20, 2013, Three Dimensional (3D) Computer Aided Drafting and Design (CADD) Models. [See **Related Resources** below.]
10. **When (stage or project completion) electronic files are used:** See Question 9 response.

11. **Sharing modeling files (file type and how they are shared):** See Question 9 response.
12. **Storing large amounts of data:** See Question 9 response.
13. **Data access for employees in remote locations:** See Question 9 response.

Agency Workflows and Efficiencies

14. **Encouraging project team members to communicate, coordinate and collaborate:** Smart Boards, and Project Delivery Operations Center used for Project Delivery meetings, etc. These methods could also be expanded for use by 3-D modeling efforts.
15. **Has modeling improved constructability reviews?** Has not expanded to this area.
16. **Has modeling improved development of PS&E bid packages?** Has not expanded to this area.
17. **Quantifiable benefits:** N/A
18. **Efficiencies gained and benefits realized:** N/A
19. **Deployment barriers or obstacles:**

    Education and training.
20. **Details and additional comments:** [No response.]

Related Resources:

"Three Dimensional (3D) Computer Aided Drafting and Design (CADD) Models," Strike-Off Letter 481-13-04, Pennsylvania Department of Transportation, December 20, 2013. http://c.ymcdn.com/sites/www.acecpa.org/resource/resmgr/strike_off_letters/481-13-04.pdf
A Strike-off Letter (SOL) describes a quality initiative and cost-saving activity initiated by the Bureau of Project Delivery. This SOL provides guidelines for the development of 3-D models. Projects defined as "moderately complex" and "most complex" in PennDOT's Design Manual 1 will realize the greatest benefits, but 3-D modeling should be considered for all projects.

Excerpts from the guidelines for implementation include:

- Determine whether 3D modeling will be used during the scoping field view and document on the Engineering and Environmental Scoping Form.
- Make LandXML translations for the following data sets when practical and relevant as determined by the ADE-Design:
    - Existing or surveyed surface.
    - Final project geometry.
    - Final design surface.
- Compress all LandXML files to the *.zip file type for loading onto the Engineering and Construction Management System (ECMS).
- Produce the plan set loaded into ECMS directly from the CADD software as a set of PDF files. A PDF file created from a scanned plan sheet should not be loaded into ECMS as part of the official plan set because a scanned image loses graphic and numeric detail. The exception to this rule is a Title sheet because of the professional seal and original signature.

- All surface and geometry files provided to bidders must contain only data represented in the official plan set. No alternate design data should be included. If such information is present, it must be redacted prior to translation to LandXML.
- If the roadway design was not developed in a 3D format, no effort should be made to recreate the design for the sole purpose of generating 3D data for translation to the LandXML format.
- While the design of structures may not be developed in 3D, such as a BRADD job, the "Use Guidelines" in the previous section must still be considered, and the small effort to convert the bridge portion of a 3D project may be warranted.

"Design Files Available in ECMS Pre-Bid," Strike-Off Letter 481-13-01, Pennsylvania Department of Transportation, February 11, 2013. http://c.ymcdn.com/sites/www.acecpa.org/resource/resmgr/strike_off_letters/sol_481-13-01.pdf This is another SOL that describes a quality initiative. Files such as InRoads or MicroStation CADD files had been provided to the successful bidder after the award process. With this SOL, these files will be provided during the project advertisement time period to allow for more accurate, comprehensive bids. To access these files, bidders must sign a one-time legal agreement acknowledging that the information is being provided for informational purposes only.

Wisconsin

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Use of Advanced Modeling in Constructability Reviews

1. **Constructability review process:** Constructability review at WisDOT is performed on preliminary plan sheets. Models are not a standard part of constructability review on most projects at WisDOT. Exceptions are our most complicated design projects, where Navisworks has been used for clash detection analysis. [Navisworks is a project review software available from Autodesk.] Over the next few years, surface model development will become common on all WisDOT projects, and opportunities for using models in constructability review will become more mainstream.

2. **Modeling is used in these preconstruction phases:**
   - Environmental review
   - Preliminary engineering
   - Design
   - Right of way

3. **Visualization used during preconstruction phase?** Yes.

3a. **Limits on visualization?** Yes. We don't have standardized policy defining when to use visualization; the use of visualization is currently a decision made by project staff. Typically visualization is used on our more complex projects with larger budgets.

3b. **Estimate of visualization cost:** This is project-specific depending on quality and detail of visualization output.

4. **Using modeling to investigate utilities, soils, etc.?** Yes. On our most complex projects, we will locate underground utilities using SPAR, GPR or hydrojet excavation. The utilities are imported into a Navisworks model for clash detection. This is not mainstream on WisDOT projects; only on the largest projects is clash detection analysis performed.

5. **Using reviewing software?** No.

Staff Responsibilities

6. **Responsibility for developing advanced model:**
    - Environmental review – both state and consultant staff
    - Preliminary engineering – both state and consultant staff
    - Planning – both state and consultant staff
    - Design – both state and consultant staff
    - Right of way – both state and consultant staff

7. **Responsibility for developing visualization model:** Consultant staff.

   State staff classification or functional area: WisDOT intends to develop workflow training for visualization techniques so WisDOT staff can deliver quality visualization output also. Presently our staff does not have workflow training available to instruct them.

7a. **Project complexity determines who develops visualization model?** N/A.

8. **Type of state employee receiving advanced modeling training:** Our roadway design staff develop surface models in Civil 3D as part of their standard roadway design workflow. Starting in July 2014 all new WisDOT design projects with earthwork in their scopes will be required to deliver surface models.

Data and File Management

9. **Types of files produced:** We develop surface models in Civil 3D DWG files.

10. **When (stage or project completion) electronic files are used:** The models are developed and maintained throughout the roadway design process. Final model files for distribution to contractors are prepared upon design completion, and delivered at the same time as final plan sheets.

11. **Sharing modeling files (file type and how they are shared):**
    - **Across the agency.** DWG; Windows network.
    - **Within the project development team.** DWG; Windows network.
    - **With consultants.** DWG; FTP share.
    - **With potential bidders.** LandXML, DWG, CSV.
    - **With contractors.** LandXML, DWG, CSV.

12. **Storing large amounts of data:** A data management and archival strategy is being developed. Present practice is to archive the entire Civil 3D project data set in its native format.

13. **Data access for employees in remote locations:** Copy to local hard drive through vpn.

14. **Details and additional comments:** [No response.]