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

Requested by
Mary Beth Herritt, Chief, Caltrans Office of Project Development

March 1, 2012

The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI 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.

Executive Summary

Background

Caltrans is working to reduce the support costs incurred during the project development process that span planning/environmental assessment, design, right of way and construction stages. The current process for developing highway infrastructure improvements is to collect location and elevation data in 3-D that is converted to a digital terrain model used in the design of 2-D plans. The Plans, Specifications and Estimate (PS&E) bid package used by contractors to provide their construction bids includes these 2-D plans.

Ideally, the PS&E package should be developed using 3-D modeling. Model-based design has the potential to improve project delivery, enhance preconstruction process reviews, optimize scheduling, streamline construction phasing and communicate project features.

Caltrans is interested in learning how other state departments of transportation (DOTs) are employing 3-D modeling and other types of advanced modeling techniques for developing highway infrastructure improvements. To aid in this effort, this Preliminary Investigation presents the results of a survey that explored the state of the practice in transportation agencies' use of advanced modeling. To supplement survey findings, we also examine domestic and international research and federal guidance related to the use of advanced modeling techniques to enhance project delivery.

Summary of Findings

To gather information about state DOT practices in the use of advanced modeling techniques, we distributed a brief online survey to members of the AASHTO Standing Committee on Highways, Subcommittee on Design. To augment the results of this **Survey of Current Practice**, we examined **National Guidance**, **Related Domestic Research** and **International Research**, and reviewed **State Agency Web Sites and Presentations**. The five sections of this Preliminary Investigation are summarized below.

Survey of Current Practice

- Eighteen state DOTs responded to the survey. Almost three-fourths of survey respondents are currently employing advanced modeling; most modeling began in the mid- to late 2000s.
    - Michigan DOT and Nebraska Department of Roads are currently implementing the software that will be used in those agencies' 3-D modeling programs, and two state DOTs—North Carolina and Mississippi—are preparing for a full program implementation in 2012.
- Maryland, Washington and Wisconsin are the only states using 4-D models that add the dimension of time (construction scheduling) to spatially based 3-D models.
    - Washington State DOT uses 4-D models only for visualization purposes. In Wisconsin, 4-D modeling is not mandatory and is at the discretion of project staff.
    - Washington State DOT models may also reflect other project considerations such as construction staging, emergency design alternatives (such as flooding and earthquakes) and historic narration.
- Among survey respondents, the most commonly used modeling tools are products from Bentley Systems Inc.: GEOPAK, InRoads and MicroStation.
- Agencies are using advanced modeling techniques for reconstruction and grading projects as well as intersection improvements, culvert replacements, storm sewer/drainage improvements and bridge replacements.
    - Most respondents report that 3-D models are being used by contractors for automated machine guidance (AMG).
- Respondents reported a range of benefits associated with modeling, although for the most part they were unable to quantify them:
    - *Time savings*. Visualization leads to faster decision-making; profiling is simpler and faster calculations for earthwork can be generated; more iterations of designs can be developed more quickly; and problems are more easily spotted and corrected earlier in the design process.
    - *Cost savings*. Lower bids, lower survey costs and less rework; more accurate estimates; and fewer change orders and field modifications.
    - *Quality*. Ability to catch avoidable mistakes; earthwork calculations are more representative of the proposed project; and conflicts can be resolved before the bid process begins.
    - *Improvements in customer relations*. Builds belief in the design and confidence in the engineer-client relationship.
- The most commonly cited challenges in implementing a modeling program are education and training, software limitations and resistance to change.
- Agencies planning to implement a modeling program are advised to provide training, get buy-in from designers, prepare for full implementation with the use of pilot projects, ensure that the 3-D software is easy to use and seek the advice of an agency with extensive experience in modeling.

National Guidance

- An October 2011 FHWA report describes how some state DOTs are using visualization to facilitate right of way acquisition.
- Three NCHRP synthesis reports, published in 2006, 2007 and 2008, assess the benefits and challenges of 3-D and 4-D modeling.

- A 2003 AASHTO publication encourages the use of visualization to minimize environmental impact and enhance environmental quality.
- A Federal Lands Highway Division manual provides guidance for the designer in using 3-D tools.
- The TRB Visualization in Transportation Committee fosters the collaborative exchange of information about visualization methods and technologies. The committee's web site provides links to a wealth of resources and case studies on the subject.

Related Domestic Research

- Three conference papers from the 2012 TRB Annual Meeting offered recommendations for optimizing geometric elements of a 3-D design; analyzed 3-D/4-D model applications in terms of communication, technical design checking, construction planning and work area management; and presented a proposed simulation-based 4-D modeling approach for highway reconstruction projects.
- A 2011 journal article examines public preferences on the use of visualization techniques to involve the public in transportation planning.
- A 2011 handbook describes how simulators can leverage visual design practices and provides recommendations on bridging 3-D design with simulators.
- A 2010 Wisconsin DOT research project characterizes the benefits associated with adoption of 3-D design and identifies strategies to overcome barriers. The project report includes recommendations for specification development for AMG and adoption of 3-D highway design technology.
- Three 2010 publications examine various elements of 3-D design:
    - An implementation plan for 3-D technologies and methods for highway design in Wisconsin is presented in a *Transportation Research Record* (*TRR*) article.
    - In a 2010 TRB Annual Meeting paper, the author examined the judgments that must be made to assign depth or elevation values to existing utility mapping for inclusion in a 3-D data depiction.
    - A *TRR* article describes a case study that integrates traffic simulation into a design visualization for an Indiana roundabout project.
- A 2006 report published by the Highway IDEA Program describes the testing of a 3-D model for an integrated design and construction process for highway bridges.
- Object-oriented design and specifications (OODAS) are assessed in a 2006 TRB Annual Meeting paper. A prototype OODAS system developed for Iowa DOT allows the user to point and click on portions of an object-oriented drawing linked to databases that contain specifications, procurement status and standard drawings.

International Research

- A 2012 TRB Annual Meeting paper described a German research project that employs various visualization techniques (2-D/3-D display, driving simulation in the virtual driving area) in applying a 3-D route search concept. The result is a new workstation that combines design methodology with hardware and software that handles the comprehensive process of "designing/checking/driving/assessing" in a practical manner.
- The application of a 4-D simulation system of bridge construction to a bridge in China is explored in a 2009 conference paper.

- A 2009 conference paper describes a collaboration between Finland and California. The developed model allows Caltrans and its contractors to apply machine guidance and construction automation.
- Software tools used in Great Britain and Europe to reduce earthmoving costs, create interchanges, and increase roadway capacity are described in a 2011 publication.

State Agency Web Sites and Presentations

- Web sites maintained by three state DOTs—Minnesota, North Carolina and Washington—provide links to visualization projects and more.
- A Wisconsin DOT presentation describes the agency's approach to model-based design.

Gaps in Findings

Survey responses indicate that modeling has yet to become a standard practice in state transportation agencies. Respondents reported extremely limited use of 4-D modeling, and for many states, 3-D modeling has yet to become the standard approach to highway design and construction. Survey respondents cited a range of benefits, from cost savings to enhancing public outreach, but were unable to quantify them. Quantifiable evidence of benefits may become more readily available as modeling practices mature.

Next Steps

Caltrans might consider the following in a continuing evaluation of best practices for the use of advanced modeling techniques to enhance project delivery:

- Consult with Washington State DOT, a recognized leader in the visualization field, to discuss Caltrans' plans for implementing a 3-D modeling program.
- Consult with agencies with experience in preparing 4-D models (Maryland State Highway Administration, Washington State DOT and Wisconsin DOT).
- Consult with agencies in various stages of implementing a 3-D modeling program.
    - North Carolina and Mississippi DOTs are preparing for an upcoming 3-D program implementation.
    - Michigan DOT and Nebraska Department of Roads are currently implementing the software that will be used in those agencies' 3-D modeling programs.
- Contact staff from Kentucky Transportation Cabinet to discuss the agency's pilot project and the guidance, requirements and standards the agency is preparing for 3-D modeling and electronic deliverables.
- Consult with New Mexico DOT to learn more about why the agency is contemplating changing its computer-aided design and drafting (CADD) platform.
- Examine the training materials provided by survey respondents to get a sense of the workflow, specific tasks and the training required for staff new to 3-D modeling.
    - In the coming months Wisconsin DOT will update its modeling training based on experience to date.

Survey of Current Practice

We conducted an online survey of members of the AASHTO Standing Committee on Highways, Subcommittee on Design to gather information from state DOTs with experience using advanced modeling techniques to develop highway infrastructure improvements. The survey consisted of the following questions:

1. Does your organization employ 3-D computer-aided design applications or models to develop digital project plans?
2. Does your organization have plans to begin use of 3-D modeling in the future?
3. Does your organization link a 3-D model presenting the existing topography and the proposed design with the following project elements:
    - Time (a 4-D model)?
    - Costs (a 5-D model)?
    - Other project considerations such as risk or movement of equipment and personnel?
4. When did your organization begin using 3-D or 4-D modeling?
5. What 3-D or 4-D computer-aided design and modeling tools are being used?
6. Are the 3-D models being used by contractors for automated machine guidance (AMG) construction techniques?
7. Please describe the types of projects for which your organization employs 3-D or 4-D modeling.
8. Can you provide project-specific examples of your organization's use of 3-D or 4-D modeling?
9. Has your organization's use of 3-D or 4-D modeling helped your project teams identify collaborative solutions?
10. Has your organization identified a reduction in construction conflicts associated with building projects in a virtual environment before awarding of the contract?
11. Please describe the benefits of 3-D or 4-D modeling your organization has realized in terms of the following. If possible, please quantify the benefits.
    - Time savings.
    - Cost savings.
    - Quality.
    - Improvements in customer relations.
    - Other; please describe.
12. Have you encountered any barriers or challenges in implementing 3-D or 4-D modeling to develop highway infrastructure improvements? Please describe.
13. What are the next steps for your organization's 3-D or 4-D modeling program?
14. What advice would you offer to a transportation agency preparing to implement 3-D or 4-D modeling to enhance project delivery?
15. Please provide contact information for the staff member in your organization responsible for overseeing the use of 3-D or 4-D applications and modeling tools.
16. Please use this space to provide details on any of your answers above or to provide additional comments.

We also asked respondents to provide guidelines or procedures related to 3-D or 4-D modeling.

We received responses from 18 state transportation agencies:

- Arkansas.
- Delaware.
- Florida.
- Indiana.
- Kentucky.
- Maine.
- Maryland.
- Michigan.
- Minnesota.
- Mississippi.
- Nebraska.
- New Mexico.
- North Carolina.
- North Dakota.
- South Dakota.
- Utah.
- Washington.
- Wisconsin.

See **Survey Results** beginning on page 10 for the full text of all survey responses.

The survey gathered information in seven topic areas related to the use of advanced modeling techniques to enhance project delivery:

- Program Background.
- Advanced Modeling Tools.
- 3-D Tools Used for Automated Machine Guidance.
- Types of Projects Rendered in 3-D or 4-D Models.
- Benefits of Advanced Modeling Techniques.
- Implementing a Modeling Program.
- What's Next.

Key findings from the survey follow.

Program Background

- Almost three-fourths of the survey respondents are currently employing advanced modeling techniques. Three states—Michigan, Mississippi and Nebraska—report plans to begin using modeling. Arkansas and Utah are not using modeling.
- Most respondents began using modeling in the 2000s.
    - South Dakota DOT is an early adopter of advanced modeling techniques, reporting that such techniques have been in use since 1996.
    - Newer programs include the modeling program at North Carolina DOT, which began in 2011 with full implementation scheduled for this year. Florida, Indiana and Wisconsin DOTs launched modeling programs in 2010.
    - Programs with a greater depth of experience include those at Maryland and New Mexico DOTs, which began in 2004.
- Maryland, Washington and Wisconsin are the only states using 4-D models that add the dimension of time (construction scheduling) to spatially based 3-D models. Washington State DOT uses 4-D models only for visualization purposes. In Wisconsin, 4-D modeling is not mandatory and is at the discretion of project staff.
    - Washington State DOT models may also reflect other project considerations such as construction staging, emergency design alternatives (including flooding and earthquakes) and historic narration.
- None of the respondents develops 5-D models that reflect costs.

Advanced Modeling Tools

The table below summarizes the 3-D or 4-D design and modeling tools used by survey respondents. We also provide a link to vendors' product information.

Use of Modeling Tools by State		
Vendor	**Tool**	**State**
Autodesk Inc.	3ds Max (formerly 3D Studio Max Design) http://usa.autodesk.com/3ds-max/	WA
Autodesk Inc.	AutoCAD Civil 3D http://usa.autodesk.com/civil-3d/	FL, WI
Autodesk Inc.	AutoCAD Land Development Desktop http://usa.autodesk.com/adsk/servlet/ps/dl/index?siteID=123112&id=2334440&linkID=9240778	NM
Autodesk Inc.	Infrastructure Modeler http://usa.autodesk.com/adsk/servlet/pc/index?id=17276659&siteID=123112	WA
Autodesk Inc.	Navisworks http://usa.autodesk.com/navisworks/features/	WI
Bentley Systems Inc.	GEOPAK http://www.bentley.com/en-US/Products/GEOPAK+Civil+Engineering+Suite/	FL, MN, MS, NC, ND
Bentley Systems Inc.	InRoads http://www.bentley.com/en-US/Products/InRoads%20Suite/	DE, IN, KY, ME, MD, NM, SD, WA
Bentley Systems Inc.	MicroStation http://www.bentley.com/en-US/Products/MicroStation/	DE, KY, ME, MD, ND, SD, WA
Google	SketchUp Pro http://sketchup.google.com/product/gsup.html	WA
Stichting Blender Foundation (open source)	Blender http://www.blender.org/	MD

3-D Tools Used for Automated Machine Guidance

- Most respondents report limited provision of models to contractors.
    - For Delaware DOT's larger earthwork projects, contractors receive existing and proposed digital terrain model (DTM) files and design files containing only the proposed 3-D triangles of the proposed DTM.
    - Florida DOT has provided 3-D models for AMG associated with several design-build projects.
    - Contractors in Minnesota are using MnDOT's 3-D models for subgrade, grading grade and in some instances finished grade, but not yet for surfacing.

    - In Wisconsin, AMG surfaces are provided to contractors at the time of project advertisement. Within the next few years, 3-D AMG surface models will be a required design deliverable on all WisDOT projects.
- Some states report movement toward providing 3-D models for AMG.
    - In addition to limited experience with pilot projects that delivered models to contractors, Michigan DOT provides cross sections that contractors use to make their own models.
    - Mississippi DOT has AMG specifications that provide guidance to contractors required to prepare their own models; the agency will eventually provide contractors with models.

Types of Projects Rendered in 3-D or 4-D Models

The table below summarizes the types of projects for which 3-D or 4-D modeling is used by survey respondents:

Projects Rendered in 3-D or 4-D Models by State	
Project Type	**State**
Design/road reconstruction/roadway projects	DE, FL, IN, KY, ME, MN, NE
Grading/base course activities	MN, MS, SD, WI
Planning, design and construction projects	WA
All designs that require geometric improvements	MD
Intersection improvements, culvert replacements, storm sewer/drainage improvements	IN
Ponds, parking lots, unbounded concrete overlays	MN
Bridge replacement and widening on existing location	NC

Benefits of Advanced Modeling Techniques

- Delaware DOT notes that possible conflicts with right of way and utilities as well as environmental impacts can be identified with the use of modeling.
- Respondents reported benefits realized from their modeling programs but were unable to quantify them, with the exception of one report of specific time savings from Washington State DOT.
- **Time savings** cited by respondents include:
    - Using visualization brought faster decision-making, saving over a month from the design to construction process with one roundabout design (Washington).
    - Visualization brings decision-makers to consensus faster (Maryland).
    - Profiling is simpler and faster calculations for earthwork can be generated (New Mexico).
    - Designers can develop more iterations of designs more quickly, leading to a streamlined design process and more refined designs (Wisconsin).
    - Easier to find problems earlier in design process, so it takes less time to correct problems (Indiana).
    - Contractor bidding is more efficient (Michigan).

- **Cost savings** reported by respondents include:
    - Bids are lower (Maine, Minnesota, Wisconsin).
    - Estimates are more accurate (New Mexico).
    - Change orders and field modifications are expected to drop (Washington).
- Improvements in **quality** associated with modeling are reported by the following:
    - Safety concerns are better addressed with 3-D models (Indiana).
    - While not quantifiable at this time, quality is enhanced by catching avoidable mistakes (Kentucky).
    - Both Michigan and Minnesota DOT report improved ride quality of the finished pavement when using machine control.
    - Quantities are more accurate, resulting in smaller change orders (New Mexico).
    - Earthwork calculations and DTMs are more representative of the proposed project (North Dakota).
    - Using visualization builds confidence and allows conflicts to be sorted out before the bid process begins. Stringent virtual review through 3-D modeling will improve the quality of the design (Washington).
- Respondents cited the following improvements in **customer relations**:
    - Delaware and Indiana DOTs have used 3-D renderings of proposed projects at public workshops and other public meetings with good results. Minnesota DOT cites the accuracy brought to meeting presentations.
    - Maryland State Highway Administration uses all types of visualizations for public outreach, including 2-D, 3-D and 4-D.
    - Washington State DOT notes that 3-D modeling serves to build belief in the design and confidence in the engineer-client relationship.
- Respondents cited other benefits of the use of advanced modeling for highway design, including safety improvements, with fewer survey and staking personnel in the way of heavy equipment (Florida), and the ability to obtain elevations anywhere on the job during construction (Minnesota).
- Mississippi DOT, which is planning a summer 2012 implementation of advanced modeling techniques, foresees a range of benefits that include more accurate earthwork calculations, a decrease in right of way acquisition, and faster and more accurate construction.

Implementing a Modeling Program

- The most commonly cited challenges in implementing 3-D or 4-D modeling are education and training, software limitations and resistance to change.
- Respondents offered this advice to agencies preparing to implement an advanced modeling program:
    - Provide training (Delaware, Indiana, Kentucky, North Carolina) and develop templates (North Carolina).
    - Prepare for full implementation with the use of pilot projects (Florida, Kentucky) and begin with small, simple projects, phasing in the new modeling techniques over time (Minnesota).

- Communicate the benefits of a model-based approach to designers to get their buy-in (Wisconsin).
- Ensure that the 3-D software is easier to use than 2-D software (Florida).
- Make sure a visualization does not sell the public on something that cannot be built (Maryland).
- Consult with an agency like Washington State DOT that specializes in these skill sets (Washington).

What's Next

- Respondents shared the next steps for their agencies' modeling programs.
  - Kentucky Transportation Cabinet is testing its pilot project and drafting guidance, requirements and standards for 3-D modeling and electronic deliverables.
  - Maine DOT is establishing the 3-D standard deliverables for state-designed projects.
  - New Mexico DOT is currently using Land Development Desktop and Bentley InRoads but considering going back to AutoCAD Civil 3D.
  - North Carolina DOT is preparing for its modeling program launch later this year by implementing template types.
  - Wisconsin DOT will implement AMG surface model deliverable requirements for all WisDOT projects and make greater use of model data developed during design in the design and construction processes.

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 5 of this Preliminary Investigation.

Arkansas

Contact: Phillip McConnell, Assistant Chief Engineer Design, Arkansas State Highway and Transportation Department, (501) 569-2301, phil.mcconnell@arkansashighways.com.

Mr. McConnell indicated that Arkansas State Highway and Transportation Department is not currently using 3-D modeling and has no plans to begin using it.

Delaware

Contact: Thad McIlvaine, Project Manager, Delaware Department of Transportation, thad.mcilvaine@state.de.us.

1. **Using 3-D modeling?** Yes.
2. **Plans to begin using 3-D modeling?** [No response.]
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** The department began 3-D modeling in the 2000s.

5. **Modeling tools:** MicroStation and InRoads.

6. **Used by contractors for automated machine guidance?** Yes. Existing and proposed digital terrain model (DTM) files and design files containing only the proposed 3-D triangles of the proposed DTM are given to the contractor only on some larger earthwork projects. We do not give these files out on a majority of projects.

7. **Type of projects using 3-D or 4-D modeling:** The department employs 3-D modeling on most of our design projects. 3-D modeling assists in providing profiles, cross sections and annotating grades within our construction plans.

8. **Project-specific examples:** 3-D modeling is done on [the] majority of our design projects. We have recently completed several contracts (Contract #24-122-03: SR 1, North Frederica Grade Separated Intersection and Contract #24-122-04: SR 1, SR 9 Grade Separated Intersection) where the existing and proposed DTMs were given to the contractor.

9. **Identify collaborative solutions?** Yes. 3-D modeling does help with identifying possible conflicts with right of way, utilities, environmental impacts, etc., and analyze alternatives to these conflicts.

10. **Identify reduction in construction conflicts?** Yes; see response to 9.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** In the design phase, more time is spent on developing the model especially if the DTM files are going to be given to the contractor. In the construction phase, as more contractors acquire the technology, there is the potential for time savings with automated machine guidance construction.

11b. **Cost savings.** Similar to the response for #11a, the design phase takes longer to develop the 3-D model which would cost more especially if the design is being done by a consultant. Potential cost savings in construction due to less time to construct.

11c. **Quality.** [No response.]

11d. **Improvements in customer relations.** In conjunction with our 3-D modeling, the department has also been providing 3-D renderings of proposed projects at public workshops. These renderings provide a real-life picture of what the proposed project will look like when it is completed and have [been] beneficial in dealing with the public.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** The time involved in providing a complete model to the contractor is one challenge. Also, when the corridor or roadway that you are modeling has several intersections, merging all of the DTMs into one sometimes presents a challenge.

13. **Next steps:** None.

14. **Implementation advice:** Ensure all of your designers and managers receive proper training on the design software.

15. **Staff contact information:** Sean Duphily, CADD [computer-aided design and drafting] Technician, Delaware Department of Transportation, (302) 760-2341, sean.duphily@state.de.us.

16. **Details or comments:** [No response.]

Florida

Contact: Bruce Dana, State CADD Coordinator, Florida Department of Transportation, (850) 245-1606, bruce.dana@dot.state.fl.us.

1. **Using 3-D modeling?** Yes.
2. **Plans to begin using 3-D modeling?** [No response.]
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** We began supporting GEOPAK Roadway/Corridor Modeler two years ago with our FDOT 2010 software release. All of the projects modeled to date are design-build, and the Central Office CADD Office (Engineering/CADD Systems Office–ECSO) has assisted those designers on those projects. We are also implementing Autodesk Civil 3D and have pilot projects under way.
5. **Modeling tools:** Bentley GEOPAK Roadway/Corridor Modeler; Autodesk AutoCAD Civil 3D.
6. **Used by contractors for automated machine guidance?** Yes. Several of the design-build projects are. Also, several classical 2-D design projects have been modeled after the fact by the contractor and were used for AMG. FDOT also used the Bentley/FHWA VBA Modeler tool to prepare proposed surfaces for jobs modeled by densely spaced proposed cross sections. Our GEOPAK criteria were designed so this could be a by-product of classical cross section design.
7. **Type of projects using 3-D or 4-D modeling:** Road reconstruction projects (dirt jobs). Other projects where earthwork is substantial.
8. **Project-specific examples:** Yes; if you would like, some presentation materials can be provided to you on several projects our office has assisted with. Please see 16. below for additional materials.
9. **Identify collaborative solutions?** No.
10. **Identify reduction in construction conflicts?** No.
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Contractor's testimony that time is saved.

11b. **Cost savings.** Contractor's testimony that money is saved.

11c. **Quality.** Contractor's testimony that grading quality is improved.

11d. **Improvements in customer relations.** [No response.]

11e. **Other; please describe.** Safety—less survey and staking personnel in the way of heavy equipment.

12. **Describe barriers or challenges:** Education: Must train designers to change their ways of thinking and old habits. Trust must be earned in the benefits and results of the newer software. Implementation is difficult. Then "What's in it for me?" Designers typically do not realize as big a reward for the effort. 3-D design must be customer-driven. Some of our Roadway Modeler project consultants have seen the light and will no longer do classical 2-D design with GEOPAK, as the time saved (in design) and conflicts found/resolved really paid off for them.

13. **Next steps:** Continue implementation and training efforts for FDOT internal and external users. Encourage the contracting industry to demand the models of their designers.

14. **Implementation advice:** 1) Proof through pilot projects. Choose pilots that are typical of the work mix you expect to move forward with. Small-scale tests are not realistic of the issues you will uncover. 2) Do a good job of software implementation where the 3-D software is as easy or easier to use than the 2-D software. FDOT has achieved this with Roadway Modeler, but is still struggling with Civil 3D.

15. **Staff contact information:** Bruce Dana, State CADD Coordinator, Florida Department of Transportation, (850) 245-1606, bruce.dana@dot.state.fl.us.

16. **Details or comments:** Please see the following for the FDOT State Kit for Civil 3D: http://www.dot.state.fl.us/ecso/downloads/publications/civil3dworkflows/default.shtm.

    For the FDOT Software for MicroStation and GEOPAK Roadway Corridor Modeler: http://www.dot.state.fl.us/ecso/downloads/software/FDOT2010CaddSoftware.shtm.

    Related video training recorded by my staff can also be found at http://www.dot.state.fl.us/ecso/downloads/clips/default.shtm.

Indiana

Contact: Elena Veksler, Manager, In-House Design Team, Indiana Department of Transportation, (317) 233-2073, eveksler@indot.in.gov.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** June 2010.

5. **Modeling tools:** InRoads.

6. **Used by contractors for automated machine guidance?** Yes. Some consultants are using it but not INDOT.

7. **Type of projects using 3-D or 4-D modeling:** Road reconstructions, intersection improvements, culvert replacements, storm sewer/drainage improvements, both urban and rural.

8. **Project-specific examples:** 3-D modeling helps us visualize ditch design, intersections with driveways and roads, culverts meeting stream flowlines, shows anomalies in roadway design. It is a huge help for sight distance calculations.

9. **Identify collaborative solutions?** Yes. It has helped us come up with better ways of modeling drives and intersections.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** It is easier to find modeling problems earlier in the design process so it takes less time to correct the problem.

11b. **Cost savings.** It is quicker to find solutions with 3-D modeling than with 2-D.

11c. **Quality.** Safety concerns are better addressed with 3-D models. Plans are closer to perfect since you can visualize the entire project.

11d. **Improvements in customer relations.** We can show the public a 3-D view of the project and they are better able to visualize what the project entails and the impact it will have on their properties.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** There is a lack of training support at our agency so implementing the new software has been tedious and time-consuming for the designers.

13. **Next steps:** None at this time.

14. **Implementation advice:** Make sure you have training support because it makes learning the software a lot easier. Other than that, 3-D modeling is a very powerful tool and is excellent to have when designing a project.

15. **Staff contact information:** Michael Jenkins, Highway Management Applications Manager, Indiana Department of Transportation, (317) 232-6733, mjenkins@indot.in.gov.

16. **Details or comments:** [No response.]

Kentucky

Contact: Kevin Martin, Transportation Engineer Branch Manager, Developmental Branch, Kentucky Transportation Cabinet, (502) 564-3280, kevin.martin@ky.gov.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** 3-D design has been around years. I personally started using it extensively in 2005. We are looking to require it in the future.

5. **Modeling tools:** InRoads and MicroStation.

6. **Used by contractors for automated machine guidance?** Yes. Most try to use our delivered models, but find too many errors and reverse engineer the paper cross sections to get a file for AMG. We hope to soon provide more accurate models and have a pilot project this year to deliver the data to the contractor and minimal cross sections, putting the emphasis on the electronic model.

7. **Type of projects using 3-D or 4-D modeling:** Almost all roadway projects. Models are required on every design project. We do not have the manpower, however, to check the quality of the model prior to bid.

8. **Project-specific examples:** We are currently modeling a six-mile, two-lane rural roadway through mountainous terrain. We are modeling the finished grade and subgrade surfaces, benching, fill slopes, hard surfaces such as edges of pavement and shoulders. All of this is done using InRoads and MicroStation.

9. **Identify collaborative solutions?** Yes. On larger, urban projects with several structures and utilities, it has been used to detect conflicts with other elements, such as existing utilities, underpass roadways in regards to bridge clearances, etc.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Not far enough along to quantify anything. It takes more effort upfront, but we feel that the results will save money later.

11b. **Cost savings.** Again, not sure what the monetary value is for us; just getting started with our pilot project.

11c. **Quality.** We feel that the quality is enhanced, if nothing more than catching avoidable mistakes. We do not know what the actual number is; a request would have to be made to research that.

11d. **Improvements in customer relations.** Not a big change. Contractors want better models, from what we have heard from the Kentucky Contractors Association.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Internally, training and knowledge of 3-D modeling. For our design consultants, it would be a shift in "the way things have always been done" mentality.

13. **Next steps:** Testing our pilot project and then drafting guidance and requirements and standards for 3-D modeling and electronic deliverables.

14. **Implementation advice:** Training, training, training. Know how to use the modeling software of your choice, work closely with the software manufacturer and pick a good project to use as a trial run.

15. **Staff contact information:** Kevin Martin, Transportation Engineer Branch Manager, Developmental Branch, Kentucky Transportation Cabinet, (502) 564-3280, kevin.martin@ky.gov.

16. **Details or comments:** [No response.]

Maine

Contact: Brian Kittridge, Maine Department of Transportation, brian.kittridge@maine.gov.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** 3-D modeling has been used to some degree since 2006.

5. **Modeling tools:** Bentley InRoads and MicroStation.

6. **Used by contractors for automated machine guidance?** Yes. The department is still determining the extent to which it will provide 3-D data to the contractors, but contractors have been creating 3-D models from the provided paper plan sets since 2005.

7. **Type of projects using 3-D or 4-D modeling:** 3-D modeling on most projects.

8. **Project-specific examples:** Yes.

9. **Identify collaborative solutions?** No.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** [No response.]

11b. **Cost savings.** Contractors suggest that the use of 3-D modeling and machine control has resulted in reduced costs. Historically, we are seeing contractors using 3-D modeling winning a higher percentage of our low-bid contracts.

11c. **Quality.** [No response.]

11d. **Improvements in customer relations.** [No response.]

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Currently, our Quality Control Technicians inspecting the contractors' work are not fully prepared to work within the 3-D modeling environment.

13. **Next steps:** Establishing the 3-D standard deliverables for state-designed projects.

14. **Implementation advice:** [No response.]

15. **Staff contact information:** [No response.]

16. **Details or comments:** [No response.]

Maryland

Contact: Eric Marabello, Chief, Design Technical Services Division, Maryland State Highway Administration, (410) 545-8770, emarabello@sha.state.md.us.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** Yes. We use MicroStation and InRoads for the development of our construction plans. A result of the design is a 3-D model that is then used for visualizations for public outreach purposes. We incorporate vehicles in the model to show what real-time travel speeds will feel like through the finished project.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** Approximately 8 years ago.

5. **Modeling tools:** We use MicroStation and InRoads for the base models for topo[graphy] and the proposed design. Then our programmer uses a program called Blender to incorporate movement; see http://www.blender.org/.

6. **Used by contractors for automated machine guidance?** No.

7. **Type of projects using 3-D or 4-D modeling:** 3-D models are created for all designs that require geometric improvements. However, the detail of the design is dependent on the type of work and scope of the project. For all major interchange projects and new alignment projects,

models are created. Not all 3-D models are rendered into a visualization. If there are public outreach needs for a project, the model [will] usually progress to a rendering or visualization and sometimes into a 4-D model.

8. **Project-specific examples:** Two projects:

   - MD 43 Extended—three miles of new alignment.
   - MD 5 Branch Ave Metro Access—interchange and new alignment.

   Both projects have visualizations that can be provided to you by request.

9. **Identify collaborative solutions?** Yes. For one of the more recent visualizations (3-D/4-D) at MD 4 Suitland Parkway, we used visualizations to help facilitate discussions with the National Park Service (NPS). The visualizations used helped the NPS understand the impacts as well as helped in determining the mitigation that would be needed to offset the impacts.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** A picture is worth a thousand words. When we need outside support from the public, the county, a city or local community, or government entity, showing the visualizations usually gets us to a consensus faster than if we had no visualization.

11b. **Cost savings.** [No response.]

11c. **Quality.** [No response.]

11d. **Improvements in customer relations.** Refer to 11a. Customer relations can be difficult; however, the more visualizations that we use help convey the engineering plans into something that is easier to understand. We use all types of visualizations for public outreach including 2-D, 3-D and 4-D.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Some of the challenges that we have encountered include limitations of the design software (InRoads and MicroStation), inconsistency in the design files—not every engineer designs the same way—and inconsistency of the product that is developed. It is difficult to standardize the way 3-D and 4-D models look and feel because they are done by consultant and state forces. It is very important that the product produced for public display always looks and feels the same.

13. **Next steps:** [No response.]

14. **Implementation advice:** It is a worthwhile investment, especially when it comes to public relations. However, make sure that the visualizations do not sell the public on something that cannot be built. Credibility will be hurt if visualizations are not fulfilled in construction.

15. **Staff contact information:** Eric Marabello, Chief, Design Technical Services Division, Maryland State Highway Administration, (410) 545-8770, emarabello@sha.state.md.us.

16. **Details or comments:** There are other names that would be more appropriate to contact when it comes to discussing details of how the modeling is completed. I will redirect the calls based on the topics of discussion.

Michigan

Contact: Dan Belcher, Support Services Manager, Michigan Department of Transportation, (517) 335-2182, belcherd@mi.gov.

1. **Using 3-D modeling?** No.
2. **Plans to begin using 3-D modeling?** Yes. Currently switching to Bentley Roadway Designer which creates better models than GEOPAK Criteria methods.
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** [No response.]
5. **Modeling tools:** [No response.]
6. **Used by contractors for automated machine guidance?** Yes. We have had a few pilot projects where we gave the contractors models. Beyond that the contractors are creating their own models. In some cases we are providing cross sections that the contractors use to make the model.
7. **Type of projects using 3-D or 4-D modeling:** [No response.]
8. **Project-specific examples:** [No response.]
9. **Identify collaborative solutions?** [No response.]
10. **Identify reduction in construction conflicts?** No.
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Contractors that receive the 3-D information prior to bidding are more efficient at creating their bids.

11b. **Cost savings.** [No response.]

11c. **Quality.** Ride quality of the finished pavement is higher than traditional staking methods.

11d. **Improvements in customer relations.** [No response.]

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Challenge for department staff to perform inspections on stakeless projects. There is a big need for Global Positioning System (GPS) equipment and training.
13. **Next steps:** Next step is performing designs using Bentley Roadway Designer so that 3-D models can be developed and then provided to the contractors.
14. **Implementation advice:** Provide the information to contractors prior to bidding.
15. **Staff contact information:** Dan Belcher, Support Services Manager, Michigan Department of Transportation, (517) 335-2182, belcherd@mi.gov.
16. **Details or comments:** [No response.]

Minnesota

Contact: Todd Bergland, Minnesota Department of Transportation, (651) 366-4608, todd.bergland@state.mn.us.

1. **Using 3-D modeling?** Yes.
2. **Plans to begin using 3-D modeling?** [No response.]
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** 2007.
5. **Modeling tools:** GEOPAK Corridor Modeler; GEOPAK Site.
6. **Used by contractors for automated machine guidance?** Yes. They are using the models for subgrade, grading grade and in some instances top of finished grade. They are not using it for surfacing ... yet. The contractors are not willing to use "Total Station" to get tolerance that is required.
7. **Type of projects using 3-D or 4-D modeling:** Grading, ponds, parking lots, unbonded concrete overlays.
8. **Project-specific examples:** Yes.
9. **Identify collaborative solutions?** Yes. Used to help ensure project accuracy. Tying of roads to ponds.
10. **Identify reduction in construction conflicts?** Yes. See #9.
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Reduction in staking requirements; contractor can apply flexible scheduling.

11b. **Cost savings.** Lower bids; lower survey costs; less rework.

11c. **Quality.** Machine control provides a better ride quality; better tie-down information.

11d. **Improvements in customer relations.** Accurate meeting presentations.

11e. **Other; please describe.** Ability to get elevations anywhere on job during construction.

12. **Describe barriers or challenges:** Software capabilities (evolution and instability); intersections; resources; staffing; accuracy of DTM/TIN [triangulated irregular network] models for existing ground.
13. **Next steps:** Waiting for a version upgrade of software. Then test, evaluate and train users.
14. **Implementation advice:** Start with small, simple projects. At the beginning, use for a portion or to supplement your existing methodology; then you can expand as your comfort level increases.
15. **Staff contact information:** Jon Mohrmann, Senior Engineering Specialist, Minnesota Department of Transportation, (320) 214-6330, jon.mohrmann@state.mn.us.
16. **Details or comments:** [No response.]

Mississippi

Contact: Keith Boteler, Roadway Design CADD Manager, Mississippi Department of Transportation, (601) 359-7290, kboteler@mdot.state.ms.us.

1. **Using 3-D modeling?** No.
2. **Plans to begin using 3-D modeling?** Yes. We're ready to move (3-D template builts as well as help guides) but we are waiting on GEOPAK SS3 which will allow much easier model creation than the current version of software.
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** Summer 2012 design implementation planned.
5. **Modeling tools:** GEOPAK.
6. **Used by contractors for automated machine guidance?** Yes. We have AMG specs and currently if AMG is used, contractors are required to create their own models since we're still a 2-D shop. We will eventually provide the models to the contractor.
7. **Type of projects using 3-D or 4-D modeling:** Will be all highway-related projects which involve grading and eventually paving.
8. **Project-specific examples:** No.
9. **Identify collaborative solutions?** N/A
10. **Identify reduction in construction conflicts?** N/A
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** N/A

11b. **Cost savings.** N/A

11c. **Quality.** N/A

11d. **Improvements in customer relations.** N/A

11e. **Other; please describe.** The benefits we foresee include more accurate earthwork calculations, some decrease in right of way acquisition, faster and more accurate construction, and much easier CEI [construction, engineering and inspection].

12. **Describe barriers or challenges:** Yes, building new template libraries (already done) and retraining design staff will be difficult.
13. **Next steps:** Implement in design.
14. **Implementation advice:** No comment since we've yet to implement in design.
15. **Staff contact information:** Keith Boteler, Roadway Design CADD Manager, Mississippi Department of Transportation, (601) 359-7290, kboteler@mdot.state.ms.us.
16. **Details or comments:** [No response.]

Related Documents:

Automated Machine Guidance Systems, Special Provision No. 907-699-1, Mississippi Department of Transportation, August 24, 2010.
See Appendix A.
This amendment to the 2004 edition of the Mississippi Standard Specifications for Road and Bridge Construction states that AMG is not a mandatory requirement. AMG, conventional staking or a combination of both may be used at the contractor's option for staking on a project.

Nebraska

Contact: James Knott, Roadway Design Engineer, Nebraska Department of Roads, (402) 479-4601, jim.knott@nebraska.gov.

1. **Using 3-D modeling?** No.
2. **Plans to begin using 3-D modeling?** Yes. We are current implementing Bentley Roadway Designer to allow the implementation of 3-D modeling.
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** [No response.]
5. **Modeling tools:** [No response.]
6. **Used by contractors for automated machine guidance?** Yes. Contractors are taking our design files and creating machine guidance files on major grading projects.
7. **Type of projects using 3-D or 4-D modeling:** We will be using the 3-D modeling on reconstruction projects.
8. **Project-specific examples:** [No response.]
9. **Identify collaborative solutions?** [No response.]
10. **Identify reduction in construction conflicts?** [No response.]
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** [No response.]

11b. **Cost savings.** [No response.]

11c. **Quality.** [No response.]

11d. **Improvements in customer relations.** [No response.]

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** The learning curve associated with a new design tool and the analysis of compatibility of the design tool with the existing legacy software.
13. **Next steps:** Training of selected staff to implement on specific projects.
14. **Implementation advice:** [No response.]
15. **Staff contact information:** James Knott, Roadway Design Engineer, Nebraska Department of

Roads, (402) 479-4601, jim.knott@nebraska.gov.

16. **Details or comments:** [No response.]

New Mexico

Contact: Gabriela Contreras-Apodaca, Regional Division Manager, New Mexico Department of Transportation, (575) 525-7330, gabriela.contreras-apodaca@state.nm.us.

1. **Using 3-D modeling?** Yes.
2. **Plans to begin using 3-D modeling?** Already in use.
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **How long have you been using 3-D or 4-D modeling:** 8+ years.
5. **Modeling tools:** LDD [Land Development Desktop] and Bentley InRoads.
6. **Used by contractors for automated machine guidance?** No.
7. **Type of projects using 3-D or 4-D modeling:** Roadway.
8. **Project-specific examples:** Bridges, roads, railroad.
9. **Identify collaborative solutions?** Yes; utilities conflicts are easier to identify.
10. **Identify reduction in construction conflicts?** Yes, is an assumption.
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** By generating a surface profiling is simpler and earthwork is faster to calculate.

11b. **Cost savings.** Estimates are more accurate.

11c. **Quality.** Quantities are more accurate and in turn change orders are smaller. Potential problems are easier to visualize.

11d. **Improvements in customer relations.** Construction is getting consistent and accurate plans.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Lack of software support from Bentley. CADD work space is limited and difficult to work with.
13. **Next steps:** Possibly going back to use AutoCAD Civil 3D.
14. **Implementation advice:** Make sure you have plenty of money and tons of technical support. Have someone who knows design and the software to be used very well. Write a contract with the software supplier that will include support and maintenance.
15. **Staff contact information:** Silas Salazar, CADD Manager, New Mexico Department of Transportation, (575) 827-9682, silas.salazar@state.nm.us.
16. **Details or comments:** The following was provided by Scott May, New Mexico Department of Transportation-SRD, (575) 525-7338, scotta.may@state.nm.us:

> We currently model (3-D) new construction with the use of Bentley MicroStation and InRoads v8i. With the use of this software we are able to model proposed roadway design

atop existing surface. The digital terrain model we generate is then used extensively in the process of creating construction documents. Although we are modeling our roadways we do not utilize all of the tools the software has available. We do not incorporate time (4-D) into our designs at this time. The software currently offers much more than we are utilizing. Unfortunately when we rolled out Bentley software we didn't set up everything to make the most of the software.

We are looking at moving forward with another CADD platform and will try to take full advantage of the tools available to us this time around. We do have a Design Manual that provides basic direction on our process for 3-D modeling which I have attached for your information. [See **Related Documents** below.]

Related Documents:

CADD Design Standards, New Mexico Department of Transportation, April 2009.
See Appendix B.
This document provides standards for CADD deliverables.

North Carolina

Contact: Glenn Mumford, Roadway Design Unit, North Carolina Department of Transportation, (919) 707-6206, gmumford@ncdot.gov.

1. **Using 3-D modeling?** Yes.
2. **Plans to begin using 3-D modeling?** [No response.]
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** Began using on a limited basis in 2011. Moving toward full implementation in 2012.
5. **Modeling tools:** Bentley Civil Geometry Software [GEOPAK].
6. **Used by contractors for automated machine guidance?** Yes. No projects with completed models have been let to contract yet, but contractors have used proposed TIN files that were created from current cross-section files.
7. **Type of projects using 3-D or 4-D modeling:** Currently used for bridge replacement projects and widening projects on existing location. New location templates have been developed, but no models have been completed for these types of projects yet.
8. **Project-specific examples:** Yes, if asked to do so we could forward design files for example projects.
9. **Identify collaborative solutions?** Too early in implementation to really know.
10. **Identify reduction in construction conflicts?** Too early in implementation to really know.
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Too early in implementation to know.

11b. **Cost savings.** Too early in implementation to know.

11c. **Quality.** Too early in implementation to know.

11d. **Improvements in customer relations.** Too early in implementation to know.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Difficult to develop and test model templates while trying to maintain project schedules. Also, typical resistance to change was exhibited by design personnel.

13. **Next steps:** Full implementation of all template types and let to contract of projects with fully developed models.

14. **Implementation advice:** Be sure templates are developed and adequate training opportunities are offered prior to implementation.

15. **Staff contact information:** Jim McMellon, CADD Support Project Design Engineer, North Carolina Department of Transportation, (919) 707-6282, jmcmellon@ncdot.gov.

16. **Details or comments:** [No response.]

Related Documents:

Corridor Modeling, Roadway Design Unit, North Carolina Division of Highways, North Carolina Department of Transportation, undated.
http://www.ncdot.org/doh/preconstruct/highway/roadway/corridor_modeling/
This web site provides resources for the designer, including a roadway design workflow; template library; and guidance for the use of GEOPAK, the agency's modeling tool.

North Dakota

Contact: Jon Collado, North Dakota Department of Transportation, (701) 328-4439, jcollado@nd.gov.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** No.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** We have been using proposed digital terrain models for some time. We started using very basic models approximately 10 years ago.

5. **Modeling tools:** Bentley Roadway Designer and MicroStation.

6. **Used by contractors for automated machine guidance?** Yes. We have produced DTMs as TINs and XMLs for selected pilot projects. We have not standardized our AMG practices.

7. **Type of projects using 3-D or 4-D modeling:** 3-D models may become a standard with our adoption of Bentley Roadway Designer. However, we are presently just delivering XS files and not the model. We did one animation project in order to generate public input and feedback.

8. **Project-specific examples:** Yes, Bentley Roadway Designer and our pilot animation project.

9. **Identify collaborative solutions?** Yes, animation for public feedback is a collaborative process.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Time and cost savings have not been directly measured. Additional time and cost have been incurred during design.

11b. **Cost savings.** Time and cost savings have not been directly measured. Additional time and cost have been incurred during design.

11c. **Quality.** Our earthwork calculations and DTMs are more representative of our proposed project.

11d. **Improvements in customer relations.** Modeling has helped improve communications with the general public.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Time and cost savings have not been immediately realized.

13. **Next steps:** We are developing our standards for AMG.

14. **Implementation advice:** [No response.]

15. **Staff contact information:** Roger Weigel, Design Engineer, North Dakota Department of Transportation, (701) 328-4403, rweigel@nd.gov.

16. **Details or comments:** [No response.]

South Dakota

Contact: Warren Ice, Project Engineer, Office of Road Design, South Dakota Department of Transportation, (605) 773-4419, warren.ice2@state.sd.us.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** All topography is an attached 3-D file and design elements are produced in 3-D using InRoads.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** 1996.

5. **Modeling tools:** MicroStation and InRoads.

6. **Used by contractors for automated machine guidance?** Yes. Surfaces are provided in Land XML format.

7. **Type of projects using 3-D or 4-D modeling:** Major grading projects.

8. **Project-specific examples:** [No response.]

9. **Identify collaborative solutions?** No.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** [No response.]

11b. **Cost savings.** [No response.]

11c. **Quality.** [No response.]

11d. **Improvements in customer relations.** [No response.]

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Designers still think and work in 2-D—plan, profile and cross section. All design standards broken up 2-D: horizontal alignment, vertical alignment and cross sectional.

13. **Next steps:** [No response.]

14. **Implementation advice:** [No response.]

15. **Staff contact information:** [No response.]

16. **Details or comments:** [No response.]

Related Documents:

CADD Procedures Manual (InRoads Manual), South Dakota Department of Transportation, April 19, 2005.
http://www.sddot.com/PE/roaddesign/plans_caddprocedures.asp
This manual includes guidelines and naming conventions, and addresses design, right of way and drafting. The manual is not intended to be a training guide or to replace the Reference Guide for InRoads software.

Utah

Contact: George Lukes, Preconstruction Engineer, Utah Department of Transportation, (801) 965-4986, glukes@utah.gov.

1. **Using 3-D modeling?** No.

2. **Plans to begin using 3-D modeling?** Yes. We think that the technology is going that way and intend to follow the technology. We have 4-D and 5-D modeling systems and have interest but haven't employed them yet. The cost, time and construction are not in line for us yet to use the technology. We may be able to employ it, but do not see the benefits due to users, e.g., contractors, project managers, etc., being able to utilize it.

Washington

Contact: Kurt Stiles, Visual Engineering Resource Group Program Manager, Washington State Department of Transportation, (360) 709-8008, kurt.stiles@wsdot.wa.gov.

1. **Using 3-D modeling?** Yes.

2. **Plans to begin using 3-D modeling?** [No response.]

3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** Yes, only for visualization purposes.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** Yes. Construction staging, emergency design alternatives (flooding, earthquake, etc.), historic narration, etc.

4. **Began using 3-D or 4-D modeling:** WSDOT uses minor 3-D modeling in the road building

software InRoads, which is part of a wider roadway design package. WSDOT also uses 3-D modeling for visualization purposes that can entail 4-D and 5-D presentations by the Visual Engineering Resource Group (VERG).

5. **Modeling tools:** InRoads for the typical WSDOT design team. MicroStation v8i 3D CADD, 3D Studio Max design, SketchUp Pro and Autodesk's Infrastructure Modeler by the WSDOT VERG.

6. **Used by contractors for automated machine guidance?** No.

7. **Type of projects using 3-D or 4-D modeling:** Visualization of statewide planning, design and construction projects. Also, visualization of other WSDOT infrastructure in rail, marine and aviation divisions of WSDOT. Lastly, VERG provides visualization for historical narration and documentation as required by federal and state laws.

8. **Project-specific examples:** One example would be using visualization to visually explain roundabout design to public and other stakeholders to gain their understanding and consent to the project.

9. **Identify collaborative solutions?** Yes. Often visualization is used to gain consent and agreement, like in conflict detection or access management along a roadway.

10. **Identify reduction in construction conflicts?** No.

11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** In one roundabout design, visualizations brought faster and more enlightened decision-making to designers and stakeholders alike. Over a month was saved from the design to construction process compared to past similar designs.

11b. **Cost savings.** Once WSDOT uses more 3-D modeling to virtually review a specific design for conflict/design issues, there will be an expected cost-saving benefit based upon the fact that change orders and field modifications will drop considerably.

11c. **Quality.** Using visualization internally in WSDOT builds confidence and belief in the project design intent. Also, conflicts can be sorted out before a bid process starts. Ultimately, the quality of the design will be improved from stringent virtual review through 3-D CADD modeling.

11d. **Improvements in customer relations.** Using visualization and 3-D modeling to show the customer (public/stakeholder) the capabilities and intent of the design builds tremendous belief in the design and also confidence in the engineer-client relationship.

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** Yes. Institutionally, WSDOT needs to invest and [expand] VERG and the visualization/virtual 3-D modeling ability so that each region in WSDOT has their own visualization tool set and that virtual modeling routinely occurs, improving overall WSDOT design and construction efforts.

13. **Next steps:** Continue building support and belief in the visualization/virtual 3-D modeling tool set statewide with the goal of improved investment and support.

14. **Implementation advice:** Consult with WSDOT VERG or another DOT/commercial venture who specializes in these skill sets. VERG is a pioneer in the visual communications industry for the AEC [architecture, engineering and construction] work effort and has assisted other DOTs in starting their visualization/3-D modeling units.

15. **Staff contact information:** Kurt Stiles, Visual Engineering Resource Group Program Manager, Washington State Department of Transportation, (360) 709-8008, kurt.stiles@wsdot.wa.gov.

16. **Details or comments:** [No response.]

Wisconsin

Contact: Brad Hollister, Methods Development Engineer, Wisconsin Department of Transportation, (920) 492-2380, brad.hollister@dot.wi.gov.

1. **Using 3-D modeling?** Yes.
2. **Plans to begin using 3-D modeling?** [No response.]
3. **Link a 3-D model with:**

3a. **Time (a 4-D model)?** Yes. While not mandatory, some of our designs completely model each construction stage. Other designs do not. We believe the benefit of fully staged design is largely during the design process; the additional thought put into the design helps identify constructability issues. Project staff make the decision on whether to fully stage the design or not.

3b. **Costs (a 5-D model)?** No.

3c. **Other project considerations?** No.

4. **Began using 3-D or 4-D modeling:** During the past two years, with our implementation of Civil 3D, we've started developing 3-D AMG surface models with our designs. We intend to make 3-D AMG surface models a required design deliverable on all WisDOT projects within the next couple years.
5. **Modeling tools:** Civil 3D, Navisworks—sparingly—special projects only.
6. **Used by contractors for automated machine guidance?** Yes. We piloted the use of contractor use of our AMG surfaces last construction season. We provided these at the time of project advertisement and found that our contractors benefit from having these surfaces during the bid development process.
7. **Type of projects using 3-D or 4-D modeling:** As we implement 3-D model deliverable requirements, we'll require development of these models based on AMG technology utilization. Right now, we're only seeing AMG on grading and base course activities, so at a minimum we'll require AMG surface delivery on these types of projects. As AMG paving technology makes its way to Wisconsin, we'll adjust project type as appropriate.
8. **Project-specific examples:** US 10: Two-lane roadway to four-lane divided (capacity expansion projects). Our Civil 3D Datum and Base Course surfaces were used. I-94 Mitchell Interchange (Major): Navisworks model developed from consultant-delivered PDF plans. This model included time and cost components also.
9. **Identify collaborative solutions?** Yes. The Mitchell interchange realized great utility of Navisworks model for engineer and contractor alike. We are early in the process of developing 3-D AMG surface models on other projects, so not many experiences to draw from.
10. **Identify reduction in construction conflicts?** No.
11. **Describe benefits of 3-D or 4-D modeling:**

11a. **Time savings.** Not quantified, but designers in their second Civil 3D project designs are reporting they can develop more iterations of designs more quickly, leading to a streamlined design process and designs refined to a greater extent.

11b. **Cost savings.** Facilitating the use of AMG technology by providing AMG surfaces leads to construction efficiencies. Also, providing these models pre-bid gives contractors more info to plan from in the development of bids, leading to reduction of risk and ultimately lower bid prices.

11c. **Quality.** Not quantified, but designers in their second Civil 3D project designs are reporting they can develop more iterations of designs more quickly, leading to a streamlined design process and designs refined to a greater extent.

11d. **Improvements in customer relations.** [No response.]

11e. **Other; please describe.** [No response.]

12. **Describe barriers or challenges:** The change from designing for a 2-D deliverable to a 3-D deliverable takes designers a while to understand. Developing 3-D designs requires greater attention to detail, and some are resistant to this change. But it's the greater attention to detail that in part helps identify constructability issues during the design process.

13. **Next steps:** 1) Implement AMG surface model deliverable requirements for all WisDOT projects. 2) Initiative to realize greater utility of model data developed during design in design and construction processes. More than AMG surface utility.

14. **Implementation advice:** Communicate the benefits of model-based approach to designers; get them behind the idea.

15. **Staff contact information:** Brad Hollister, Methods Development Engineer, Wisconsin Department of Transportation, (920) 492-2380, brad.hollister@dot.wi.gov.

16. **Details or comments:** We have guidance in our training. In the upcoming months, we'll be updating this based on our experiences thus far.

National Guidance

Visualization for Right-of-Way Acquisition, Office of Planning, Environment and Realty, Federal Highway A, October 2011.
See Appendix C.
This report identifies some of the reasons state DOTs have used visualization to facilitate right of way (ROW) acquisition. Select state DOTs are featured to illustrate how visualization is being applied. Key findings include:

- Benefits have generally outweighed the costs associated with developing the visualization presentations. Benefits most frequently reported include:
  - Better communication with property owners and other stakeholders about project impacts, thus potentially lowering condemnation rates.
  - Reduced acreage of land to be acquired.
  - Potential cost savings through reduced litigation and associated condemnation fees or damages.
- Use of visualization for ROW acquisition has likely not been as widespread as in other stages of transportation project delivery because:
  - Visualizations have been perceived as costly to produce or only useful for complex projects.
  - Some state DOTs lack the internal resources (staffing, funding or hardware/software) to develop and display visualizations.
  - There are concerns that visualization presentations might not exactly replicate the look of the actual project, thus potentially damaging public perception.
- Recommendations to overcome barriers to the use of visualization include:
  - Spreading the cost of visualization development among the various disciplines of transportation project development.

  - Making laptop computers and media software available for mobile use in the field, when possible.
  - Creating a standard method for gathering feedback on, and evaluating the benefits of, using visualization for ROW acquisition to help strengthen the case for its use.

Information Technology for Efficient Project Delivery, *NCHRP Synthesis 385*, October 2008.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_385.pdf
This synthesis identifies best practices for the seamless sharing of information throughout all phases of the project delivery process. Included in this review is an examination of barriers to implementation of the 3-D design model concept:

- Software application interoperability.
- Lack of quantified, documented return on investment.
- Rate of software application development.
- New requirements of human resource skills, knowledge and mindset.
- Lack of emphasis on process improvement techniques.

Emerging Technologies for Construction Delivery, *NCHRP Synthesis 372*, October 2007.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_372.pdf
This synthesis explores emerging technologies used by transportation agencies for construction projects, including 4-D computer-aided design and modeling for constructability analysis and improved communications (public outreach and visualization of project staging).

The report's summary (page 5 of the report; page 14 of the PDF) provides a list of unresolved technical and commercial issues associated with the use of 4-D modeling identified in the literature:

- Equitable methods to distribute modeling costs to project participants and beneficiaries.
- Multiple project stakeholder buy-in.
- New models must be created for each project in the transportation industry as the terrain or site model is typically a large percentage of the 3-D model.
- New models must be created for differing levels of required model detail.
- Access to sophisticated modeling tools requires licensing.
- Cost associated with providing collaborative environments.
- Analysis methods are not yet fully integrated into the simulation.
- Accommodation of differing design, work process and other database schemas by the project stakeholder involved.

Chapter Five, Four-Dimensional Computer-Aided Drafting Modeling, begins on page 41 of the report (page 50 of the PDF). When this synthesis was published, 4-D modeling was not in wide use. Of the 47 transportation agencies responding to the researchers' questionnaire, only four state DOTs indicated experience with 4-D modeling (California, Kentucky, Ohio and Wyoming). These agencies reported factors that restrict implementation of 4-D modeling, citing most often agency procedural issues, a lack of end-user technical skill and training, and unawareness of the potential benefits. Other issues affecting implementation include software interoperability issues, contract specification issues, conflicting technology standards, agency budgeting, hardware availability and noncooperation of designers.

Visualization for Project Development, *NCHRP Synthesis 361*, June 2006.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_361.pdf
This synthesis focuses on the best practices and experiences to date within transportation agencies that are developing and incorporating visualization into the project development process. The report provides an overview, details case studies, addresses the challenges of visualization and compares the results with a similar study from 1996.

Results of interviews and surveys used to gather information for this synthesis indicate that most transportation agencies are reactive to the development of visualization. In some cases, people with minimal to no experience with visualization are determining its use or nonuse for their project(s). All agencies interviewed for this project would like to see guidelines, best practices and cost-benefit analyses compiled for the use of visualization, with the goal of formally recognizing visualization as a core service within the project development process.

Visualization in Transportation: A Guide for Transportation Agencies, AASHTO Task Force on Environmental Design, American Association of State Highway and Transportation Officials, July 2003.
http://design.transportation.org/Documents/VisualizationGuideJuly2003.pdf
From the summary on page 15 of the report (page 19 of the PDF): Visualization is an effective tool to engage and facilitate healthy, informed discussion among project team members, the public, and transportation officials. The results contribute to improved participation and collaboration, which is integral to developing context sensitive solutions that advance transportation goals while acknowledging the needs of the community. These results not only minimize environmental impact but enhance environmental quality.

Design Visualization Guide, Federal Lands Highway Division, FHWA, undated.
http://www.efl.fhwa.dot.gov/manuals/dv/
This online guide is intended to show the designer how to use 3-D tools in GEOPAK and MicroStation to create useful visualizations of design projects. Also included are a discussion of advanced tools and techniques for producing visualizations and case studies illustrating several techniques and presentation technologies.

National Committees

Visualization in Transportation Committee, Transportation Research Board.
http://www.trbvis.org/MAIN/TRBVIS_HOME.html
Formally recognized in 2006, this committee is part of the Policy and Organization Group within TRB. *From the web site*: The scope of the committee is to foster and disseminate collaborative exchange and research that enhances the usable knowledge of visualization methods and technologies for their potential in addressing critical transportation issues of today, as well as promoting innovative approaches to society's transportation needs of the future.

Find case studies at http://www.trbvis.org/MAIN/CASE_STUDIES.html.

Related Domestic Research

"Optimizing Geometric Elements of a Three-Dimensional Alignment in a Single-Stage Highway Design Process," Gautham Anand Kumar Karri, Avijit Maji, Manoj K. Jha, *TRB 91st Annual Meeting Compendium of Papers DVD*, Paper #12-4470, 2012.
Paper available at http://amonline.trb.org/1sqt68/1
In this paper, the authors employed a piecewise polynomial approach to represent a 3-D highway alignment that eliminates the need of first locating a horizontal alignment and then fitting an appropriate vertical alignment on it. Previous research shows that this single-stage process is efficient and can address issues with sight distance inconsistencies at the onset of the design process by efficiently performing a series of iterations. The paper concludes with a numerical example using real highway and topographic data from Frederick County, MD, that demonstrates the applicability of the developed methodology.

"Benefits of 3D/4D CAD Model Applications for Constructability Review in Transportation Projects," William J. O'Brien, Pierre Gau, Cameron Schmeits, Jean Goyat, Nabeel Khwaja, *TRB 91st Annual Meeting Compendium of Papers DVD*, Paper #12-3329, 2012.
Paper available at http://amonline.trb.org/1slu51/1
This conference paper presented recent developments and applications of 3-D/4-D modeling on two transportation projects and the added value of such applications for constructability reviews. The 3-D and 4-D computer-aided design model applications developed for the two transportation projects described in this paper emphasize the benefits of this new technology in terms of communication, technical design checking, construction planning and work area management applied to transportation projects.

"Simulation-Based Four-Dimensional Modeling of Urban Highway Reconstruction Planning," Amin Hammad, Mohammed Mawlana, Ahmad Doriani, David Chedore, *TRB 91st Annual Meeting Compendium of Papers DVD*, Paper #12-3866, 2012.
Paper available at http://amonline.trb.org/1so0k6/1so0k6/1
In this conference paper, the authors proposed a new methodology that integrates simulation techniques and 4-D visualization methods. Results of the authors' investigation indicate:

- The proposed simulation-based 4-D modeling approach for highway reconstruction projects provides a practical tool for automatically detecting spatio-temporal conflicts between subprojects.
- Available road and bridge design software packages lack the needed interoperability to facilitate 4-D modeling.
- The case study demonstrated the feasibility of the proposed approach by being able to detect and visualize conflicts in a semihypothetical setting. By applying the proposed methodology, planners can focus their attention on the areas of potential conflicts and avoid these conflicts.

"Public Preferences on the Use of Visualization in the Public Involvement Process in Transportation Planning," Ruey Long Cheu, Marilyn Valdez, Srivatsava Kamatham, Raed Aldouri, *Transportation Research Record*, Vol. 2245, 2011: 17-26.
Citation at http://dx.doi.org/10.3141/2245-03
This study examined public preferences on the use of visualization techniques to involve the public in transportation planning. Prototype 2-D, 3-D and 4-D visualization models were developed for projects and presented at public meetings where stated preference surveys were conducted. The same models were also presented in a survey conducted via the Internet. Results indicate:

- More than 71 percent of the respondents thought that transportation planning agencies should devote more time and budget to develop advanced visualization models to encourage public participation.

- More than 75 percent of the respondents indicated that they would be more willing to participate and encourage others to participate in the public involvement process if better visualization tools were used.

Chapter 39, Roadway Visualization, *Handbook of Driving Simulation for Engineering, Medicine, and Psychology*, Michael A. Manore, Yiannis Papelis, CRC Press, 2011.
Publisher's information available at http://www.crcpress.com/product/isbn/9781420061000
This chapter in a recently published handbook explores the effective integration of driving simulation into the highway project development process. The authors consider how simulators can leverage visual design practices (visualization) and provide recommendations on bridging 3-D design with simulators.

3D Design Terrain Models for Construction Plans and GPS Control of Highway Construction Equipment, Research and Innovative Technology Administration, Report No. CFIRE 02-05, March 2010.
http://www.wistrans.org/cfire/documents/CFIRE_02-05_Final_Report.pdf
In this project, researchers sought to identify and characterize benefits and impediments associated with the adoption of 3-D design and construction technologies, identify strategies to overcome the impediments and offer recommendations to transportation agencies. Researchers also examined the functionality of 3-D design software to suggest techniques that could assist in evaluating software products.

Benefits associated with 3-D design methods include:

- Support for AMG.
- Detection and elimination of design errors prior to construction.
- Improved visualization.
- Having a more comprehensive representation of design intent.

Significant impediments to overcome prior to adoption of 3-D design methods cited by survey respondents include:

- Lack of resources.
- Agency lack of knowledge.
- Entrenched business practices.
- Lack of functionality in currently installed software.
- Required staff training.
- Legal factors, including legal standing for 3-D digital data in contract documents, electronic signatures, transfer of liability as related to data exchange, data security and auditability of plans.
- Professional licensure for those responsible for 3-D model development.

A summary of recommendations begins on page 8 of the PDF, with specific recommendations for:

- Obtaining buy-in and commitment from upper management.
- Specification development for AMG.
- Adoption of 3-D highway design technology.
- Developing or improving 3-D data flows from design to construction.
- Broader integration of multiple 3-D technologies.

"Planning the Implementation of Three-Dimensional Technologies for Design and Construction," Alan Vonderohe, Jerry Zogg, Gary Whited, Kenneth Brockman, *Transportation Research Record*, Vol. 2183, 2010: 129-138.

Citation at http://dx.doi.org/10.3141/2183-14
In this project, researchers developed a high-level implementation plan for 3-D technologies and methods for highway design and construction in Wisconsin. The plan includes six initiatives that address:

- An ongoing height modernization and continuously operating reference station program.
- Standards, procedures and training for 3-D data collection.
- 3-D model content and format standards.
- Additional specifications for AMG.
- Field technology and inspection.
- Infrastructure life cycle uses of 3-D data.

The plan differentiates between priorities (importance) and precedence (dependencies) among initiatives and goals within them.

"Integration of Traffic Simulation into Design Visualization," Ting Wei, Paul Jarboe, *Transportation Research Record*, Vol. 2165, 2010: 89-95.
Citation at http://dx.doi.org/10.3141/2165-10
One shortcoming of 3-D modeling software that produces photorealistic visualization is its failure to produce realistic traffic movements. Similarly, traffic simulation software that produces realistic traffic movements generally cannot produce photorealistic visualization. Researchers described a case study in which VISSIM, a microscopic simulation program for multimodal traffic flow, and 3ds Max, a modeling, animation and rendering package, were used to integrate traffic simulation into a design visualization for the Keystone Avenue Project in Carmel, IN. This project involved the upgrade of six at-grade, signalized intersections along Keystone Avenue to six teardrop roundabout interchanges. The case study successfully incorporated realistic traffic movements into a photorealistic visualization through a four-step process.

"Collecting and Converting Two-Dimensional Utility Mapping to Three-Dimensional," James Herman Anspach, *TRB 89th Annual Meeting Compendium of Papers DVD*, Paper #10-0681, 2010.
Citation at http://trid.trb.org/view.aspx?id=909585
Assigning depth or elevation values to existing utility mapping is becoming more pervasive as agencies move from a 2-D CAD design platform to 3-D platforms. Judgments or assumptions about the presence or location of a utility are required because these utilities are not exposed and cannot be directly observed and measured. The author discussed the variety of sources for these judgments and recommended documentation practices.

Accelerating the Design and Delivery of Bridges with 3D Bridge Information Modeling: Pilot Study of 3D-Centric Modeling Processes for Integrated Design and Construction of Highway Bridges, Innovations Deserving Explanatory Analysis (IDEA), Highway IDEA Program, Final Report for Highway IDEA Project 108, August 2006.
http://onlinepubs.trb.org/onlinepubs/archive/studies/idea/finalreports/highway/NCHRP108_Final_Report.pdf
In this project, researchers tested a 3-D-centric model for an integrated design and construction process for highway bridges. Work began with building parameter dictionaries for typical medium-span highway bridges, and then moved to specifying and refining data flow for a completed integrated design, presenting a software demonstration illustrating parameter-driven 3D-centric bridge structure design, and identifying technical and coordination issues. A prestressed concrete bridge provided by Pennsylvania DOT was modeled parametrically in 3-D and evaluated by a private contractor.

"Enhancing Highway Geometric Design: Development of Interactive Virtual Reality Visualization System with Open-Source Technologies," Kai Han, Dan Middleton, Alan Clayton, *Transportation Research Record*, Vol. 1980, 2006: 134-142.
Citation at http://dx.doi.org/10.3141/1980-19
The authors described the development of a visualization system that applies an open-source virtual reality modeling technology with proven key techniques. The result is a system capable of supporting the construction of a 3-D road surface with accurate geometry and providing vehicle-based navigation with controlled driver perspectives. Case studies using real-world data provided the opportunity to integrate data, create 3-D modules and demonstrate successful implementation of the visualization system.

"Feasibility of Using Three-Dimensional Graphics and Object-Oriented Design to Improve Construction Specifications," Edward J. Jaselskis, Russell Walters, Zhili Gao, Manop Kaewmoracharoen, *TRB 85th Annual Meeting Compendium of Papers CD-ROM*, Paper #06-1449, 2006.
Citation at http://trid.trb.org/view.aspx?id=776899
An object-oriented design and specifications (OODAS) system allows users to point and click on portions of an object-oriented drawing linked to relevant databases containing information such as specifications, procurement status and standard drawings. Projects based on OODAS could ultimately reduce the chance of error, improve quality, decrease rework and shorten the duration of projects. The study shows that the estimated cost to develop a prototype OODAS system for Iowa DOT is $575,000 plus an annual maintenance cost of $87,000.

International Research

"Three-Dimensional Methodology for Design Process of Safe Rural Highways," Wolfgang Kuhn, Ingolf Leithoff, Ronny Kubik, *TRB 91st Annual Meeting Compendium of Papers DVD*, Paper #12-3066, 2012.
Paper available at http://amonline.trb.org/1sl3lg/1sl3lg/1
German researchers are developing a new kind of design methodology that applies a 3-D route search concept. The 3-D route is created by superimposing the classic design elements from the horizontal and vertical projections. After breaking down the 3-D route into the individual design levels, two-stage safety checks follow according to geometric criteria (guideline specifications) and expected driving behavior (driving simulation). Various visualization techniques (2-D/3-D display, driving simulation in the virtual driving area) support design engineers in the interactive planning and checking process. The new workstation combines design methodology with hardware and software components that handles the comprehensive process of "designing/checking/driving/assessing" in a practical manner.

"Highway Bridge Construction Process Simulation Base on 4D Visualization," ChengHan Zhou, WeiDong Wang, *GeoHunan International Conference: Challenges and Recent Advances in Pavement Technologies and Transportation Geotechnics*, 2009: 138-145.
Citation at http://trid.trb.org/view.aspx?id=900772
This study established a 4-D simulation model for bridge construction management by integrating the construction schedule and resource consumption progress with the bridge 3-D model. Based on this model, a 4-D simulation system of bridge construction was developed. The Bridge Construction 4-D Simulation System was applied in the construction management of DaWu River Bridge, a 340-meter prestressed concrete continuous rigid frame bridge.

"Construction Automation Process Development—Advancing the Collaboration between Finland and California," Rauno Heikkilä, Ty A. Lasky, Kevin Akin, *26th International Symposium on Automation and Robotics in Construction*, 2009.
http://www.iaarc.org/publications/fulltext/Construction_Automation_Process_Development_Advancing_the_Collaboration_between_Finland_and_California.pdf
From the conclusion: The total process model for automation for construction and maintenance is expected to provide substantial benefits for transportation infrastructure. Research, development, and pilot testing in both Finland and California have demonstrated the feasibility and many of these benefits, and have also identified areas for further investigation and improvement. The model will allow us to identify key features and requirements for Caltrans and its contractors to appropriately apply machine guidance and construction automation. As noted with respect to California's results, a critical need is a detailed business case analysis demonstrating the cost-benefit for machine guidance and the use of a total process model for the complete infrastructure lifecycle.

Software for Road Infrastructure: Planning, Design, Construction and Management of Road Assets, Supplement to *World Highways and ITS International*, Route One Publishing Ltd., December 2011.
Publication information available at http://www.ropl.com/pdf/Software_2011.pdf
Topics covered in this publication include integration of design software functions; collaboration tools for organizing and tracking files; and a wide range of software tools used to increase roadway capacity, reduce earthmoving costs, create interchanges, simulate traffic and reconstruction work, and improve integrated data handling.

State Agency Web Sites and Presentations

Minnesota

Visual Imaging, MnDOT Visualization Services, Minnesota Department of Transportation.
http://www.dot.state.mn.us/visualization/
Find links here to current or future MnDOT construction projects using visualization tools and MnDOT's visualization YouTube channel.

North Carolina

Enterprise Visualization, North Carolina Department of Transportation.
http://www.ncdot.org/it/visualization/
This web site offers a history of the agency's activities in visualization, a discussion of products and a portfolio of project illustrations and renderings.

Washington

Visual Engineering Resource Group, Washington State Department of Transportation.
http://www.wsdot.wa.gov/business/visualcommunications/default.htm
This web site offers examples of visualization projects. Other Washington State DOT web pages of interest:

- Find examples of design visualizations at http://www.wsdot.wa.gov/Projects/I5/ne134thi205/DesignVisualizations.htm.
- Find technical documentation at http://www.wsdot.wa.gov/Design/CAE/Technotes.htm.

- Find links to a wide range of resources from the Computer Aided Engineering Office at http://www.wsdot.wa.gov/Design/CAE/default.htm.

Wisconsin

"The Move to Model-Based Design at the Wisconsin Department of Transportation," Jerry Zogg, Wisconsin Department of Transportation, Karen Weiss, Autodesk Inc., International Highway Engineering Exchange Program, 2011.
http://www.iheep2011.com/images/docs/presentations/3A%20-%20Model%20Based%20Design%20at%20WisDOT.pdf
Model-based design, as employed by Wisconsin DOT, is the same work concept with different tools that produces a higher quality product. Money is saved by reducing the time needed for design and reducing mistakes. Having surfaces ready for AMG usage substantially impacts construction operations.

Slide 23 of this presentation presents the contractors' perspective on model-based design:

- 3-D models convey design intent much better than a 2-D plan, which reduces uncertainty in bidding.
- Availability of 3-D models frees contractor staff from development, leaving more time for preparation of multiple bids and resulting in greater competition and more bids submitted to WisDOT.
- Enhanced identification and design of cost reduction incentives.
- Better information for planning project earthwork activities.
- 3-D model checking is much easier than plan checking.

Lessons learned on the design side include:

- Project timelines were not impacted.
- Able to do things that could not be done before.
- Model-based design excels in complex areas such as intersections, crossovers, cul-de-sacs and gore areas.

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION NO. 907-699-1 **CODE: (SP)**

DATE: 08/24/2010

SUBJECT: Automated Machine Guidance Systems

Section 699, Construction Stakes, of the 2004 Edition of the Mississippi Standard Specifications for Road and Bridge Construction is hereby amended as follows.

907-699.01--Description. After the first paragraph of Subsection 699.01 on page 585, add the following:

This work may be performed utilizing Automated Machine Guidance technologies and systems in accordance with the standard specifications and contract documents. Automated Machine Guidance (AMG) is defined as the utilization of positioning technologies such as Global Positioning Systems (GPS), Robotic Total Stations, lasers, and sonic systems to automatically guide and adjust construction equipment according to the intended design requirements. The Contractor may use any type of AMG system(s) that result in compliance with the contract documents and applicable Standard Specifications.

Automated Machine Guidance (AMG) is not a mandatory requirement. Automated Machine Guidance (AMG), conventional staking, or a combination of both may be used at the Contractor's option for staking on this project.

907-699.02--Materials. After the last sentence of the first paragraph of Subsection 699.02 on page 585, add the following.

All equipment required to accomplish automated machine guidance shall be provided by the Contractor. The Contractor may use any type of AMG equipment that achieves compliance with the contract documents and applicable Standard Specifications.

907-699.03--Construction Requirements. After the last paragraph of Subsection 699.03 on page 587, add the following.

907-699.03.1--Automated Machine Guidance.

907-699.03.1.1--Automated Machine Guidance Work Plan. The Contractor shall submit a comprehensive written Automated Machine Guidance Work Plan to the Engineer for review at least 30 days prior to use. The submittal of a AMG Work Plan shall be an indication of the Contractor's intention to utilize AMG instead of conventional methods on the project areas and elements stated in the Work Plan. The Engineer shall review the Automated Machine Guidance Work Plan to ensure that the requirements of this special provision are addressed. The Contractor shall assume total responsibility for the performance of the system utilized in the Work Plan. Any update or alteration of the Automated Machine Guidance Work Plan in the course of the work shall be approved and submitted to MDOT for determination of conformance with requirements of this special provision.

The Automated Machine Guidance Work Plan shall describe how the automated machine guidance technology will be integrated into other technologies employed on the project. This shall include, but not limited to, the following:

1. A description of the manufacturer, model, and software version of the AMG equipment.
2. Information on the Contractor's experience in the use of Automated Machine Guidance system (or Related Technologies) to be used on the project, including formal training and field experience of project staff.
3. A single onsite staff person as the primary contact, and up to one alternate contact person for Automated Machine Guidance technology issues.
4. A definition of the project boundaries and scope of work to be accomplished with the AMG system.
5. A description of how the project proposed secondary control(s) is to be established. It shall also include a list and map detailing control points enveloping the site.
6. A description of site calibration procedures including, but not limited to, equipment calibration and the frequency of calibration as well as how the equipment calibration and information will be documented to MDOT and the Project Engineer. The documentation shall contain a complete record of when and where the tests were performed and the status of each equipment item tested within or out of the ranges of required tolerances.
7. A description of the Contractor's quality control procedures for checking mechanical calibration and maintenance of equipment. It shall also include the frequency and type of checks to be performed.
8. A description of the method and frequency of field verification checks and the submission schedule of results to the Project Engineer.
9. A description of the Contractor's contingency plan in the event of failure/outage of the AMG system.
10. A schedule of Digital Terrain Models (DTM) intended for use on the project. This shall be submitted to the Engineer for review, feedback, and communication.

The Contractor and MDOT will agree on the quantity and schedule of Contractor-provided training on the utilized AMG system required under Subsection 907-699.03.1.3.

907-699.03.1.2--State's Responsibilities. The District Surveyor will set the primary horizontal and vertical control points in the field for the project as per latest edition of the MDOT Survey Manual. The control points shall be in Mississippi State Plane coordinate system.

MDOT will provide an electronic alignment file and primary control file for the project. This file will be based on the appropriate Mississippi State Plane Coordinate Zone either West or East. These files will be created with the computer software applications MicroStation (CADD software) and GEOPAK (civil engineering software). The data files will be provided in the native formats. The Contractor shall perform necessary conversion of the files for their selected grade control equipment, field verify the data for accuracy, and immediately report any errors to MDOT.

MDOT will provide design data, if available, in an electronic format to the Contractor. These files will be created with the computer software applications MicroStation (CADD software) and GEOPAK (civil engineering software). The data files will be provided in the native formats as specified in the Data Format section of this specification. No guarantee is made to the data accuracy or completeness, or that the data systems used by MDOT will be directly compatible with the systems used by the Contractor. Information shown on the paper plans marked with the seal (official plans as advertised) shall govern.

The Engineer will perform spot checks as necessary of the Contractor's machine control grading results, surveying calculations, records, field procedures, and actual staking. If the Engineer determines that the work is not being performed in accordance with the Specifications, the Engineer shall order the Contractor to re-construct the work to the requirements of the contract documents at no additional cost to the Department.

907-699.03.1.3--Contractor's Responsibilities The Contractor shall provide formal training, if requested, on the use of the Automated Machine Guidance Equipment and the Contractor's systems to MDOT project personnel prior to the start of construction activities utilizing AMG. This training is for providing MDOT project personnel with an understanding of the equipment, software, and electronic data being used by the Contractor.

The Contractor shall use the alignment and control data provided by MDOT.

The Contractor shall bear all costs, including but not limited to the cost of actual reconstruction work that may be incurred due to errors in application of Automated Machine Guidance techniques or manipulation of MDOT design data in Digital Terrain Models (DTM).

The Contractor shall be responsible for converting the information on the plans and/or electronic data file provided by MDOT into a format compatible with the Contractor's AMG system.

The Contractor shall establish secondary control points at locations along the length of the project and outside the project limits and/or where work is performed beyond the project limits as required by the Automated Machine Guidance system utilized. The Contractor shall establish this secondary control using survey procedures as outlined in the latest edition of the MDOT Survey Manual. A copy of all new control point information shall be provided to the Engineer prior to construction activities. The Contractor shall be responsible for all errors resulting from their efforts and shall correct deficiencies to the satisfaction of the Engineer and at no additional cost to the State.

The Contractor shall preserve all reference points and monuments that are established by the District Surveyor outside the construction limits. If the Contractor fails to preserve these items, they shall be re-established by the Contractor to their original quality at no additional cost to the State.

The Contractor shall set grade stakes at the top of the finished sub-grade and base course at all hinge points on the typical sections at 2000-foot maximum intervals on mainline, critical points such as, but not limited to, PC's, PT's, beginning and ending super elevation transition sections, middle of the curve, and at least two locations on each of the side roads and ramps, and at the beginning and end of each cross slope transition where Automated Machine Guidance is used. These grade stakes shall be established using conventional survey methods for use by the Engineer to check the accuracy of the construction.

The Contractor shall meet the same accuracy requirements as detailed in the Mississippi Standard Specifications for Road and Bridge Construction. Grade stakes shall be established as per Section 699 of the Mississippi Standard Specifications for Road and Bridge Construction for use by the Engineer to check the accuracy of the construction.

The Contractor shall be responsible for implementing the AMG system using the Mississippi State Plane Coordinate System. No localization methods will be accepted.

907-699.03.1.4--Data Format. It is the Contractor's responsibility to produce the Digital Terrain Model(s) and/or 3D line work needed for Automated Machine Guidance. MDOT does not produce this data in its design process. MDOT does provide CADD files created in the design process to the Contractor. The CADD files provided by MDOT are provided in the native software application formats in which they are created with no conversions, and their use in developing 3D data for machine guidance is at the discretion of the Contractor. The CADD files that may be available are listed below. Cross-Sections are one of the items provided but are not necessarily created at critical design locations. Therefore their use in Digital Terrain Models (DTM) for AMG is limited.

1. Project Control - Microstation DGN file and ASCII file
2. Existing Topographic Data - Microstation DGN file(s)
3. Preliminary Surveyed Ground Surface - GeoPak TIN, if available
4. Horizontal and Vertical alignment information - GeoPak GPK file and/or Microstation DGN file(s)
5. 2D Design line work (edge of pavement, shoulder, etc.) - Microstation DGN file(s)
6. Cross sections - Microstation DGN file(s), GeoPak format
7. Superelevation - Microstation DGN file(s), GeoPak format
8. Form Grades - Microstation DGN file(s)
9. Design Drainage - Microstation DGN file(s)

It is expressly understood and agreed that MDOT assumes no responsibility in respect to the sufficiency or accuracy of these CADD files. These files are provided for convenience only and the contract plans are the legal document for constructing the project.

907-699.05--Basis of Payment. Add the "907" prefix to the pay items listed on page 588.

APPENDIX B

CADD Design Standards

This document is formatted for two-sided printing.

Software Versions

MicroStation 8.11.xx.xx (V8i)

InRoads 8.11.xx.xx (V8i)

Author

Original document prepared for the New Mexico Department of Transportation by:

MJM Consulting, LLC: 2009

Table of Contents

This Page Intentionally Left Blank

Overview

This manual was created for the New Mexico Department of Transportation in order to help standardize **C**omputer **A**ided **D**rafting and **D**esign (**CADD**) deliverables produced within and for the department. Items discussed in this section:

- Purpose
- Glossary of Terms
- Paradigms
- Symbols

Purpose

The New Mexico Department of Transportation (NMDOT) contracts companies to provide Computer Aided Drafting and Design (CADD) projects. The creation of these files is merely the initial process that will make up their life span. These files will be shared and referenced by many individuals and therefore must adhere to a standard in order to alleviate any potential confusion by users. The purpose of this document is to provide these standards in a format that is easily understood with any knowledge of CADD. It is to be noted that all CADD deliverables must meet the standards provided in this document. Please refer to the contract between the Consultant and the NMDOT for the exact terms and conditions regarding procedures and standards to be followed by the Consultant.

Glossary of Terms

AutoCAD - CAD platform designed by AutoDesk, Inc

Base File – MicroStation or AutoCAD file created with design elements to be used as a reference file only

CAD – Acronym for Computer Aided Drafting

CADD – Acronym for Computer Aided Drafting & Design

Cells/Cell Libraries – A group of elements created for use as a single element repeatedly. The single group of elements is known as a "cell", where as a collection of cells is known as a "cell library"

Color Table – Used to assign specific colors to elements using numeric values

Configuration Files – Generic term for ASCII text files used by MicroStation to control startup, program settings, and overall operability

Consultant Deliverable Guidelines – Document detailing consultant deliverable requirements, namely digital file submission

.dgn – Default file extension for files created by MicroStation

.dwg – Default file extension for files created by AutoCAD

Extended Characters – Special symbol characters located within a MicroStation font resource file

Levels/Layers – One method in which CAD programs segregate information for the user to aid in the display of the design. For example, the centerline of a roadway may be placed on level number 13, or named "Centerline". The striped centerline may be placed on another level number 14, or named "Striped CL". The user would then have the ability to show one of these centerlines by merely turning off the other level

Linear Elements – Made up of either lines or various types of arcs, linear elements account for a majority of a design file

MicroStation - CAD platform designed by Bentley Systems, Inc. MicroStation is the default CAD system for the New Mexico Department of Transportation

PCN – Acronym for Project Control Number. A PCN is a numeric value assigned to every civil engineering project to aid the DOT in tracking the design

Pen Table – An ASCII file used to control the output of a design file when printing

Raster Images – A photograph used in a design file to display either the project area, or a specific item within the project (i.e. a scanned New Mexico map to show location of project on the vicinity map). "Raster image" is typically used in reference to an Aerial photograph

Reference File – A term used to describe a source file when the information is viewed from another file. A reference file is typically a base file used for information for the sheet file (i.e. plan and profile sheet)

Resource File – MicroStation uses data files to display fonts, linestyles, colors, etc. These data files are referred to as "resource files"

Share – Folders located on a server with user and or group permissions

Servername – Example name of a server on the NMDOT Domain or a corporate domain

Sharename – Example name of folder "shared" on the NMDOT servers or a corporate server

Symbology – This term refers to the weight, color, and style of vector elements in a design file

UNC – **U**niversal **N**aming **C**onvention; designated by \\servername\sharename

Vector Elements – Any element created within a CAD application is a vector element. The most common elements are lines and arcs. These elements are often the output of the engineering software using either MicroStation or AutoCAD

Working Units – Working units are merely units of measurement. Imperial units are survey feet (master units) and thousandths (sub-units)

Paradigms

Several typefaces and symbols are used in this document to help the user navigate through the document.

Typefaces:

Normal:

This typeface is used to relay information and is used to guide the user through the steps involved in running the PPG.

<u>Bold/Italic/Underlined</u>:

This typeface is used as an indicator of a hyperlink. Hyperlinks are used to ease navigation throughout this document as an electronic file.

Notable

This typeface is used in conjunction with the information and alert symbols to relay important information.

Symbols:

This symbol is used to call attention to an action occurring, or an expected action.

This symbol is used to relay information concerning an individual area in a dialog box.

►

This symbol used in conjunction with the bold typeface is to relay a specific selection from a pull down menu (e.g. **Start►Programs►Bentley**).

This Page Intentionally Left Blank

Survey Standards

This manual follows the typical process for a highway engineering project. The field survey parameters and NMDOT standards for surveying are the basis for any NMDOT project, and it is essential these guidelines are met. Items discussed in this section:

- State Plane Coordinates
- Standard Points List
- NMDOT Feature Table
- CAD Standards

State Plane Coordinates

The New Mexico Department of Transportation designs all projects using New Mexico State Plane Coordinate System 1983 (NMSPC83F).

Standard Points List

The NMDOT has determined the need for standard points assignments. The assignment of such a system ensures the delineation of existing/proposed remains in tact. From the initial survey to the creation of detour alignments, the points assignments are critical to easily identify points located in the field or created in the office. See Table 2.1 for the NMDOT Point Listing.

Point Type	Point Range
Existing	
Control	1-99
Location Survey	100-2999
ROW-Existing Points	3000-4999
Proposed	
ROW-Proposed Points	5000-6999
Design	7000+

Table 2.1

For figure numbers and their assignments, refer to the ***Alignment Section*** of this document.

NMDOT Feature Table

The feature table maps all survey elements using custom scripting (see figure 2.1). This custom scripting enables the feature table to provide complete mapping to NMDOT standards with little cleanup. The NMDOT feature table also contains attribute tags and features for many of its codes (see figure 2.1).

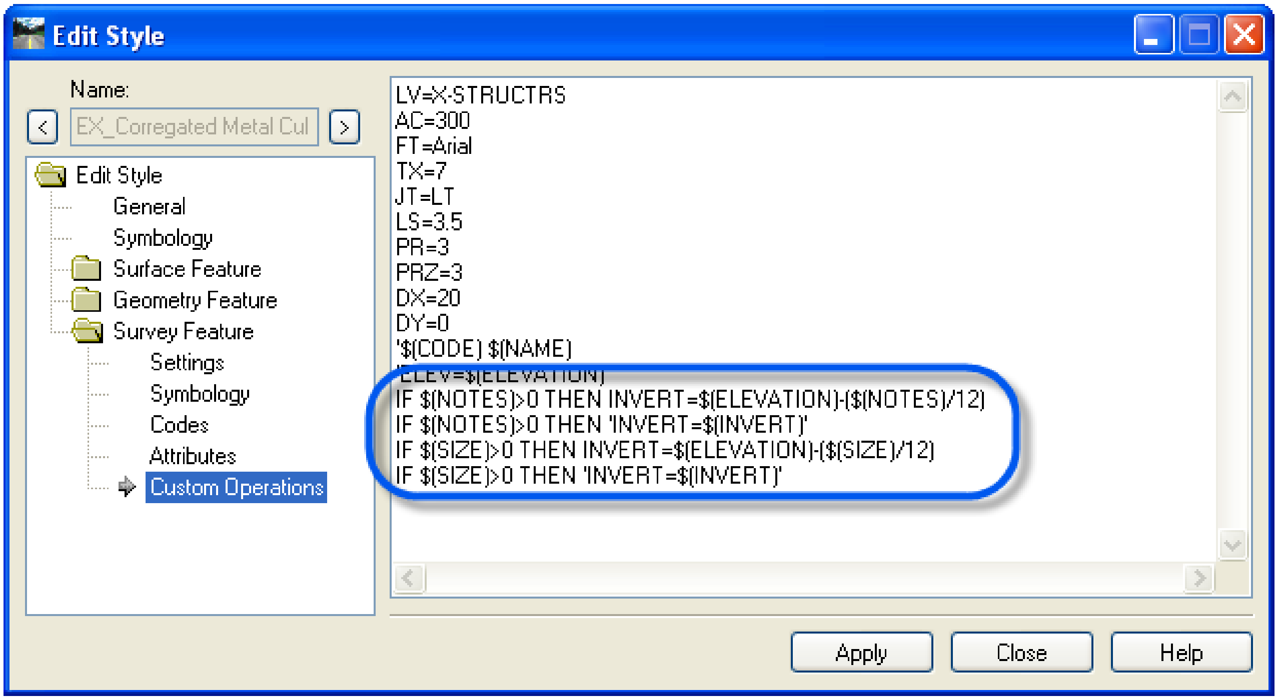


Figure 2.1

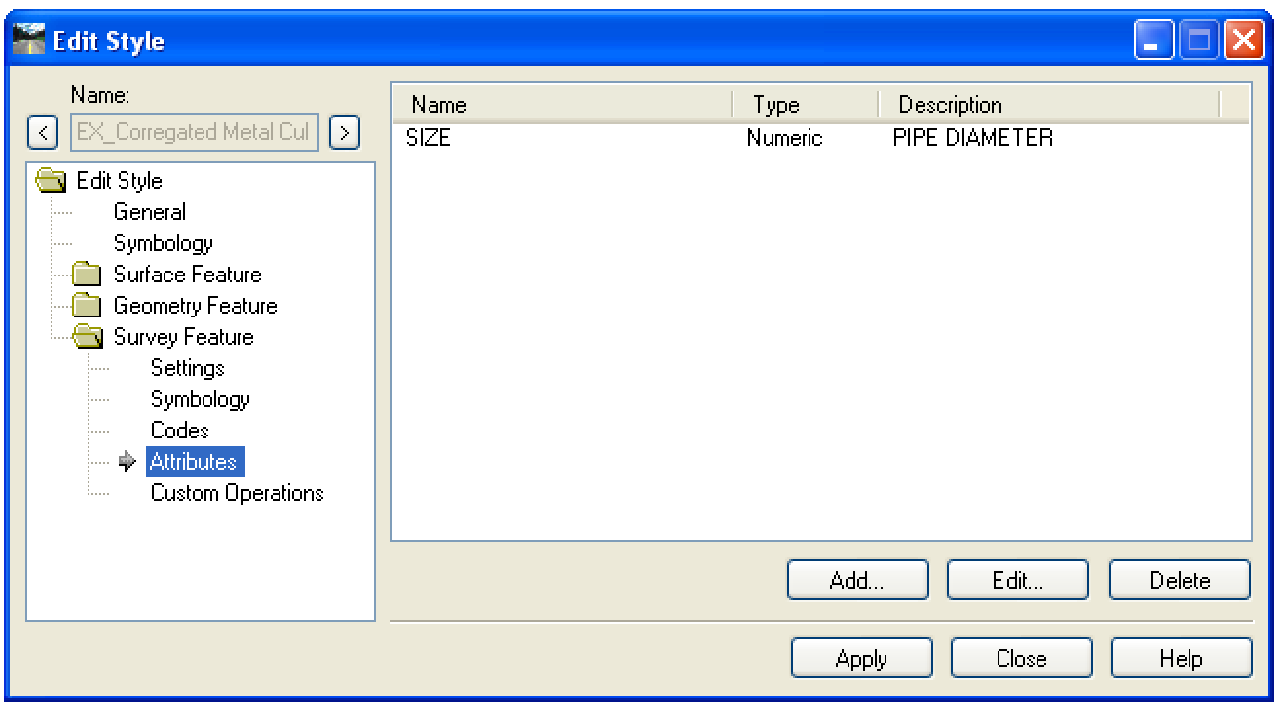


Figure 2.2

When importing points into InRoads Survey, it is important to note that the feature table has been designed to allow for a column of the survey points file to be labeled as a

"Note" (see figure 2.1). This "Note" label is interpreted by the feature table as a pipe diameter or a mile post number. This feature will also be included in other features in the near future. The feature table's design includes the ability to recognize attribute tags of "size" and "number" (see figure 2.2). If attribute tags are not used in the field, the code can be changed while editing the Survey Book within InRoads.

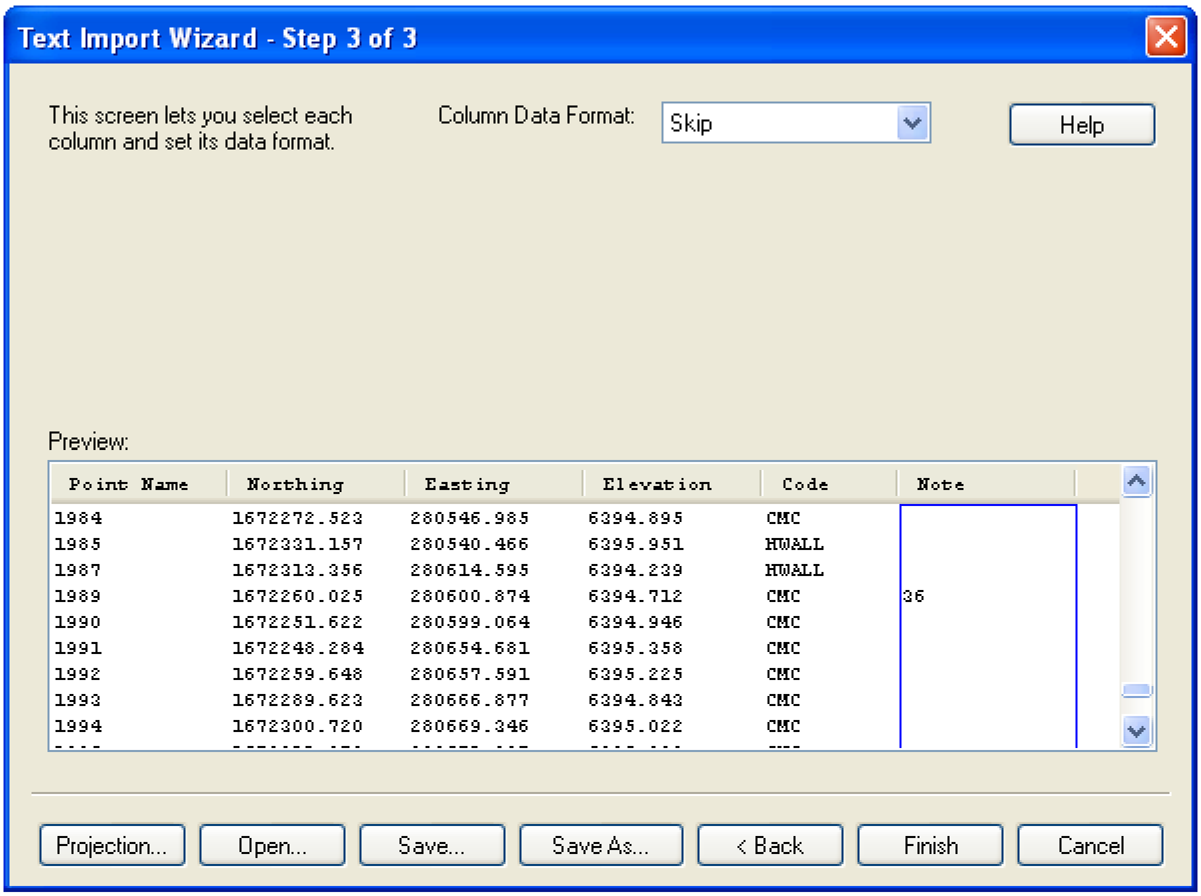


Figure 2.3

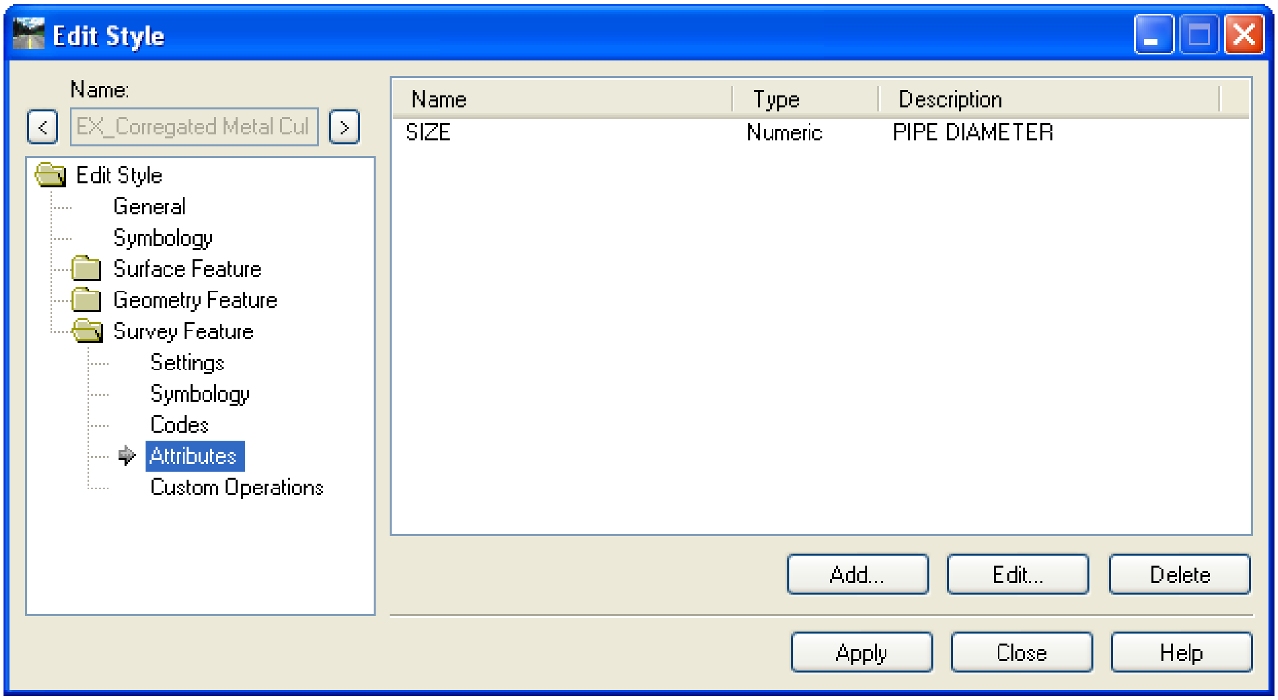


Figure 2.4

Another added benefit built into the NMDOT feature table is the use of InRoads tags into the MicroStation design file. These tags are automatically placed when the points are imported and written to the design file. They can be viewed in MicroStation using the AccuSnap pop-up or an application called "Infosnap". Infosnap is a third-party application that displays information about an element that is tentatively snapped to for a short period of time (see figure 2.5). Infosnap is freeware and is available on the internet (www.ustation.se).

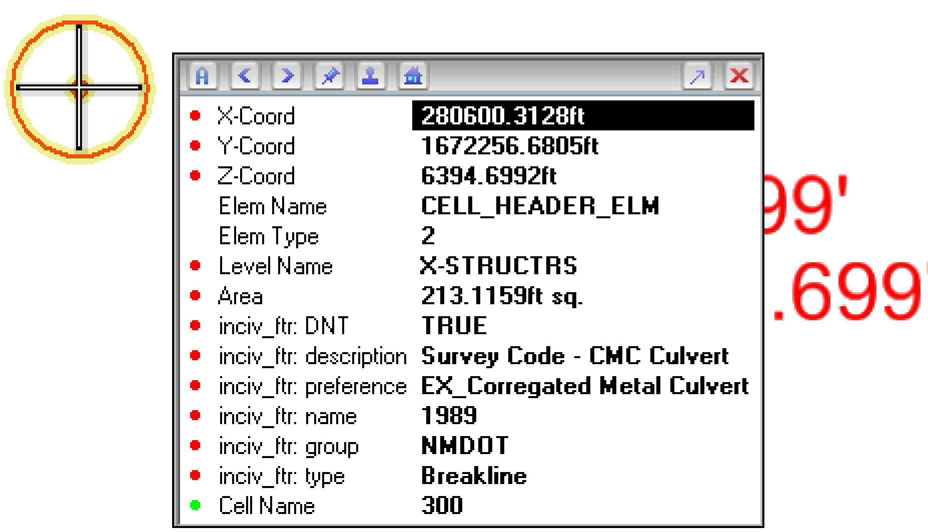


Figure 2.5

Below are the NMDOT standard field codes (categorically sorted):

Code	Descriptor	Description	Attribute Name	Cell	Level
		Control Property			
107	AC	Aluminum Cap		107	X-PTS_CONTROL
107	ACAP	Aluminum Cap		107	X-PTS_CONTROL
127	AX	Axle		127	X-PTS_CONTROL
112	BM	Bench Mark		112	X-PTS_CONTROL
106	BRC	Brass Cap		106	X-PTS_CONTROL
105	CALC	Calculated Point		105	X-PTS_CALC
100	CP	Control Point		100	X-PTS_CONTROL
125	NAIL	Nail		125	X-PTS_CONTROL
110	PCON	Photo Control		110	X-PTS_CONTROL
118	PIPE	Pipe		118	X-PTS_CONTROL
126	PK	PK Nail		126	X-PTS_CONTROL
101	PLCAP	Plastic Cap		101	X-PTS_CONTROL
113	RBR	Rebar	Size	113	X-PTS_CONTROL
104	RWBC	ROW Brass Cap		104	X-PTS_CONTROL
129	SFB	See Field Book		129	X-PTS_CONTROL
103	TR	T-Rail		103	X-PTS_CONTROL
		Alignments			
216	BOP	Beginning of Project		+	X-MISC_TOPO
214	BOS	Beginning of Survey		+	X-MISC_TOPO
204	CC	Curve Center		+	X-CL_SURVEY
212	CS	Curve to Spiral		+	X-CL_SURVEY
217	EOP	End of Project		+	X-MISC_TOPO
215	EOS	End of Survey		+	X-MISC_TOPO
201	PC	Point of Curvature		+	X-CL_SURVEY
207	PCC	Point of Compoun Curve		+	X-CL_SURVEY
203	PI	Point of Intersect		+	X-CL_SURVEY
205	POC	Point on Curve		+	X-CL_SURVEY
200	POT	Point on Tangent		+	X-CL_SURVEY
206	PRC	Point of Reverse Curve		+	X-CL_SURVEY
202	PT	Point of Tangency		+	X-CL_SURVEY
210	SC	Spiral to Curve		+	X-CL_SURVEY
211	SCPI	Spiral Curve Point of Intersect		+	X-CL_SURVEY
209	SPI	Spiral Point of Intersect		+	X-CL_SURVEY
213	STT	Spiral to Tangent		+	X-CL_SURVEY
208	TTS	Tangent to Spiral		+	X-CL_SURVEY
		Structures/Drainage			
308	BR	Bridge		308	X-BRIDGE
303	CAST	Cast Iron Pipe	Size	303	X-STRUCTRS
301	CBC	CBC Culvert	Size	301	X-STRUCTRS
314	CLNOUT	Cleanout		314	X-SANITARY
300	CMC	CMC Culvert	Size	300	X-STRUCTRS
315	CON	Concrete		315	X-CONCRETE
315	CONC	Concrete		315	X-CONCRETE
302	CPC	Conc. Pipe Culvert	Size	302	X-STRUCTRS
311	DI	Drop Inlet	Size	311	X-STRUCTRS
313	FL	Flow Line		313	X-MISC_TOPO
313	FLOW	Flow Line		313	X-MISC_TOPO
312	GRA	Grate	Size	312	X-STRUCTRS
316	HWALL	Head Wall		316	X-STRUCTRS
305	INV	Invert		305	X-STRUCTRS
304	PA	Pipe Arch	Size	304	X-STRUCTRS
309	PIER	Pier		309	X-STRUCTRS
306	SOF	Soffit		306	X-STRUCTRS
317	WWALL	Wing Wall		317	X-STRUCTRS
318	HGATE	Irrigation Head Gate		318	X-STRUCTRS
319	PVC	PVC Pipe		319	X-STRUCTRS
320	RRAP	Rip Rap		320	X-RIPRAP
		Surface Modeling			
403	BD	Bar Ditch/Uphill Side		403	X-MISC_TOPO
401	BLF#	Brealine/Field Number	Number	401	X-MISC_TOPO
405	EOM	Edge of Mat		405	X-EO_MAT
400	GND	Ground Shot		400	X-MISC_TOPO
400	GRND	Ground Shot		400	X-MISC_TOPO
		Topography			
515	BLDG	Building		515	X-BUILDING
505	CB	Curb	Size	505	X-CURB_GUTTER
505	CURB	Curb	Size	505	X-CURB_GUTTER
508	CG	Cattle Guard	Width	508	X-BARRIER
502	FC	Fence Corner	Type	502	X-FENCE
501	FEN	Fence	Type	501	X-FENCE
500	GATE	Gate		500	X-FENCE

Code	Descriptor	Description	Attribute Name	Cell	Level
		Topography			
509	GR	Guard Rail		509	X-BARRIER
514	MB	Mail Box		514	X-MISC_TOPO
511	MP	Mile Post	Number	511	X-SIGN
506	PM	Parking Meter		506	X-MISC_TOPO
518	RR	Rail Road		518	X-RAILROAD
519	RRARM	Rail Road Arm		519	X-RAILROAD
520	RRLT	Rail Road Light		520	X-RAILROAD
521	RRSW	Rail Road Switch		521	X-RAILROAD
513	SIGNMULTI	Sign Multiple Post	Description	513	X-SIGN
512	SIGNONE	Sign Single Post	Description	512	X-SIGN
507	SW	Side Walk	Depth	507	X-SIDEWALK
526	TBOOTH	Telephone Booth		526	X-MISC_TOPO
510	TREE	Tree	Type	510	X-VEGETATION
516	WALL	Wall	Type	516	X-WALL
528	SH	Shore		310	X-MISC_TOPO
529	PAV	Pavement		504	X-MISC_TOPO
530	CAN	Canopy		517	X-MISC_TOPO
531	X	Chiseled X		121	X-MISC_TOPO
532	CLM	Centerline of Mat		406	X-MISC_TOPO
533	EF	End of Fence		503	X-FENCE
534	STO	Stone		124	X-MISC_TOPO
535	TB	Top of Bank		402	X-MISC_TOPO
536	TOE	Toe of Bank		407	X-MISC_TOPO
537	DESC	Descanso		537	X-MISC_TOPO
Utilities					
667	DM	Dead Man Anchor		667	X-ELECTRICAL
601	EBOX	Electric Box		601	X-ELECTRICAL
602	EMETER	Electric Meter		602	X-ELECTRICAL
603	EMH	Electric Man Hole		603	X-ELECTRICAL
613	FH	Fire Hydrant		613	X-WATER
624	GASREG	Gas Regulator		624	X-GAS
625	GASTANK	Gas Tank		625	X-GAS
626	GASWELL	Gas Well		626	X-GAS
620	GL	Gas Line		620	X-GAS
622	GMETER	Gas Meter		622	X-GAS
661	JCTB	Junction Box		661	X-ELECTRICAL
662	PBOX	Pull Box		662	X-ELECTRICAL
640	PEDT	Pedestal Telephone		640	X-TELEPHONE
660	PEDTV	Pedestal Television		660	X-TELEVISION
621	PEL	Petroleum Line		621	X-PETROLEUM
644	PP	Power Pole		644	X-ELECTRICAL
665	PTP	Combination Pole		665	X-MISC_TOPO
605	PWL	Power Line		605	X-ELECTRICAL
650	SDL	Storm Drain Line		650	X-STORM
630	SL	Sanitary Sewer Line		630	X-SANITARY
606	SLP	Street Light Pole		606	X-ELECTRICAL
666	SP	Service Pole		666	X-MISC_TOPO
631	SSMH	Sanitary Sewer Man Hole		631	X-SANITARY
651	STMH	Storm Drain Man Hole		651	X-STORM
627	TANKPRO	Propane Tank		627	X-GAS
632	TANKSEPT	Septic Tank		632	X-SANITARY
641	TL	Telephone Line		641	X-TELEPHONE
642	TMH	Telephone Man Hole		642	X-TELEPHONE
643	TP	Telephone Pole		643	X-TELEPHONE
669	TRS	Traffic Signal		669	X-ELECTRICAL
623	VALVG	Gas Valve		623	X-GAS
612	VALVW	Water Valve		612	X-WATER
668	VP	Vent Pipe		668	X-SANITARY
614	WATFCT	Water Faucet		614	X-WATER
615	WATWELL	Water Well		615	X-WATER
610	WL	Water Line		610	X-WATER
611	WMETER	Water Meter		611	X-WATER
663	WX	Wire Crossing		663	X-ELECTRICAL
673	CATV	Cable Television		673	X-TELEVISION
674	COMMS	Communications Feature		674	X-ELECTRICAL
675	GVENT	Gas Vent		675	X-GAS
676	MBOX	Monitor Box		676	X-ELECTRICAL
677	TCAB	Telephone Cabinet		677	X-TELEPHONE
678	TRANS	Transformer		678	X-ELECTRICAL
679	TSCAB	Traffic Signal Cabinet		679	X-ELECTRICAL
680	VAULT	Utility Vault		680	X-UNKNOWN

Figure 2.6

InRoads Preference Files

The InRoads platform uses a preference file (*.XIN) to set various parameters for its commands and output. This file is used to control color, weight, linestyles, offsets, fonts, and various civil engineering-related values. NMDOT has created a standard initialization file for use by internal design sections and its consultants. The use of the NMDOT initialization file assures adherence to the NMDOT CADD standards for all project deliverables. The NMDOT has created several scales to be used in many of the commonly used commands/tools in InRoads. Only the Engineering Automation Bureau has the authority to make modifications to the initialization files provided by the NMDOT. Items discussed in this section:

- XIN File

XIN File

This file controls all aspects of InRoads settings and symbologies. The XIN file controls aspects such as Metric or Imperial units, significant digits displayed, and AASHTO values used to calculate curves, superelevations, etc (see figure 3.1). The XIN file also controls levels used, colors, weights, linestyles, offsets, and fonts used in the creation of profiles, cross sections, the display of features embedded in .dtms (see ***Section 4***). Within the XIN file are the settings for **Feature Styles and Symbologies**. These two components are used throughout the activated InRoads tools. The **Feature Styles** refer to the settings for items (e.g. the display of structures) in plan, profile, and cross section views. The **Feature Style** refers to symbologies defined in the **Symbology Manager**. The **Symbology Manager** controls plan, profile, and cross section views as well as the levels, colors, linestyles, and scales are being utilized for the element displayed.

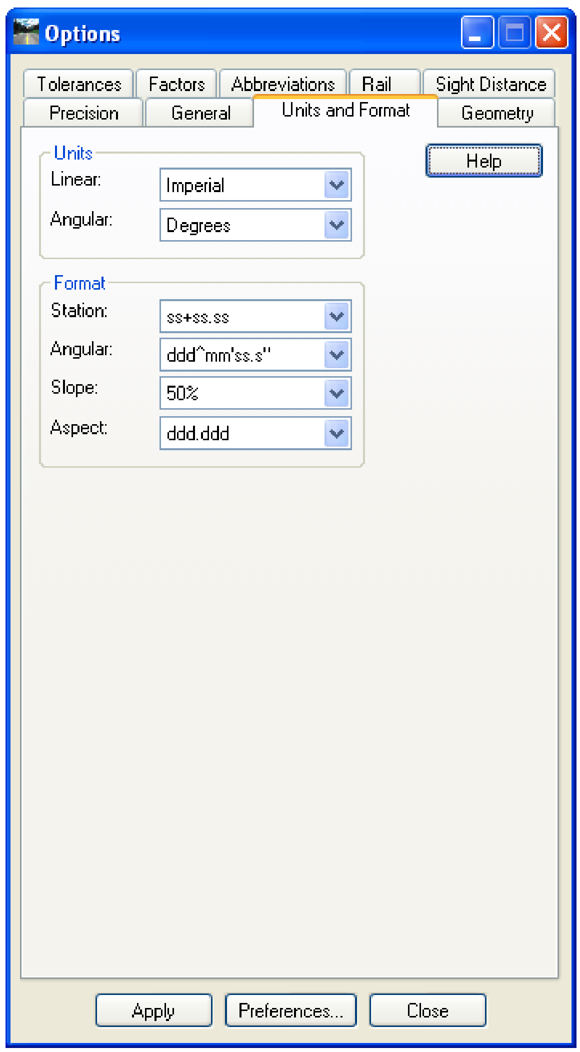


Figure 3.1

For information on loading preference files and commands, see the InRoads Help Reference Guide.

Each tool has specific scales, or preferences, based on the command and its normal use for NMDOT projects. The individual preferences can be accessed by selecting the **"Preferences"** button located in the command dialog box (see figure 3.2).

Typically, the preferences available are based on final plan sheet scales. Two notable exceptions to this standard are: superelevation commands and the Place Cross Section command. The superelevation commands are based on design speeds: 35 to 75 miles per hour (see figure 3.3) in 5 MPH increments. The **Create Cross Section** command only utilizes a 20 scale layout in portrait and landscape and also has a preference to place cross sections for volumes calculations with no sheet border. In most of the NMDOT activated commands, the "Default" preference contains the same properties as a proposed 100 scale preference. This duplication of properties is to help the end user avoid "accidental" use of non-standard preferences.

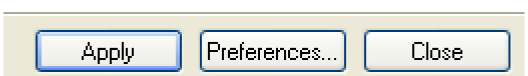


Figure 3.2

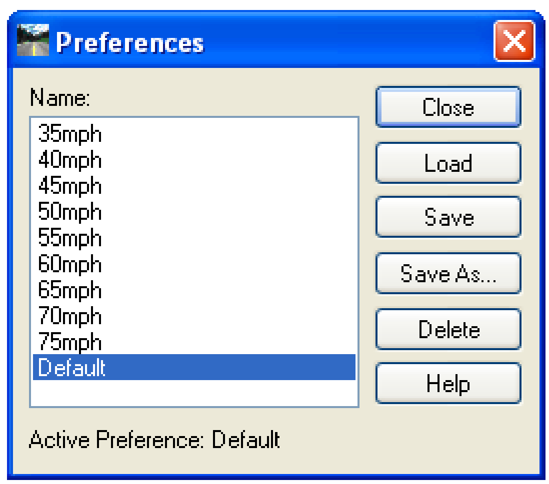


Figure 3.3

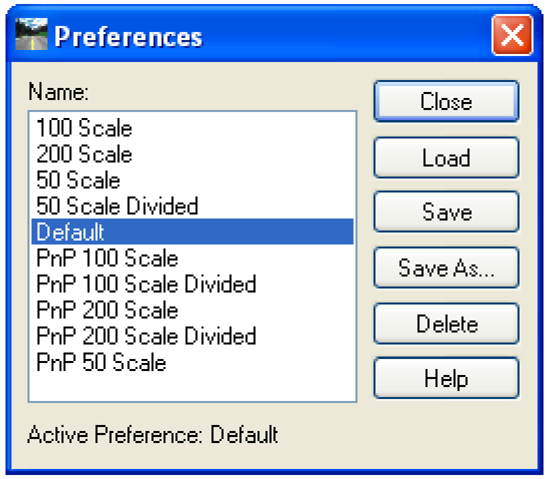


Figure 3.4

InRoads 8.5 Initialization files are not compatible with current NMDOT standards and should not be used with a NMDOT MicroStation/InRoads V8i project format.

Digital Terrain Models

Digital Terrain Models (DTM) are three dimensional objects which represent existing or proposed surfaces. DTM's consist of points or lines which represent survey shots, calculated points, or calculated breaklines. DTM's enable the engineering of projects in a computer environment, assuring accurate layout, elevation, and quantities when the project is constructed. Items discussed in this section:

- DTM Features
- DTM Symbology
- Naming Conventions

DTM Features

NMDOT has utilized intelligent DTMs since 2005. Intelligent features allow for the dynamic display and reporting of underground, at-grade, and over-head features found in any given project. Features used for NMDOT projects include all location survey points imported using the NMDOT preferences, existing drainage structures and transition control points created when creating a model of the proposed surfaces.

It is vital to the project that the NMDOT preference file be used when importing features into the existing surface and when running the **InRoads Modeler** command. The NMDOT preference file contains all prudent symbologies which are assigned to each feature when written into InRoads DTM's.

The location survey points are written to the existing DTM by using the **Survey Data to Surface** command. The features written to the surface contain the information from the feature table which is mirrored on the initialization files, thus allowing users to display the information at any time using the **View Horizontal Annotation** command.

The previous workflow placing existing/proposed drainage structures (e.g. CMC, CPC) has been standardized within the NMDOT. When placing drainage structures, the name used for each individual structure is the station where the structure crosses the centerline. The description used is as follows: the number of structures at that station, the length of the structure, the type of structure, and a short description to distinguish a "Normal" structure from an abnormal situation (e.g. 1x30" 76.38 CMC Silted East end). Along with the name and description of the structure, the "Feature Style" must be selected, the Point Type must be set to "Breakline", and the "Exclude from Triangulation" must be toggled (see figure 4.1).

Any description given to a structure can easily be identified by hovering over the element in MicroStation (see figure 4.2).

All symbology settings for drainage structures are based on a "top of pipe" shot and not an invert.

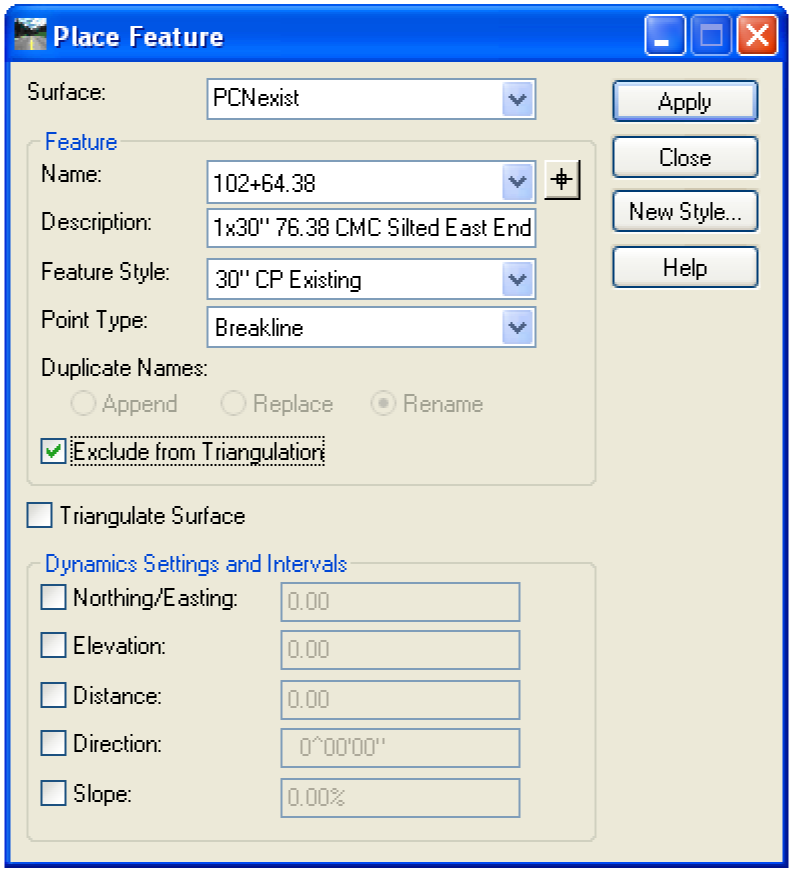


Figure 4.1

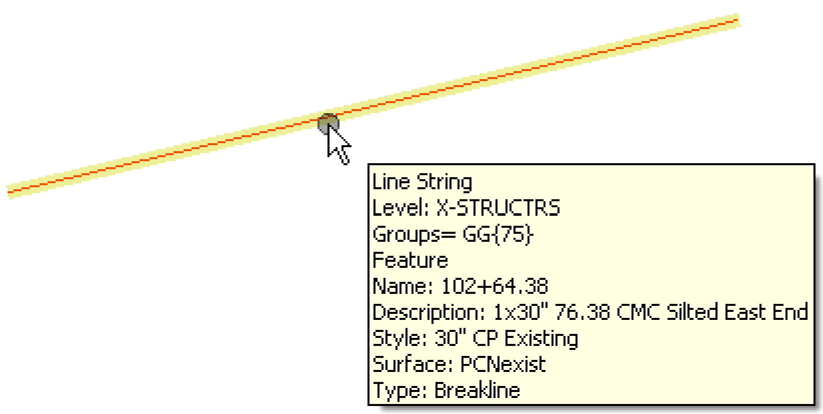


Figure 4.2

DTM Symbology

The NMDOT preference file has symbology settings to be assigned to InRoads DTM's based on the surface they represent. These symbologies must be assigned to all DTM's submitted to NMDOT. The default InRoads symbology assigned to all DTM's is "default". Unless modified, the "default" symbology uses the "default" level, weight, color, and style of '0'. The NMDOT Initialization files contain symbology setting for "existing", "top", "ogfc", "utbc", and "pmbp" to coincide with the NMDOT Template Library (see ***Section 7***).

Naming Conventions

InRoads data files identify two names: internal and file. The internal name is seen when the file is opened in InRoads through various commands or using the InRoads Explorer window (see figure 4.2). The file name is the name when viewed using Windows Explorer (see figure 4.3).

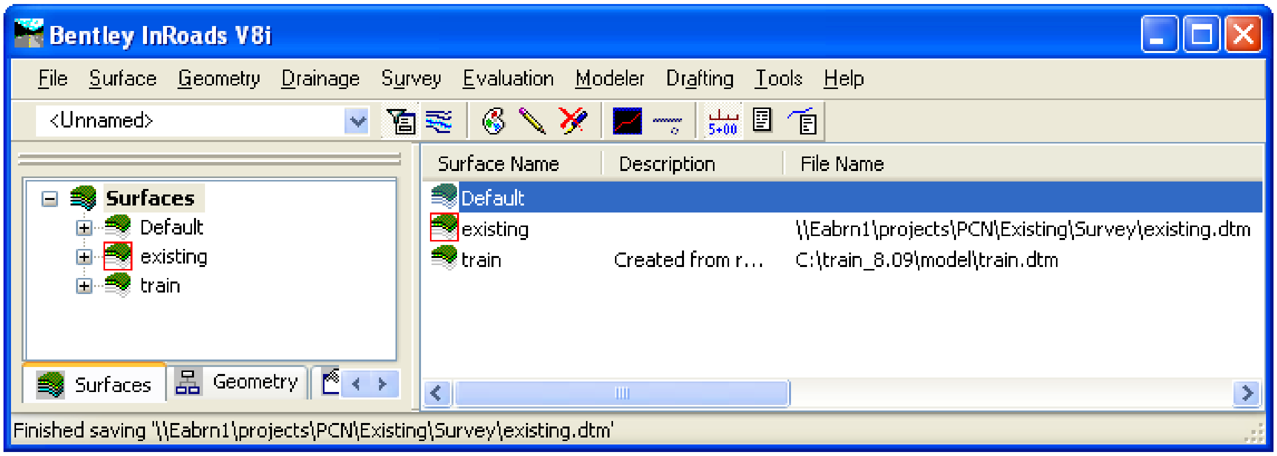


Figure 4.2

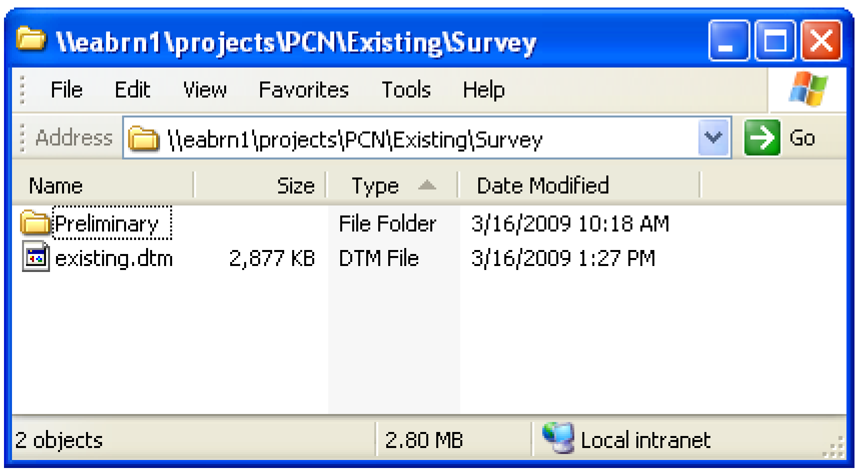


Figure 4.3

The surface number (NN) is optional only if one surface exists with the naming convention (e.g. PCNExist.dtm, PCNtop.dtm).

Existing	Proposed
PCNExisNN.dtm	PCNtopNN.dtm

Table 4.1

Upon completion of roadway modeling and the proposed surface(s), the internal and external names must be modified to coincide with NMDOT surface naming conventions.

Geometry

NM Department of Transportation has developed a standard for InRoads geometry elements such as horizontal and vertical alignments. It is important for all NMDOT projects to follow the standard naming conventions for geometry elements due to the interactivity of the NMDOT and its consultants during the design process. Adherence to these standards allows for reviews of data to be completed in an easier and faster manner. In many instances, multiple consultants will be involved in an NMDOT project, thus making a standard absolutely necessary. Item discussed in this section:

- Geometry Projects
- Horizontal Alignments
- Vertical Alignments

Geometry Projects

InRoads geometry projects are the "containers" for geometry elements (see figure 5.1) which are stored as files located on a server or local drive. All geometry elements (horizontal alignments, vertical alignments, and the COGO buffer) are stored in the geometry project.

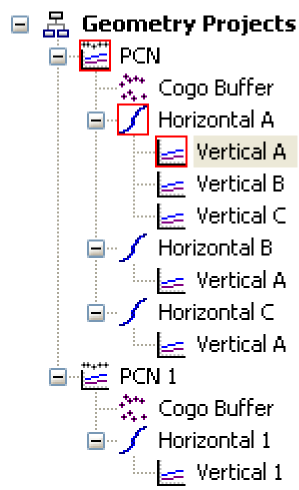


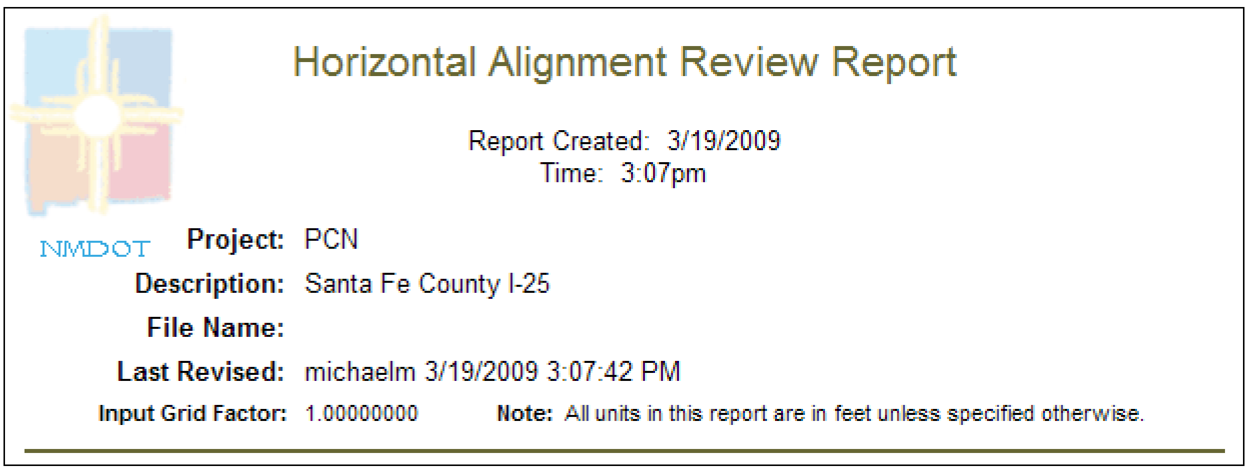
Figure 5.1

In the figure above, Horizontal A and Vertical A are the active alignments. This is noted by the red box encircling their respective icons. As seen above, it is possible to have multiple geometry projects open within the same session of InRoads, but each project name must be unique (see InRoads help guide for more information regarding Geometry Projects).

Naming Conventions

The NMDOT naming convention for geometry projects is segregated into two methods: existing and proposed. All proposed geometry project files are simply named with the project control number (PCN), unless multiple geometry project files are used. If multiple geometry projects are used, the use of alpha suffixes is mandatory (e.g. 3999A.alg) beginning with "A". All existing geometry project files follow the same naming convention with the sole exception of the use of "exist" following the PCN (e.g. 3999existA.alg).

Each geometry project must have an internal description assigned. The description must contain the County, or Counties, and the main route (see figure 5.2). This will aid consultants and internal design sections in identifying reports and projects in relation to geographic location.



Horizontal Alignment Review Report

Report Created: 3/19/2009
Time: 3:07pm

NMDOT

Project: PCN

Description: Santa Fe County I-25

File Name:

Last Revised: michaelm 3/19/2009 3:07:42 PM

Input Grid Factor: 1.00000000 **Note:** All units in this report are in feet unless specified otherwise.

Figure 5.2

All InRoads files (including .dtm, .ird, .itl, and .alg) are stored in the \data\ folder. A \data\ directory has been included for each of the following design sections: Aviation, Construction Signing, Drainage, Envrionmental, Roadwaydesign, Right of Way, Traffic, and Utilities (see NMDOT CADD Drafting Standards for more information on project directory structure). InRoads files for Bridge Design are to be saved to the \Bridge\Design\ folder.

Horizontal Alignments

The InRoads design package bases all civil designs on the use of horizontal alignments. Horizontal alignments are a series of curves and tangents which can represent roadways, intersections, ditch lines, right of way, retaining walls, breaklines, or any other linear feature found in a civil design. NMDOT's CADD Design Standards address the use of horizontal alignments as they represent all types of roadway centerlines. There are several methods for creating horizontal alignments. Some of the popular methods are the use of graphic elements in a MicroStation design file, importing an .xml file, importing an .ics file, use of COGO points, and the use of the InRoads Traverse command. NMDOT highly recommends the use of either COGO points by way of the InRoads Traverse or Locate commands. The use of the Traverse command to create horizontal alignments (see the InRoads Help for more information on the use of these commands) is also acceptable. By using the Traverse, or Locate commands, this enables the user to assign specific point numbers, use existing survey points, and ensures a spatially-correct alignment if based off of existing survey points.

NMDOT utilizes descriptive naming for horizontal and vertical alignments. Personnel names, temporary names, version names are not acceptable. NMDOT reserves the right to reject any InRoads geometry files containing non-acceptable naming conventions.

Station Equations

In some instances, a station equation is necessary. Station equations are often used to tie proposed alignments to existing stationing, or for detour alignments (see the InRoads Help for instructions on creating, editing, or deleting station equations). When a station equation is to be used, NMDOT standards require each station equation to be preceded with an Alpha character, beginning with "A". For each station equation, the Alpha character used will be incremental. NMDOT refrains from placing stations equations for every curve and requires its consultants to refrain from this practice as well.

For point numbers and their assignments, refer to the ***Survey Section*** of this document.

Vertical Alignments

InRoads assigns each vertical alignment to a horizontal "parent" alignment. NMDOT naming conventions for vertical alignments call for the horizontal alignment name followed by the letter "V" and a counter (see figure 5.3) separated by an underscore. The use of the counter is only necessary when more than one vertical alignment is associated with a horizontal alignment.

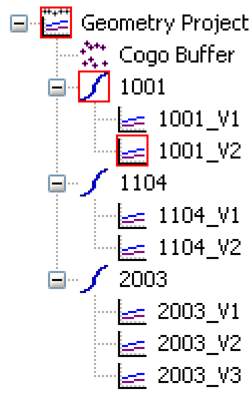


Figure 5.3

A description must be included with every vertical alignment created. The description should include the date the vertical alignment was created followed by a hyphen and the roadway the alignment is associated with (see table 5.3).

Name	Description
1001_V1	10/07/08 - I-25 mainline
2003_V2	01/04/09 – NB Frontage road
1104_V1	09/16/08 – South to West Ramp

Table 5.3

This Page Intentionally Left Blank

Profiles and Cross Sections

NMDOT has developed specific standards for the display of profiles and cross sections. Both profiles and cross sections allow for a three dimensional view of the project on a basic level. Along with displaying the existing and proposed geometry elements, profiles and cross sections are used with ROW location in regard to slope treatments, structure placements, and depths of material of the design. Items discussed in this section:

- Profiles
- Cross Sections
- Surface Features

Profiles

An InRoads profile is a longitudinal view of the existing ground and provides the engineering team an avenue to present the geometry for the new alignment. All profiles for NMDOT civil design projects must be based on a horizontal alignment and not MicroStation graphics. NMDOT has included specific parameters in the initialization files to be used for every NMDOT project. These parameters have been in use within the DOT for over 7 years and are included in the NMDOT initialization files (see figure 6.1).

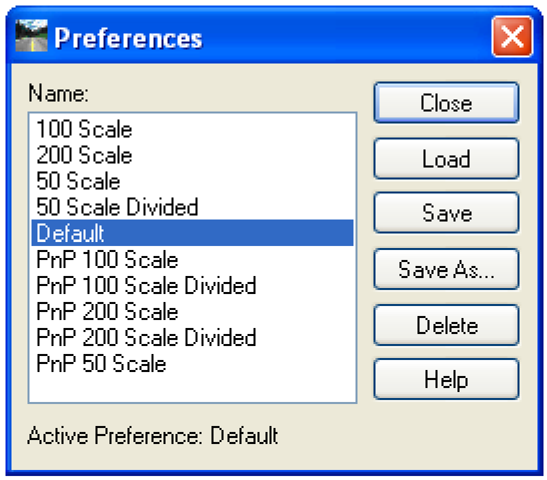


Figure 6.1

Existing and proposed structures are represented in profiles using cell libraries and custom linestyles. The display of these features is automatic in the NMDOT project workflow.

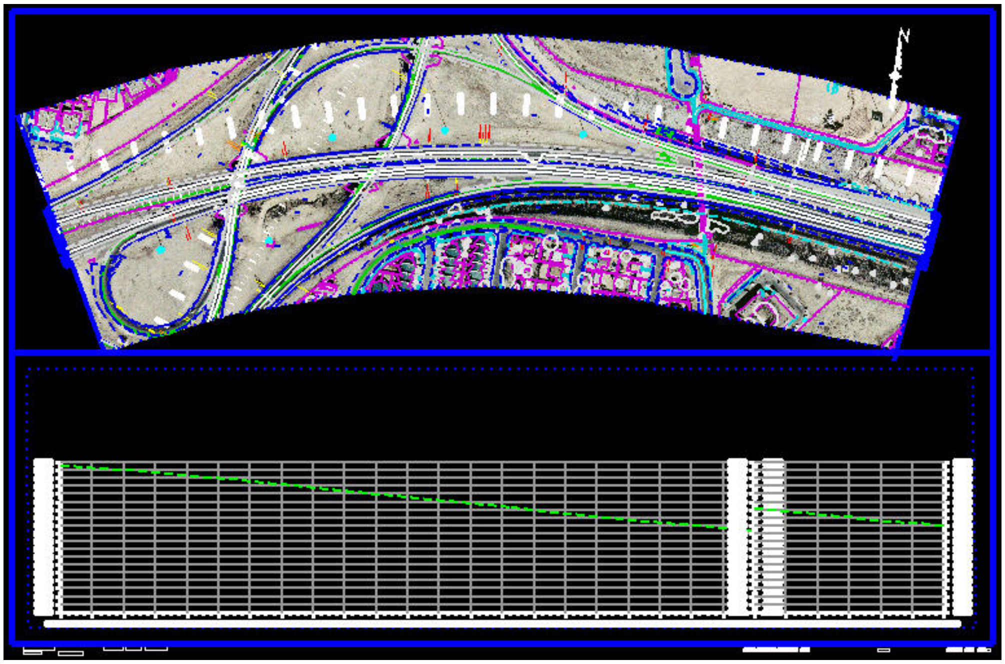
The profile sets are displayed in a specific file (see NMDOT CADD Drafting Standards for naming conventions and file locations) and are referenced into the project sheet files. The actual display of the project profile and information therein may vary from project to project (see table 6.1). The variance of profile sets is due to sheet scale and type of road represented by the profile.

Profile Scale/Name	Vertical Exaggeration	Major Ticks (stationing)	Minor Ticks per Major (stationing)	Right/Left Major Ticks (elevation)	Right/Left Minor Ticks per Major (elevation)
100scale (same as "default")	10:1	100'	3	5	1
200scale	10:1	100'	3	5	1
PnP_100 scale	5:1	100'	3	5	1
PnP_200 scale	5:1	100'	3	5	1
PnP_200 scale divided	2:1	100'	3	10	4
PnP_100 scale divided	2:1	100'	3	10	4

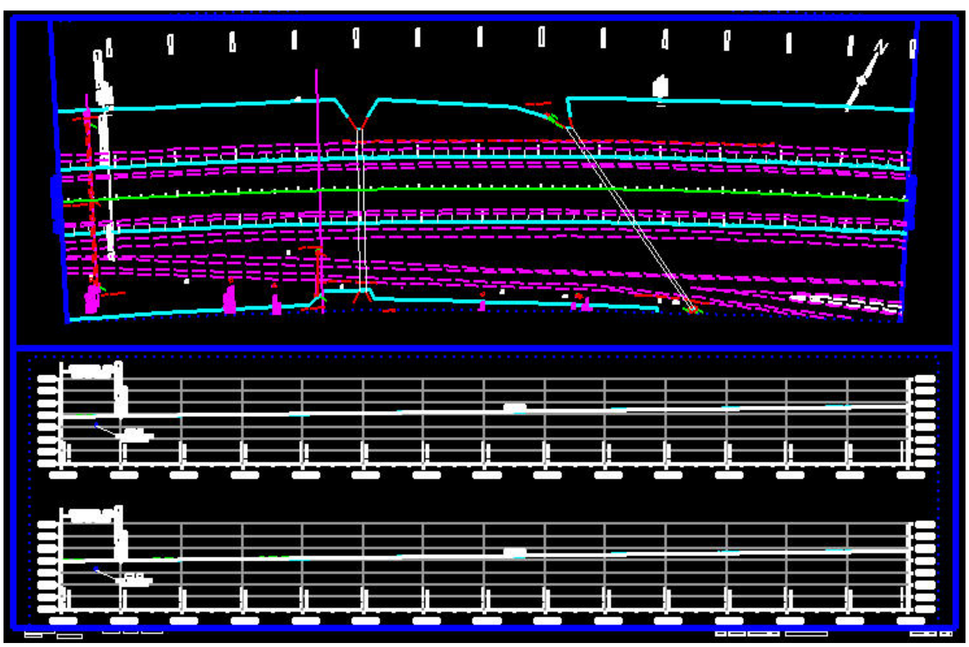
Table 6.1

The following images represent the profile InRoads "preferences" when based on the NMDOT Preferences:

PnP_200 Scale:



PnP_200 Scale Divided:



The “divided” preference is often used when the project entails a divided highway, i.e. an interstate. The 200 scale preference is used for rural projects, whereas the 100 scale preference is used for urban projects.

Please refer to the NMDOT CADD Standards for leveling and symbology standards for profile grids, axis, annotation, surface features, and all vertical alignment display properties.

Cross Sections

A cross section is a planar view of the roadway at a specific station. InRoads allows the display of multiple cross sections at a given interval along an alignment. Both existing and proposed surfaces can be displayed in a cross section along with ROW lines, centerlines, and drainage structures. NMDOT’s initialization files have four different preferences to be used. The preference used most often for submittals is “default”. This preference allows for the cross sections to be batch plotted. The variances in each of the preferences are due to the type of submittal and the recipient. The “default”, “structures”, and “portrait” preferences are designed to print at 20 scale on an 11”x17”.

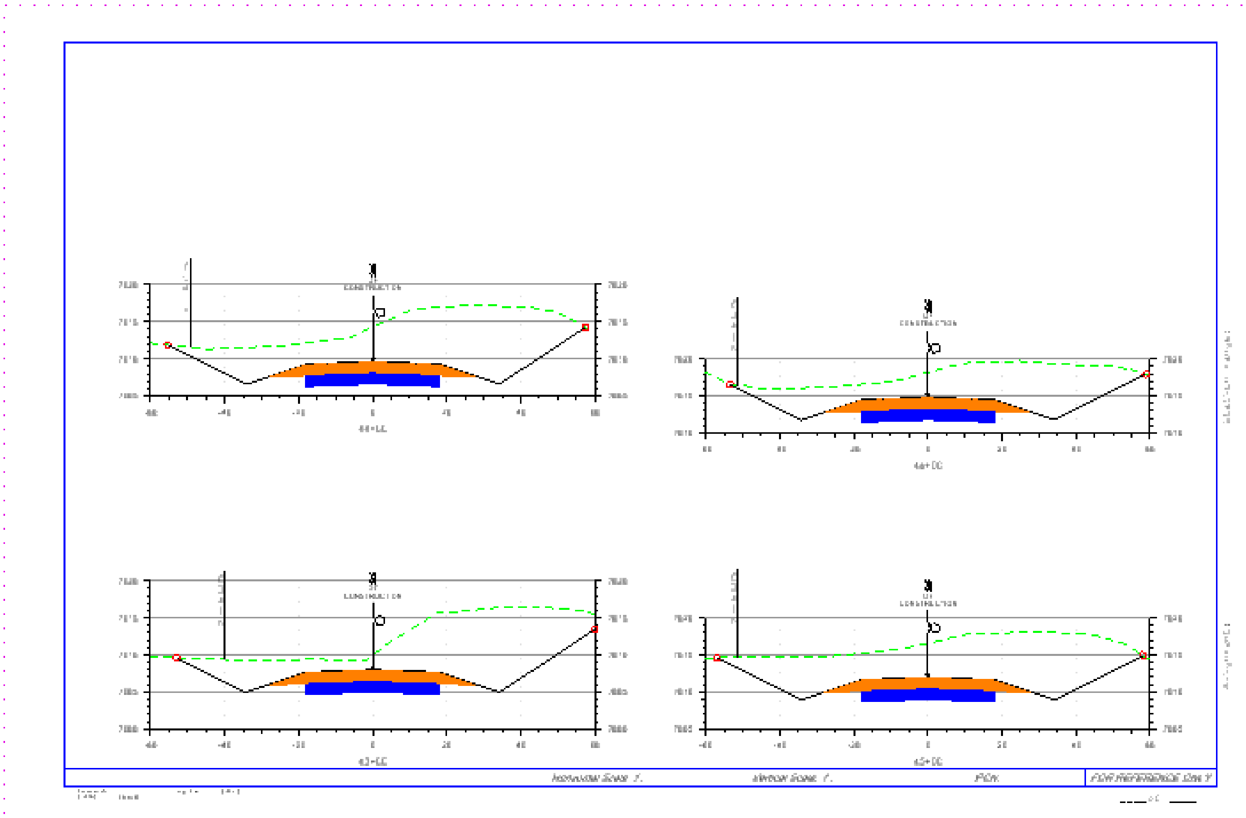
Preference Name	Vertical Exaggeration	Spacing	Major Ticks (offset)	Minor Ticks per Major (offset)	Major Ticks (elevation)	Minor Ticks per Major (elevation)
Default	2	Shape/ 340x220	20	3	5	4
20 Scale - Portrait	2	Cell/ Reference	20	3	5	4
20 Scale - Landscape	2	Cell/ Reference	20	3	5	4
volumes	2	stacked	20	3	5	4

Along with the existing and proposed surfaces, ROW callouts and centerline callouts should be included in all cross sections. ROW and centerline callouts are automatically included in each cross section as features of the existing surface (see ***Section 4*** for more information).

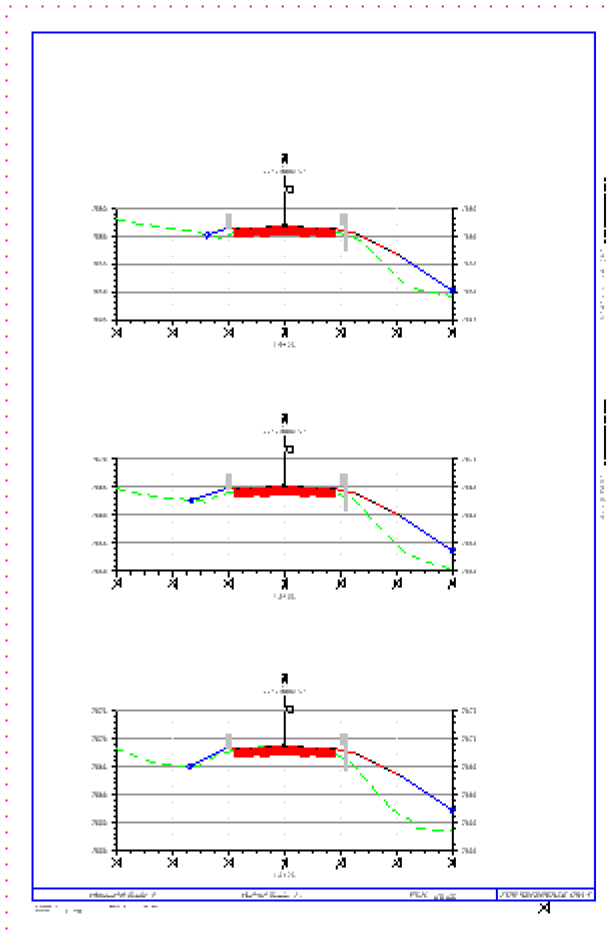
Please refer to the NMDOT CADD Drafting Standards for leveling and symbology standards for cross section grids, axis, annotation, and surface features display properties.

The following images represent the **Create Cross Section** InRoads "preferences" when based on the NMDOT initialization files:

Default:



Portrait:



This Page Intentionally Left Blank

Corridor Modeling

One of the strongest features of the InRoads platform is the ability to model the proposed surfaces using the existing surfaces as a basis. This feature is often referred to as "corridor modeling". NMDOT has provided standardized files to make corridor modeling easier for the user. Items discussed in this section:

- Template Library
- Corridors
- Model Editing

Template Library

NMDOT has provided a standardized template library for use by its designers and consultants. This library contains templates, and more importantly, a vast inventory of components. The components were designed to account for various design scenarios with little modification. Elements within each component coincide with the NMDOT initialization files and cell libraries. The template library consists of three templates:

Template Name	Description
Bridge 2-12' Lanes	Bridge Sections
Rural Recon 2-12' Lanes	Rural Interstate/Divided Roads
Urban-Recon 2-12' Lanes	Urban Reconstruction applications

The folder structure within the template library contains project folders for templates and components to be populated during the design of the project. It is recommended that the PCN in both folders be replaced with the actual project control number. NMDOT has embraced the use of components and strongly suggests the creation of the finish grade only and not surfaces representing the subgrades.

When the model is complete and the surfaces have been created, the renaming of the surfaces should occur based on the naming conventions set forth in ***Section 4*** of this document.

All templates created for any NMDOT project must contain the project control number followed by a short description of the template. The use of the description field is mandatory to enable information transfer to the DOT easier.

Name	Description
3999RampA	North to South ramp template

Excerpts from the InRoads template library report for each template have been included along with images of each template.

Roadway Libraries

In every roadway library, a corridor exists and is used in conjunction with a specific template library. Corridors are entities containing "template drops" at specific stations. Each "template drop" specifies which template is run from the station, at what interval, and how the template contributes to calculating "daylight points".

NMDOT does not provide a standardized roadway library due to the varying methods of implementing roadway libraries and projects. NMDOT does, however, have a naming convention for the library file and internal roadways.

NMDOT naming conventions for the roadway library consists of the project control number and resides in the \Data\ directory. Each roadway within the library must contain the route/road the roadway applies to and a counter if more than one roadway is used for the route/road. The description must contain the route/road, quadrant (if applicable), and the station range covered by the roadway.

Name	Description
I25_North	I25 North bound from station 200+50 to 375+25
ExitRamp100	North to West ramp

Model Editing

NMDOT does not recommend post-model editing (i.e. editing surfaces in cross sections), however, it may be necessary to make such modifications (see the **InRoads Help** for more information). If these types of modifications are made to proposed surfaces, NMDOT requires the description of the surface edited to be modified to reflect the type of change made.

Surface Name	Description
3999top	Surface edited to include retaining barrier station 5+11 to 6+07
4125top	Surface edited station 10+00 to 12+40 to warp slope for ROW

This Page Intentionally Left Blank

Reports

The InRoads application has many reports to aid the user in acquiring necessary documentation for alignments, surfaces, volumes, etc. Along with simple reports (i.e. horizontal alignment report), InRoads offers more complex reports including End-Area Volume Reports. Items discussed in this section:

- Reports
- Naming Conventions

Reports

InRoads reporting method is strictly .xml-based. NMDOT has identified the many benefits of using .xml-based reporting such as customizable reports. All customized reports will be made available to NMDOT employees as well as its consultants. All customized XML style sheets will be posted to the NMDOT website when they become available and will include a short description and instructions for use. All custom style sheets are included in the consultant workspace.

Naming Conventions

All reports to be retained indefinitely must meet the NMDOT criteria for naming conventions and stored in the \Data\ directory. All reports must have the project control number, a short descriptive name, and a counter if more than one report exists.

Report Type	Name
Horizontal	3999horiz.html
Vertical	3999vert2.html
End Area Volume	2512end_area_vol.html

APPENDIX C

Visualization for Right-of-Way Acquisition

FINAL
October 2011

Prepared for:
U.S. Department of Transportation
Office of Planning, Environment, and Realty
Federal Highway Administration

Prepared by:
U.S. Department of Transportation
Research and Innovative Technology Administration
John A. Volpe National Transportation Systems Center

Acknowledgements: The U.S. Department of Transportation John A. Volpe National Transportation Systems Center (Volpe Center), in Cambridge, Massachusetts, prepared this report for the Federal Highway Administration's (FHWA) Office of Real Estate Services. Carson Poe, of the Multimodal Systems Analysis Center of Innovation led the project team, which consisted of Sharon Chan Edmiston and David Perlman, also of the Multimodal Systems Analysis Center of Innovation, and Kirsten Holder of MacroSys.

The Volpe Center project team wishes to thank the numerous stakeholders, listed in Appendix A, who kindly provided their time, knowledge, guidance, and comments in completing this study. The project team would also like to thank Rich Coco, the FHWA project lead for this effort, for his guidance in selecting stakeholders to interview and developing the report.

Contents

List of Figures

List of Tables

List of Acronyms

2-D	Two-dimensional
3-D	Three-dimensional
4-D	Four-dimensional
AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
CAD	Computer-aided design
Caltrans	California Department of Transportation
DOTs	Departments of Transportation
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GTC	Genesee Transportation Council
IT	Information Technology
MPOs	Metropolitan planning organizations
Mn/DOT	Minnesota Department of Transportation
MoDOT	Missouri Department of Transportation
NCDOT	North Carolina Department of Transportation
NCHRP	Construction Sciences Research Foundation
NEPA	National Environmental Policy Act
NIST	The National Institute of Standards and Technology
NYSDOT	New York State Department of Transportation
ODOT	Ohio Department of Transportation
PDG	Project Development Guide
ROW	Right-of-way
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SHPO	State Historic Preservation Office
TRS	Transportation Research Services, Inc.
The Uniform Act	The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970
VTrans	Vermont Agency of Transportation
WYDOT	Wyoming Department of Transportation

Executive Summary

The use of visualization technologies and techniques by State Departments of Transportation (DOTs), especially for public involvement purposes, is well-documented. A 2006 Federal Highway Administration (FHWA) scan of transportation agencies, however, showed that visualization use during the right-of-way (ROW) acquisition process of transportation project delivery is not as common, despite the potential benefits. This report identifies some of the reasons, while exploring how select state DOTs have applied, or are applying, visualization to facilitate ROW acquisition. The study synthesizes and presents the findings from a literature review, as well as a series of phone discussions with stakeholders who expressed interest in using visualization technologies to enhance the ROW acquisition process. It is expected that transportation officials will use this information to improve and facilitate their own transportation ROW acquisition processes and outcomes.

Key findings include:

- The ways that ROW practitioners at state DOTs are introduced to visualization varies, leading to (1) a broad range of visualization techniques used, (2) differences in terminology, and (3) varying levels of awareness about visualization opportunities among disciplines.

- ROW practitioners who have incorporated visualization into the ROW acquisition process have experienced a number of benefits that have generally outweighed the costs associated with developing the visualization presentations. Some of the frequently expressed benefits are:
    - Better communication with property owners and other stakeholders about project impacts, thus potentially lowering condemnation rates;
    - Reduced acreage of land to be acquired; and,
    - Potential cost savings through reduced litigation and associated condemnation fees or damages.

- Use of visualization for ROW acquisition has likely not been as widespread as in other stages of transportation project delivery because:
    - Historically, ROW practitioners have had limited awareness of visualization's potential uses in the ROW acquisition process;
    - Visualizations have been perceived as costly to produce or only useful for complex projects;
    - Some state DOTs lack the internal resources (staffing, funding, or hardware/software) to develop and display visualizations; and,
    - There are concerns that visualization presentations might not exactly replicate the look of the actual project, thus potentially damaging public perception.

In addition to these findings, the project team learned about cost saving methods for ROW staff to expand use of visualization during ROW acquisition. The following recommendations, which are among several others reported in Section 4, are intended to help ROW staff overcome barriers to visualization use, and ultimately better identify and capitalize on opportunities.

- Develop an understanding of what "visualization" can mean in the ROW acquisition context and then market the various techniques within ROW offices.

- Spread the cost of visualization development among the various disciplines of transportation project development.

- Make laptop computers and media software available for mobile use in the field, when possible.

- Create a standard method for gathering feedback on, and evaluating the benefits of, using visualization for ROW acquisition to help strengthen the case for its use.

1. INTRODUCTION

This research explores the ways that select State Departments of Transportation (DOTs) have used visualization technologies and applications to facilitate the right-of-way (ROW) acquisition process. Best practice applications of visualization given certain ROW acquisition situations are identified, along with effective strategies for seamlessly incorporating visualization into the ROW acquisition process. Transportation officials will be able to use this information to improve and facilitate their own transportation ROW acquisition processes and outcomes.

1.1 Background

In 2006, FHWA conducted a domestic scan on right-of-way (ROW) acquisition and utility relocation. During the scan, FHWA learned that a few state DOTs were beginning to test the idea that visualization could be a valuable tool to use in the ROW acquisition process. Specifically, Florida DOT (FDOT) showed examples of where it had overlaid aerial photographs with computer-aided design (CAD) drawings, and Minnesota DOT (Mn/DOT) had used three-dimensional (3-D) videos to show property owners the potential impacts of highway improvements to surrounding properties (Cambridge Systematics 2006). Two years later during an international scan of ROW practices, FHWA identified similar applications of visualization at transportation agencies in Australia (FHWA 2008). There, visualization was used to communicate a project's ROW requirements and impacts to property owners and relevant stakeholders to help avoid or mitigate the costs of eminent domain court proceedings.

Based on these examples, as well as a growing belief that there are significant benefits to using visualization techniques in the ROW acquisition process, in 2009 the American Association of State Highway and Transportation Officials (AASHTO) surveyed all state DOTs to elicit basic information about their experiences using visualization to facilitate ROW acquisition.[1] The responses indicated that the use of visualization technologies for ROW acquisition purposes is currently much less prevalent than its use in other areas of highway project delivery.[2] With that said, some of the respondents mentioned they could foresee advantages of expanding visualization's use to the ROW acquisition practice, and most were interested in learning more about what their peers had been doing in this area.

1.2 Purpose and Methodology

This report is intended to identify and disseminate information about the pros and cons of utilizing visualization for ROW acquisition, as well as potentially effective practices for doing so. The research is based on phone discussions[3] with transportation agency stakeholders who indicated previous experience with using visualization for ROW acquisition. Several consultants with experience developing visualizations for transportation agencies were also contacted for their input; they were selected based on information and suggestions gathered from the FHWA and the DOT interviewees. Phone discussions were held from May through June 2010 and included both ROW and visualization professionals from:

- California Department of Transportation (Caltrans)
- FHWA Resource Center
- Florida Department of Transportation (FDOT)
- Minnesota Department of Transportation (Mn/DOT)
- Missouri Department of Transportation (MoDOT)
- New York State Department of Transportation (NYSDOT)

---

[1] For these purposes, "ROW" refers to the land a roadway and any related facilities occupy.
[2] See Appendix E for the AASHTO survey and responses received.
[3] A list of stakeholders interviewed is included in Appendix A. The calls followed the discussion guide included in Appendix B. The project team tailored the discussion guide to each participating stakeholder, as appropriate.

- North Carolina Department of Transportation (NCDOT)
- Office of the Attorney General of Texas
- Ohio Department of Transportation (ODOT)

Questions focused on the history of visualization use at the agency, the benefits—perceived or real—of doing so, and barriers associated with more fully using visualization for ROW acquisition, among other topics.[4] Where possible, the project team collected quantitative data on the costs and savings associated with using visualization for ROW acquisition. Property owners were not interviewed for this research.

Additional information on the uses of visualization was obtained through a review of literature and documentation collected from interviewees, other state DOTs, and several visualization vendors throughout the research process. The project team then synthesized phone discussion notes and relevant supplemental information collected to formulate the challenges, lessons, and recommendations described below. The report results should inform the development of guidelines for how DOTs and other transportation agencies can incorporate visualization into the ROW acquisition process.

Example Visualizations:

Choosing Visualization for Transportation
http://choosingviz.org/

Eastern Federal Lands Highway Division Design's visualization website
www.efl.fhwa.dot.gov/technology/dv.aspx

Florida DOT Casselberry Interchange Visualization
http://fhwa.ccr.buffalo.edu/case_study_casselberry.html

Mn/DOT Visualization Services
www.dot.state.mn.us/visualization/

NCDOT's Enterprise Visualization website
www.ncdot.org/it/visualization/

NCDOT Example Visualizations
www.youtube.com/view_play_list?p=7EA152FF8EAF0184

NYSDOT's Project Visualizations for the I-87 Exit 6 Bridge Replacement
www.nysdot.gov/regional-offices/region1/projects/i87-exit6/photos

TRB's Visualization in Transportation Committee website www.trbvis.org/MAIN/TRBVIS_HOME.html

[4] See Appendix B for the complete phone discussion guide.

2. WHAT IS ROW ACQUISITION AND VISUALIZATION?

ROW acquisition is a process that involves obtaining necessary property rights for a transportation project when an existing ROW cannot accommodate the planned expansion of an existing facility or the construction of a new facility. In some cases, the process can be controversial, expensive, or time consuming. Visualization can serve as an effective aid to the ROW acquisition process, improving its predictability (e.g., potentially fewer legal disputes) and better informing property owners, while accelerating the overall project delivery process. This, in turn, could enhance the negotiation process, potentially reducing the likelihood of condemnation. This report examines some cost generalities as well as the relative benefits of using visualization in the ROW acquisition process. The following section introduces ROW acquisition (section 2.1), visualization (section 2.2), and how visualization can be a tool throughout the transportation project delivery process (section 2.3).

2.1 ROW Acquisition

When ROW is required for an existing facility, or the construction of a new facility, an agency owning a public road may acquire any necessary property. ROW acquisitions must adhere to the U.S. Constitution's Fifth and Fourteenth Amendments, which prevent private property from being taken for public use without just compensation. The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (the Uniform Act), as amended, establishes standard procedures and requirements for any agency using federal funds to acquire ROW, to ensure that property owners experience the protection that the Fifth Amendment provides. These provisions, together with state-specific requirements and statues, guarantee fair and timely compensation for any property acquisition.

The provisions emphasize acquisition through negotiation rather than condemnation, which is the formal application of eminent domain to transfer a property title from its private owner to the government. The ROW acquisition process can be very expensive, time consuming, and potentially controversial—all concerns given the Federal government's commitment to provide due process and just compensation, acquire property without delaying public projects, promote public confidence in Federal and federally-assisted land acquisition programs, and ensure that public dollars are spent appropriately.

ROW acquisition activities typically span several stages of the project delivery process, beginning in planning and extending into environmental review, design, and during and after construction. These activities can be divided into five basic steps, each of which can benefit from the use of visualization: [5]

1. **Planning**. A transportation agency may initially identify the general need to acquire property during the planning stage. Public meetings, notices, and correspondence are ways agencies may communicate this need. Specific property needs will not be identified until after the National Environmental Policy Act (NEPA) process is completed.

2. **Appraisal**. The term "appraisal" means a written statement that a qualified appraiser independently and impartially prepares to set forth an opinion of defined value of an adequately

[5] The entire process and requirements are articulated in 49 CFR 24 Subpart B "Real Property Acquisition," which can be found at www.fhwa.dot.gov/legsregs/directives/fapg/cfr4924b.htm. The FHWA Project Development Guide is also a useful reference for the highway ROW acquisition process and includes information on relevant laws, policies, and best practices for ROW acquisition. It is available at www.fhwa.dot.gov/realestate/pdg.htm.

described property as of a specific date. The appraisal is supported by the presentation and analysis of relevant market information.

Once a transportation agency expresses interest in acquiring property, and before the initiation of negotiations, the agency must establish an amount that it believes is just compensation for the real property. To do so, an appraiser will inspect the property to determine its fair market value, an estimate that must be supported in the appraisal. The Uniform Act requires that property owners or designated representatives be given the opportunity to accompany the appraiser during the property inspection. This allows property owners to identify any features that might affect the appraised value, and assists the appraiser in locating features of the property that are not immediately obvious. Just compensation shall not be less than the approved appraisal of the fair market value of the property, taking into account the value of allowable damages or benefits to any remaining property.

Once ROW practitioners establish and review an estimate of just compensation, the Uniform Act requires that the Agency, as soon as feasible, notify the owner in writing of the Agency's interest in acquiring the real property and the basic protections provided to the owner by law. The appraisal process provides another opportunity for ROW practitioners to be in contact with landowners. Properties are reviewed, offers are made, and negotiations can follow.

3. **Acquisition**. After receiving an offer, a property owner may accept its terms or proceed to the negotiation phase. If negotiations fail to resolve any differences between the agency and the property owner in a timely manner, the acquiring agency may choose to authorize an administrative settlement. If all efforts by the acquiring agency fail to result in a negotiated acquisition, agencies are permitted to rely on their power of eminent domain by filing a condemnation case. Through condemnation proceedings, a jury determines the appropriate level of compensation. Alternatively, if a property owner determines that an acquisition has occurred when the responsible agency did not formally acquire property, the owner may file an inverse condemnation lawsuit in order to receive just compensation for the alleged uncompensated acquisition.

4. **Relocation Process**. If the acquisition of ROW requires that occupants relocate, the Uniform Act outlines benefits and protections for residents, businesses, or personal property that are displaced. These benefits and protections include payments for moving expenses, payments for replacement housing, standards for replacement housing, and the availability of relocation planning and advisory services.

5. **Property Management**. With property acquired and its occupants relocated, the acquiring agency is responsible for managing the property and moving, selling, or demolishing any improvements to the property.

2.2 Visualization

Visualization is any process, technique, or method used to convey complex technical information in a comprehensible, dynamic, visual manner. Generally, information is compiled from photographs, maps, geographic information systems (GIS), computer-aided design (CAD) software, and other resources and then combined with computer graphics to create accurate depictions of what a place might look like after changes are implemented. Visualization tools include:

- Sketches, drawings
- Artist renderings
- Maps
- Physical models

- Simulated photos
- Computer-modeled images
- Videos
- Interactive GIS
- GIS based scenario planning tools
- Photo manipulation
- Computer simulation
- Interactive 3-modeling

Although these techniques range in level of technological sophistication required (visualizations increasingly involve the use of computer-based tools and display methods), they share a major similarity: each provides a method for graphically presenting the potential impacts of a proposed project on the existing conditions around the project. All of the tools can effectively communicate before and after site conditions, specific project designs and details, or impacts to a project area. [6]

For the purpose of this report, the project team used the terms *visualization*, *visualization technology*, and *visualization technique* synonymously. The team also differentiated between "traditional" and "advanced" methods of visualization, though the term "traditional" should not suggest that advanced skills or expertise are not needed to develop them. For these purposes, "*traditional visualization*" refers to two-dimensional (2-D) images or three-dimensional (3-D) models that can usually be created without highly specialized computer hardware, software, or expertise. In this study, "*advanced visualization*" means any computer-generated visualization that displays information in at least three dimensions. Some advanced visualizations are four-dimensional (4-D), with "time" being the fourth dimension represented. Advanced visualization typically involves the addition of "realism" to the presentation, including the display of people, vehicles, and textures, such as what the pavement or vegetation might look like.

2.3 Potential Uses of Visualization in Transportation Project Delivery

Transportation agencies have used visualizations in a variety of ways, especially in light of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) requirement that state DOTs and metropolitan planning organizations (MPOs) employ visualization techniques to facilitate public involvement the planning phase of project delivery. Recently, state DOTs have cited improved public involvement as one of the primary reasons for developing visualizations (NCHRP 2006 and FHWA 2009). Other common applications of visualization in transportation are for alternatives analysis, environmental review, and design evaluation (Volpe Center 2007 and 2009).

Historically, use of visualization in the ROW acquisition practice has been less prevalent or has focused on traditional techniques, such as 2-D graphic images and overlays of roadway engineering and ROW plans on aerial photographs. In cases where advanced visualizations have been used, ROW officials have found that the same hardware and software used to create visualizations for other stages of transportation project delivery (and often the same visualizations) can be used for ROW acquisition purposes—potentially opening the door for visualization cost-sharing agreements among disciplines. Figure 1 summarizes some of the current uses of visualization throughout the transportation project delivery process. As shown, there are also opportunities for visualization use during each stage of the ROW acquisition process, such as in ROW planning, appraisal, acquisition, relocation process, and property management.

---

[6] For more information see FHWA's Visualization in Planning website at www.fhwa.dot.gov/planning/vip/index.htm. Additionally, the January/February 2010 issue of *Public Roads* (www.fhwa.dot.gov/publications/publicroads/10janfeb/02.cfm) offers more information on 3-D, 4-D, and dynamic (animated or real-time simulation) technological tools for design visualization.

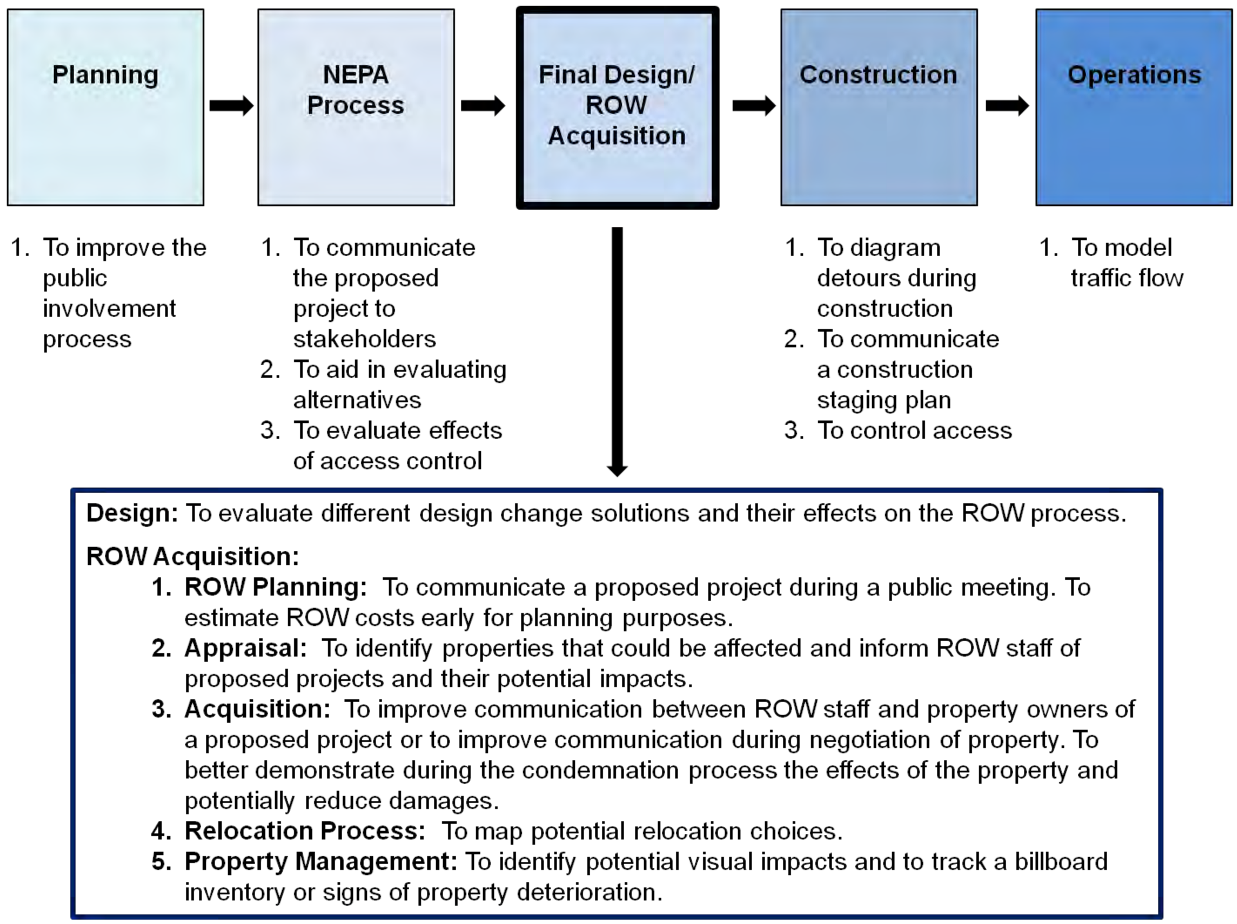


Figure 1. Potential uses for visualization throughout the transportation project delivery process. There are opportunities for any ROW acquiring agency to use visualization throughout project delivery, including the planning, the NEPA process, final design, ROW acquisition, construction, and operations phases. There are often opportunities for transportation agency personnel to use visualizations created for one stage of project delivery for other stages as well. The base data (ground photography, aerial images, etc.) used to develop a visualization are often useful to practitioners in disciplines other than those for which the visualization was initially developed.

Table 1. Examples of Traditional and Advanced Visualization Techniques

	Visualization Tools	Description	Relative Cost
Traditional visualization (“low-tech” visualization)	2-D graphic image	A graphic representation rendered by hand or with a computer. Two-dimensional graphic images include sketches, drawings, maps, or artist renderings.	Lower cost
	2-D graphic overlay	A transparent graphic representation overlaid onto another graphic image with a computer. Two-dimensional graphic overlays include simulated photos and maps or plans overlaid with aerial photography.	Lower cost
	Physical model	A physical model, typically constructed by hand and that can be physically manipulated, that depicts an existing condition or a proposed change. Physical models are portable, easily manipulated, and a tactile visualization alternative to electronic media.	Moderate to higher cost
Advanced visualization (“high-tech” visualization)	Interactive 3-D (virtual-reality) model	A computer-generated virtual-reality 3-D surface model in which any location and view can be navigated to interactively by the user. The interactive 3-D model can be a simple wireframe or a textured “mesh” surface. Photographic images can be draped on the surface, and above-ground features can be added into the model. Modeling tools are integrated within common CADD programs allowing simple 3-D models to be generated at low to moderate cost. The 3-D models can be imported into Adobe Acrobat 3-D PDF documents and navigated interactively using tools within Adobe Reader. The 3-D models can also be imported into global map viewing programs such as Google Earth.	Low to moderate cost for simple models; higher cost for more complex
	3-D image or video	A rendered graphic image that depicts several angles, or perspective views, of a proposed change. Three-dimensional images or videos include animations, computer-modeled images, interactive GIS, photo manipulations, and computer simulations. Specialized software can add effects and elements of realism, such as lighting, perspective, and shading.	Higher cost
	4D video, or computer animation	A series of closely spaced 3-D graphic images of a surface model following a designated orientation and path and joined to create a moving image. Four-dimensional videos include the passage of time. These tools are used to simulate the dynamics of traffic operations and transportation facilities in actual service from a road user’s perspective.	Highest cost

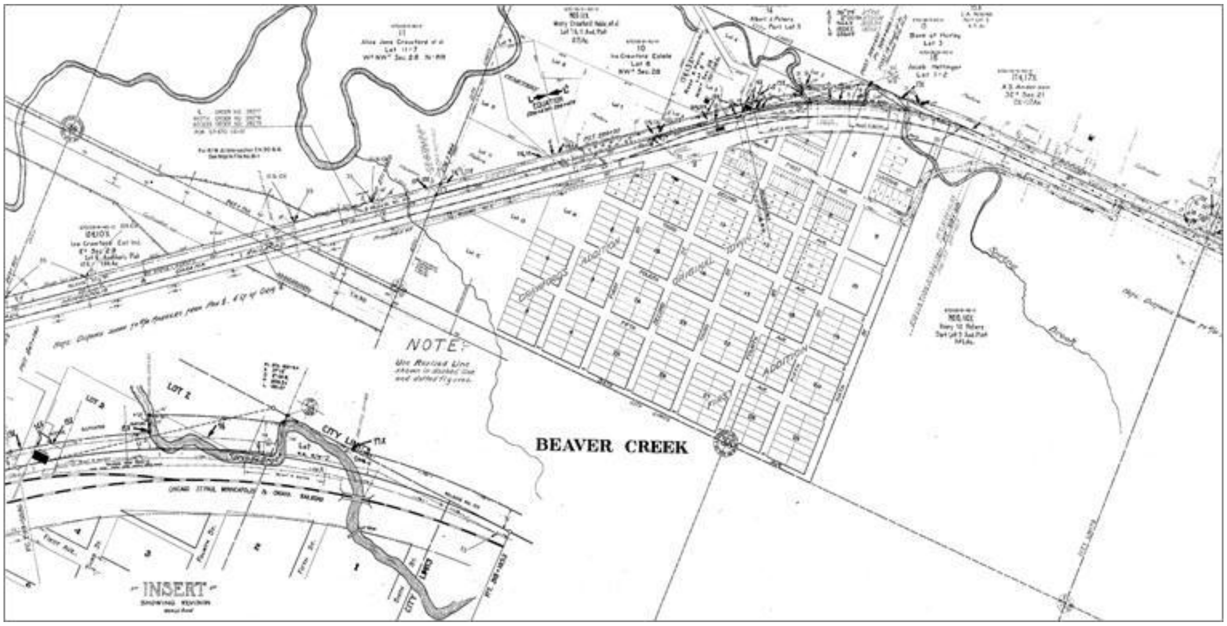


Figure 2. Traditional Visualization: **2-D Graphic and 2-D Overlay**
Black and white ROW plan drawing (top), Source: Mn/DOT. A color aerial photograph with a ROW plan overlaid in a GIS software program. On the ROW plan, one edge of the road pavement has been manually marked in the GIS with a green dot; a transect perpendicular to the road has been manually drawn in the GIS with a red line between the DOT's property lines, which have also been manually drawn in blue (bottom), Source: USDOT Volpe Center.

Figure 3. Advanced Visualization: 2-D Graphic with a 3-D Overlay
Aerial photo and plan drawing with 3-D model components of proposed infrastructure. Source: FDOT.

Figure 4. Advanced Visualization: 3-D Image or Video
Photo simulation of proposed overpass condition on I-87 in New York (top), Source: NYSDOT.
Existing and proposed conditions in a 3-D split-screen, fly-over visualization (bottom), Source: NCDOT.

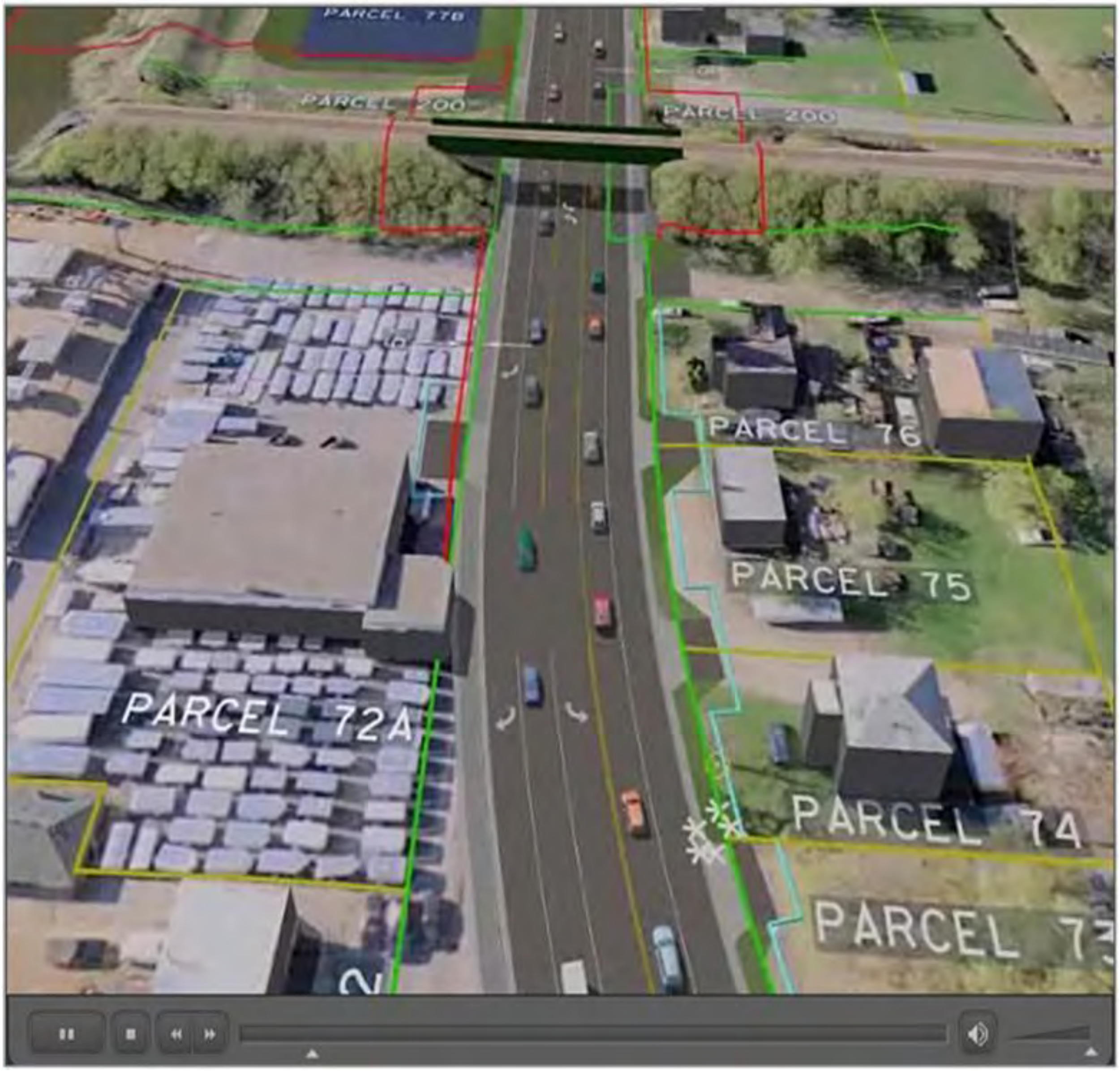


Figure 5. Advanced Visualization: 4-D Video
Screenshot from a 4-D video for US Highway 12 pilot project in Minnesota. The video includes parcel data, highway and building images, roadway infrastructure, and moving vehicular traffic. Yellow lines represent parcel boundaries; green lines represent existing ROW boundaries; red and blue lines represent future ROW boundaries after acquisition. To see the video, visit www.dot.state.mn.us/visualization/. Source: Mn/DOT.

Table 2. Example Visualization Software Programs*

ArcGIS	Family of programs that is used to compile, manage, analyze, and display geographic information; allows the user to create and store many layers of geographically-related information.[7]
AutoCAD	Used to build 2-D plans and 3-D structures with exact measurements to create 3-D computer-modeled visualizations.
CommunityViz	CommunityViz is GIS software designed to help users visualize, analyze, and communicate about important community planning decisions.
CORSIM	"Corridor Simulation Model" developed by FHWA; micro-simulation program commonly used for modeling vehicle traffic operations.
Google Earth	Google Earth is a virtual globe, map, and geographic information program that displays satellite images of varying resolution of the Earth's surface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle, with perspective. Google Earth offers a "street view" perspective for many roads, allowing users to view locations as they would appear in person at the location being viewed.
Microstation	MicroStation is a CAD software product for 2- and 3-D design and drafting, developed and sold by Bentley Systems.
PARAMICS	Software program used to model the movement and behavior of individual vehicles and transit on local arterial and regional freeway networks.
PDF (Adobe)	File format to view, package, and share 2-D and 3-D design data. A 3-D PDF provides an image view that allows users to rotate, zoom, and pan an object within the PDF file itself (which may be accompanied in the same file by 2-D text or images).
Photoshop (Adobe)	Photo-editing software program used to alter and enhance raster images (photographs, 3-D model stills, illustrations, scans, etc.); used to incorporate stills from 3-D models into photographs.
SketchUp	2-D and 3-D modeling program that lacks the photo-realistic end result of 3-D Studio MAX but allows for experimentation.
SYNCHRO and **SimTraffic**	Software suite, with some animation capabilities, used to analyze transportation models that include traffic movement and behavior on surface roads and freeways.
TransCAD	GIS and transportation modeling in one platform; used for travel demand modeling, mapping, visualization, and analysis. Note: Genesee Transportation Council (GTC) uses TransCAD for its travel demand model.
3-D StudioMax	Renders stills or animations from AutoCAD and other 3-D models; applies photo-realistic material surfaces to images and animations.
VISSIM	3-D "microsimulation" programs that can be used to model movement and behavior of small surface roads and complex, large-scale transit systems.

**This is not a comprehensive list of visualization software programs, but instead is intended to provide basic information on some of the more common applications. The type and scale of a project will determine the type of visualization used.*

[7] Caltrans provided the project team with material on operations and the use of GIS, See Appendix F.

3. FINDINGS AND CONCLUSIONS

Most interviewed stakeholders agreed that property owners are typically more comfortable with ROW acquisitions in instances where state DOTs are able to portray project details accurately and early during the ROW acquisition process. They also agreed that visualizations, regardless of the form they take, can improve the quality of interactions with property owners by allowing the owners to better anticipate and understand changes to their own and nearby properties. As one stakeholder asserted, the adage "a picture is worth a thousand words" holds true when it concerns the use of visualization. However, while most state DOTs currently use at least some basic form of visualization during public involvement efforts to communicate potential project impacts, few have extended its use to the ROW acquisition process. The following section suggests reasons why.

3.1 State DOTs Using Visualization for ROW Acquisition

ROW acquiring agencies that are pioneering the application of advanced visualization techniques in the ROW acquisition process have typically experienced positive outcomes from using visualization despite not having standard practices in place for doing so. Key findings identified that:

- ROW practitioners have been introduced to visualization in a several ways
- A broad range of visualization techniques have been used
- Anecdotally, the benefits of using visualization for ROW acquisition generally outweighed the costs

3.1.1 State DOT ROW practitioners have been introduced to visualization in several ways

State DOT stakeholders identified a variety of ways in which they had been introduced to visualization, with no one approach being recognized as more effective than another. Ohio DOT (ODOT) learned about the use of advanced 3-D graphic techniques for the ROW process through a consultant that presented an overview of its services to ODOT leadership. Afterwards, the leadership believed that visualization could aid in the ROW acquisition process, and acquisition negotiators began to make use of a consulting firm for some of their larger ROW acquisition projects. North Carolina DOT (NCDOT) began using visualization for ROW acquisition after a reorganization of the agency. In this case, the DOT director was already aware of visualization's use within other state DOTs for public hearing purposes. After learning more about the ROW acquisition process, the director recognized the benefits of using visualization for ROW acquisition and recommended that the agency's negotiators make use of existing visualization resources for their own purposes. Caltrans learned how other DOTs were using visualization techniques at an FHWA peer exchange. Caltrans was already using visualization techniques to analyze environmental impacts, but the peer exchange helped demonstrate best practices for applying visualization techniques to the ROW acquisition process.

Most of the state DOTs with which the project team spoke did not come up with the idea to use visualization for acquisition independently. In each case, an outside entity (e.g., DOT leadership, consultant, or other DOT office) was responsible for identifying, via peer exchanges, visualization demonstrations, and other meetings, possible visualization applications for ROW staff. However, this should not imply that all ROW, survey, and design staffs were unfamiliar with some of the visualization techniques available. Often visualization techniques are used for other stages of project development, such as public participation, and some ROW staff indicated being aware of these techniques. It had simply not been standard practice to use visualization for ROW acquisition.

Figure 6. Map of planned ROW acquisition overlaid on aerial imagery of Chicago O'Hare International Airport
Source: Federal Aviation Administration, Chicago O'Hare International Airport Draft EIS.

3.1.2 A broad range of visualization techniques have been used for ROW acquisition

The type of visualization techniques used for ROW acquisition varies greatly among agencies. Some state DOTs have used comparatively straightforward visualization techniques, such as drawings or 2-D aerial imagery overlaid on ROW plans and maps in Google Earth. These applications typically require less expensive software, less storage capacity, and less technical computing expertise. Other DOTs have developed advanced visualizations to convey complex information in simple ways.

Opinions about traditional versus advanced visualization methods have differed depending on the situation. Missouri DOT (MoDOT) believed that traditional visualizations, such as a 2-D drawing of a parcel, would be sufficient if the property to be acquired could be purchased for a reasonable price. The DOT noted that although "problem properties" might benefit from an advanced visualization, those properties often are not known until the end of the acquisition process. In cases where a property turned out not to be a "problem," advanced visualizations might drive up project cost unnecessarily. Another stakeholder commented that some ROW acquisition tasks can be completed very simply or routinely, and that traditional visualizations offer a way to accomplish the task effectively at effort levels commensurate with the project. Some researchers, however, have suggested that traditional visualizations are not always easily understood by the public.[8] Most stakeholders interviewed for this study agreed that newer, 3-D

[8] Hixon III, Charles . 2006. "Visualization for Project Development: A Synthesis of Highway Practice." NCHRP Synthesis 361.

media hold potential to enhance the effectiveness of project negotiators, especially for large parcels that might require more attention.

Based on their experiences, most state DOTs interviewed, including ODOT, Mn/DOT, and NCDOT, believed that advanced visualization techniques were superior to customary approaches that rely on engineering drawings and ROW plans in educating property owners, sustaining community relations, and avoiding potential lawsuits. According to these DOTs, property owners have sometimes viewed the plans simply as “lines on paper” and not always as the intended conceptual aids. With advanced visualizations, ROW acquisition negotiators have been able to more comprehensively represent and communicate overall “macro” impressions of projects, as well as their potential impacts on specific parcels. One FHWA stakeholder noted “3-D visualizations give the ability to show improvements from different and more natural perspectives.” ODOT pointed out that before using 3-D visualization was an option, appraisers and negotiators would take 2-D plans to property owners, lay them on a table, and hope that the changes could be properly communicated. This should not imply that these ROW agents were not thorough in completing their job duties, but that without advanced visualization tools, providing the level of detail required to ensure understanding was not possible. For example, sometimes ROW agents go into the field and stake ROW lines to show horizontal changes to the property. A line of stakes on a property may not always give the owner a feel for elevation differences between the improvement and the property that might be created. In these cases, advanced visualizations could be more informative and detailed than stakes in the ground or points and lines plotted on paper to show a proposed change.

Despite this feedback, the merits of low-tech visualizations, or those that do not involve 3-D computer renderings, for ROW acquisition applications should not be discounted. While some visualization developers might create complex images and multifaceted designs, such elements are not always necessary. In some cases, it may be beneficial to keep the visual concepts at a more basic level. MoDOT commented that it may be difficult to justify creating a sophisticated visualization for a project that only involves a few miles of property. Similarly, FDOT and FHWA suggested that, in the minds of the intended audience, a physical model may be a more tangible representation of a planned project, as it is more difficult to manipulate than a computer-generated model.

Figure 7. Google Earth images that show aerial images, parcel boundaries, and properties in California (top and bottom). Source: Caltrans.

3.1.3 Benefits of using visualization for ROW acquisition generally outweighed the costs

Several stakeholders indicated that benefit-cost analyses for visualization—and particularly those used for ROW acquisition—are rare and difficult to perform. In their experiences, cost effectiveness of visualization for ROW acquisition was generally based on a qualitative assessment rather than benefit-cost data. Most interviewees noted that under their current procedures, they do not have a standard process for feedback from the public and property owners. They acknowledged that having a way to do so would likely improve their ability to quantify the success or utility of visualization in the ROW process, as well as to gain support for its increased use in acquiring ROW.

Nevertheless, there was general agreement among those interviewed that the benefits of visualizations often outweigh the costs, especially when the costs are shared among all the acquiring agency groups that could benefit during the transportation project delivery process. The major benefits documented include:

- Better communication of project impacts to property owners and other stakeholders
- Potential reduction in the amount of land to be acquired
- Potential lawsuit prevention or reduced condemnation damages
- Fewer errors and better project coordination
- Potential to amortize cost across several disciplines

3.1.3.1 ***Better communication of project impacts to property owners and other stakeholders***

Impacts to parcels can be subjective, and appraisers and property owners sometimes hold different opinions about the level of damage associated with a given transportation improvement. Such differences in opinion can negatively affect the negotiations process. One goal in the ROW acquisition process, then, is to minimize confusion about project details, potentially circumventing contention.

Visualizations afford this ability by presenting more realistic and precise representations of the project scope and scale. For this reason, they can serve as an aid to help property owners better understand the real impacts to their property. According to Caltrans and ODOT, ROW officials have previously marked up technical engineering plans to explain project impacts, but sometimes found that property owners did not have the expertise to fully comprehend the 2-D plans. For this reason, some interviewees indicated that, whenever possible, they use advanced visualizations when speaking with property owners about ROW acquisition. Equipped with a laptop, a negotiator can visit a property owner, explain project specifics through the visualization, and then answer questions in person and in real-time. Visualizations might even help communicate to a property owner, as a member of the traveling public, a highway project's anticipated safety or travel time improvements.

MoDOT and NCDOT reported that bridge and interchange projects that impact large areas, and often involve numerous engineering drawings or are completed in several phases over a long period of time, can be particularly confusing for property owners. Visualizations enable the state DOT to communicate the context and changes related to these types of projects in ways not possible (e.g., from various angles, approaches, or times of day) with traditional methods. FHWA noted that 2-D plans alone do not sufficiently communicate elevation changes or cross-sections of properties to property owners. With the aid of aerial imagery and visualization, property owners gain a more comprehensive understanding of the anticipated changes. In another example, ODOT has observed that business owners are often most concerned about changes to access, visibility, and parking, property characteristics that are difficult to envision using overhead engineering diagrams. In addition to better depicting these project aspects, advanced visualizations can also describe project details such as the appearance of sound walls, driveway alignments, and grade changes.

An ancillary benefit of using advanced visualization techniques to communicate more accurately with property owners is improved or sustained community relations. For example, Mn/DOT commented that visualizations have helped gain local business and municipality support for highway projects. While their approval is not always required, their consent early on can help streamline the project delivery process. Interviewees frequently remarked that property owners appreciated when state DOTs provided visualization presentations, even in cases that were not potentially controversial or contentious. NYSDOT commented that visualizations can help alleviate intimidation that property owners might feel, suggesting that using visualizations can help the ROW acquisition process seem less "transactional." NCDOT and Mn/DOT agreed that property owners, having seen a 3-D visualization, seemed to have less "anxiety of the unknown."[9]

3.1.3.2 *Potential reduction in the amount of land to be acquired*

Some DOTs interviewed speculated that using visualization while planning a proposed acquisition(s) could reduce the amount of land to be acquired. With visualization, ROW managers might realize that the proposed transportation project could fit within the existing ROW, potentially alleviating the need to acquire additional property. In particular, 3-D modeling may inform designers and engineers about existing site conditions (such as the property lines, infrastructure, and utilities present), enabling acquisition decisions, for example, on the amount of land to be acquired, to be made with the best information available.

In addition, visualization can help illustrate the location and number of parcels that need to be bought, ultimately helping appraisers justify cost estimates and explain the total budget impact of a given acquisition.

3.1.3.3 *Potential lawsuit prevention, reduced court costs, and reduced damages*

Although transportation agencies rely on experienced appraisers who follow nationally-recognized professional appraisal standards to determine appropriate levels of just compensation, appraisals are inherently subjective valuations.[10] Such subjectivity can make it difficult to predict the impact of condemnation on acquisition costs, including the likelihood of an acquisition proceeding to condemnation, the cost of legal fees, and potential awards a jury might grant.[11] Keeping this in mind, condemnation typically represents a last resort for agencies in ROW acquisition because it usually indicates property owner dissatisfaction and can jeopardize the goals of the acquisition process. Condemnation can also extend project delivery timeframes and overall project costs, resulting in diminished public trust.

NCDOT, NYSDOT, and ODOT believed that the risk of litigation could decrease when property owners better understand the impacts to their property. Although state DOTs proportionally experience few ROW acquisition lawsuits that go to a jury (based on the most recent FHWA data available, the condemnation rate in 2010 was 16.5 percent nationally, and ranged between 0.2 percent and 51.3 percent at the state

---

[9] Evaluation of Mn/ DOT's "Right of Way Visualization Pilot Project" provided to FHWA via email, July 15, 2010. According to the evaluation, it is best to show to landowners any available visualization during initial field visit. Landowner comments on Mn/DOT's pilot visualization included "We're able to see projects as Mn/DOT does;" [the visualization] "relieved anxiety of the unknown;" and [we are now] "more comfortable" with the project.
[10] Hakimi, Shadi and Kara M. Kockelman. Fall 2005. "Right-of-Way Acquisition and Property Condemnation: A Comparison of U.S. State Laws." Journal of the Transportation Research Forum.
[11] Jury awards are particularly unpredictable in partial acquisitions, where landowners may seek compensation for damages incurred to the remainder of their property (Heiner and Kockelman 2004).

level)[12], the cost and time commitment of those lawsuits can be monumental. This is particularly evident in urban areas where land prices are comparatively high and damages awarded to a property owner could be significant. Some researchers have shown that condemnation awards can add between 25 and 40 percent to basic acquisition costs.[13] Determining which project(s) might result in a lawsuit is difficult, but most interviewed state DOTs agreed that the cost of creating several visualizations would likely be less than the cost of proceeding with one lawsuit.

Nonetheless, some acquisitions will proceed to condemnation despite attempts to negotiate with landowners, and a large claim could have a significant impact on a state DOT's project budget. In court, visualizations can help the jury better understand a proposed project's impacts to the property owner(s) and thus rule accordingly. Several interviewees cited instances in which visualizations were deciding, or mitigating, factors in cases like these. FDOT described how it used a 3-D physical model to effectively convince the jury that prospective changes did not restrict access to a business (a car wash), preventing a potential damage award of over $500,000. According to the interviewee, commercial and industrial property owners are sometimes particularly concerned about access, and visualizations are an effective way to communicate that the impacts of access adjustments are expected to be minimal. Additionally, FDOT believed that this particular court ruling also prevented additional lawsuits from being filed based on the precedent the case set, ultimately saving the agency millions of dollars.

NCDOT described another court case in which the property owner's counsel used a visualization to demonstrate a certain (and inaccurate) noise effect, which ultimately helped secure a decision in favor of the landowner. Although erroneous information was presented, the visualization made an impact on the jury. NCDOT did not have its own visualization to refute the argument. In other instances, visualization has even prevented cases. One interviewee recounted a situation that was settled out of court once the property owner's counsel learned that the state DOT planned to develop a 3-D model for the case.

In Mn/DOT's experience, visualization has not always expedited the direct purchase process or reduced the condemnation rate. This could be attributed, however, to changes in the state's eminent domain policy and not the availability of advanced visualizations. What Mn/DOT did report is that the public has been "impressed" with visualization products and the low cost associated with developing them. Mn/DOT commented that visualization presentations have "given the agency technical legitimacy in what it's doing and has helped build trust."

Finally, since visualizations can help minimize negotiation time, thus maintaining project schedules, inflationary costs related to materials and engineering expenses might also be limited.

3.1.3.4 *Fewer errors and better project coordination*

One DOT noted that 3-D data provides staff with more detailed project information so they can better coordinate projects. According to the DOT, 3-D data reduces the number of errors related to vertical and horizontal layout. In one example cited, there was twenty-foot gap in the design on a plan that the state had already certified. After viewing the project in a 3-D visualization, the project team was able to notice the error and avoid potential problems during construction.

---

[12] The range of this statistic has been shown to vary based on certain acquisition practices, such as the amount of time given to landowners to consider compensation offers and the use of "quick take" procedures, as well as demographic variables, such as the degree of urbanization, education levels, and political party affiliation (Hakimi and Kockelman 2006). A "quick take" occurs when an agency acquires property prior to settling on a compensation amount in order to facilitate tight project timeframes. FHWA Annual ROW Statistics are available at www.fhwa.dot.gov/realestate/rowstats/index.cfm.

[13] Heiner, Jared D. and Kara M. Kockelman. January 2004. "The Costs of Right of Way Acquisition: Methods and Models for Estimation." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

3.1.3.5 *Potential to amortize cost across several disciplines*

Since many disciplines in the project delivery process will likely benefit from visualizations, the cost for developing the visualizations could potentially be amortized across the disciplines. If consideration of visualization techniques were fully integrated into a planning process that is inclusive of all project delivery disciplines (including realty and ROW practitioners), those involved in the discussions could articulate their respective visualization needs and determine how the entire agency could share the costs rather than charging them to one specific office or project.

3.2 Why Using Visualization for ROW Acquisition is Not More Widespread

Evidence from the interviews suggests that there are four principal reasons why the use of visualization is not as prevalent in the ROW acquisition process as it is in other stages of highway project delivery:

- Visualization uses are unconventional in the ROW acquisition process
- A perception that visualizations are costly to produce or only useful for complex projects
- Lack of internal resources to develop and display visualizations
- A concern that visualizations might not look exactly like the actual project

3.2.1 Visualization uses are unconventional in ROW acquisition

At a fundamental level, there may be a discrepancy among ROW professionals as to what constitutes "visualization." One stakeholder indicated that "3-D imaging" was sometimes used synonymously with "visualization," while others noted that visualization in the ROW context means "anything that can help the property owners understand what the changes to his/her property will be."

Advanced visualization techniques in transportation settings have sometimes been viewed as public involvement tools, and less so as tools to aid ROW acquisition. This is likely attributable to limited or inconsistent intra-agency communication as well as a perception that ROW offices within state DOTs follow older data management methods and can sometimes be reluctant to try new techniques. The latter reason suggests that visualization staff should better market their capabilities. One DOT commented that although the staff members developing visualizations sit in an office nearby the ROW office, to date the two groups had not communicated about creating visualization for ROW acquisition. Typically, one of this DOT's discipline area employees will complete and submit a visualization request that clearly specifies what he/she wants the visualization to communicate. However, it was reported that the DOT' ROW practitioners had probably only had limited exposure to visualization, and thus it is unlikely that they were aware of all available visualization options (and their potential benefits). This DOT's visualization staff recognized this as a possible area for future outreach that would require management support to initiate trial projects.

One district or region within a state DOT may use visualizations or new visualization techniques, while other districts or regions are either unaware of them or are not ready to change existing negotiation methods already perceived as effective. Some state DOT interviewees indicated that visualization techniques for ROW acquisition had not been widely adopted due to satisfaction or familiarity with existing practices, and unfamiliarity with visualization technologies. For instance, FDOT commented that "the lion's share of our parcels can be clearly displayed through construction plans, an overhead view of what's coming. That will suffice for negotiation." MoDOT questioned the need to spend additional funds to create visualizations when the agency historically has been able to acquire properties for reasonable costs without them. Despite acknowledging that visualization could be helpful in contentious acquisitions, MoDOT has remained reluctant to utilize visualizations for ROW acquisition, citing a fear that extra data collection necessary to develop visualizations would strain project development timelines. Ultimately, managers would need to weigh the pros and cons of this rationale based on project requirements.

Figure 8. Halff Associates Inc. images show roadway configurations, driveways, buildings, and vehicle access. Source: Halff Associates Inc.

3.2.2 Perception that visualizations are costly to produce or only useful for complex projects

Some DOTs indicated that very few projects (in one case, less than five percent) use visualization, and then only when there is a "high-profile" need. Visualizations were more likely to be created on projects where the cost of developing them represented a minor percentage of the larger cost. On smaller, low-budget projects, however, it was expected that the production of sophisticated, 3-D visualizations would be cost prohibitive given increasing pressure to “do more with less.” One interviewee said that a “six-figure dollar amount” for visualization would immediately be considered cost-prohibitive. In fact, several DOTs, including Caltrans, Mn/DOT, and MoDOT, cited labor, data-gathering, and training costs as the main deterrent to using visualization for ROW acquisition.

According to FDOT and MoDOT, visualizations, unlike ROW plans, do not necessarily need to be generated to complete the acquisition process and, thus, doing so might be viewed as an unnecessary expense—particularly during economically stressed times. FDOT indicated that the economic downturn had shifted the nature of their projects, and therefore, their acquisitions. Recent budget strains had forced them to focus on small improvement projects rather than new construction, requiring mainly simple partial acquisitions with little threat of condemnation. Several interviewees indicated that they had only considered using visualization in contentious acquisitions, particularly when they proceed to condemnation or when a landowner files an inverse condemnation suit and juries are asked to imagine complicated issues based on the plaintiff's contradictory descriptions. In these instances, the use of visualization “limited to specific parcels with unique issues that are hard to visualize” was recognized as a potential deciding factor in multi-million dollar settlements. Except in the specific instances cited above, these organizations could not justify the cost of developing visualizations for single properties, or those with a low risk of litigation.

This apprehension may be unfounded, especially when visualization development costs are balanced against considerations such as overall project and ROW cost; the likelihood that the property owner(s) are resistant to ownership transfer; the likelihood of condemnation proceedings and large damages; and the number of acquisitions being performed (per parcel visualization cost might be minimized with several acquisitions). None of the interviewees had collected quantifiable data on the effectiveness of their visualizations for ROW acquisition relative to the costs of producing them. In one example, none of the projects for which visualization had been used in the ROW acquisition process had been constructed, rendering measurement of ultimate success impossible. Another state DOT questioned the feasibility of conducting an accurate cost-benefit analysis, citing the individuality of acquisitions and an inability to control variables other than the use of visualization.

Mn/DOT, provided information on a pilot it conducted in 2007 to help landowners better understand highway construction improvements and corresponding property acquisition impacts. By assembling aerial photography, electronic highway design files, property lines, rendering, and animation, Mn/DOT created a 3-D video model of the "After Condition" for a proposed urban highway reconstruction. According to Mn/DOT's pilot project evaluation, although property owners believed the visualization cost seemed “reasonable” when broken down on a parcel-by-parcel basis, “[i]nformal, formal, and statistical product evaluations were attempted, but it was found very difficult to measure results of utilizing this tool for right of way acquisition purposes.”

In general, however, the development costs of visualization tools for ROW acquisition depend on several factors, not limited to:

- The complexity of the project and parcel(s)
- The requirements of the project manager
- Equipment and staff time needed to take site photos; gather aerial imagery; and ROW, construction and cross-section plans
- Staff time needed to develop the visualization

Costs increase as visualizations become more elaborate and realistic, and begin to include elements like vegetation, people, or vehicles. For example, 2-D plan drawings, where the CAD drawings are already completed for design, that are overlaid on photos without animations typically cost between a few hundred dollars to a few thousand dollars including staff time. Three-dimensional PDFs[14] generally require 1 to 2 days labor and cost $1,000 to $2,000 to create. Animations that one DOT produced in-house were described as being more expensive than 3-D PDFs, with costs ranging from $3,000 to approximately $25,000. The high-end of that estimate was based on the in-house development costs of a 3-D fly-over, split-screen animation covering a project that was roughly 5 miles in length. It required approximately 600 labor hours at a rate of $40/hour. In another case, Mn/DOT spent $35,000, or $406 per parcel, in direct labor cost to develop a visualization of proposed acquisitions along a 1.5-mile section of urban roadway. Though no evidence was found to confirm the assertion, NCDOT reported that some consultants have charged upwards of $75,000 per minute of animation. Instead, one consultant indicated that animation costs vary from $3,000 to $100,000 depending on the level of detail desired, whether images are available, the amount of coordination time needed with the DOT, and whether photo-realism is needed. Another consultant mentioned that an animation of one parcel, 1–10 minutes in duration, is typically about $15,000–$75,000, including time required to serve as a non-testifying expert.[15] In most cases, however, visualization tools for ROW acquisition cost those interviewed approximately $10,000 to $15,000 per visualization.

Table 3. Approximate relative costs and development time frames for traditional and advanced visualizations. Two-dimensional graphic overlays are the least costly and time-consuming visualization to develop. Computer animations, which typically require the most time to develop, are the most expensive, ranging from $3,000 to $100,000 or more. *Source: The costs and development time lines are based on information provided during telephone conversations between the project team and both DOT and consultant stakeholders.*

	Visualization Tool	Approximate Cost	Approximate Development Time
Traditional visualization (“low-tech” visualization)	2-D graphic overlay	$200 to $2,000 per overlay	1 hour to 2 days
	Physical model	~ $3,000 per parcel	1 week to 4 months
Advanced visualization (“high-tech” visualization)	3-D image or 3-D PDF	$1,000 to $2,000 per 3-D image	1 to 2 days
	3-D or 4-D video, or computer animation	$3,000 to $35,000 per video when developed in-house; $3,000 to $100,000 per video when contracted	1 week to 4 months for lower cost animations. Visualizations in the $75,000 cost range might take 8-9 months to develop.

Some interviewees also cited the expense of purchasing the requisite software and hardware as additional cost barriers. Caltrans indicated that the computers of ROW practitioners are often “woefully inadequate” for visualizations and that presenting visualizations to property owners could require the purchase of laptops. According to Caltrans, “[e]ven when an enthusiastic ROW person who wants to try something innovative is identified, his/her computer is underpowered.” This trend, however, may be changing. NCDOT said that over the last decade some of its ROW offices have equipped agents with laptops for property owner meetings, and are even considering functionality that would enable agents to print property owner compensation checks in the field.

[14] See ftp://ftp2.bentley.com/dist/collateral/Web/Civildemo.pdf for an example of a 3-D PDF.
[15] This consultant noted that visualizations for public meetings that might involve 50-300 parcels or more could cost well above $75,000.

FDOT cited a secondary cost beyond the need to purchase additional hardware and software. When one of its physical models was admitted in court, an expert witness was required to testify that it was accurate. Although FDOT acknowledged that its ROW office likely had the capabilities to create or explain visualizations, it was not permitted to present the model already developed in court unless it was accompanied and supported by the testimony of an engineer, which is required under state law. This sort of uncertainty about potential extra secondary costs could dissuade agencies from using visualization for ROW acquisition, and encourage status quo practices.

3.3.3 Lack of internal resources to develop and display visualizations

All of the DOTs interviewed had some in-house visualization development expertise, ranging in size from two staff people in NYSDOT's headquarters to several groups spread across a number of districts in Ohio. Most, however, indicated having had limited experience developing visualizations for ROW acquisition purposes. They also noted that workloads were becoming increasingly strained and that staff sizes were not growing in a commensurate way. NCDOT pointed to the design and art skills necessary to produce high-quality visualizations, stating that when it had the opportunity to expand its visualization team, it had sometimes been difficult to attract potential staff with this requisite background.

Additionally, according to one consultant stakeholder, visualization software can be very data-intensive and most state DOT ROW staffs do not have the computer hardware, even if they had the time, to manage these data in-house. Likewise, most DOTs interviewed had no standard practices for using visualization.

3.3.4 A concern that visualizations might not look exactly like the actual project

Some state DOTs expressed a concern that visualizations might differ from the end project leading to property owner dissatisfaction between the expected and actual results. One stakeholder cited an example where the final project differed in appearance from an animation because seedlings, as opposed to the mature trees displayed in the visualization, had been planted at the project site. Based on this experience, a DOT might hesitate to employ visualization early in the project development process due to a fear that it could create an unrealistic expectation among property owners that the projects, when built (often years in the future), would exactly match the visualized representation. Additionally, it is possible that a DOT periodically revise its ROW needs as the acquisition process proceeds, potentially making the agency feel compelled to adjust and readjust visualizations created for the acquisition.

Additionally, one DOT exhibited hesitation in considering the use of computer-generated visualizations in condemnation proceedings, suggesting that "a technological presentation…brings up more questions in court." This assertion was based on the notion that computer-based visualizations are inherently pliable and, therefore, open to manipulation.

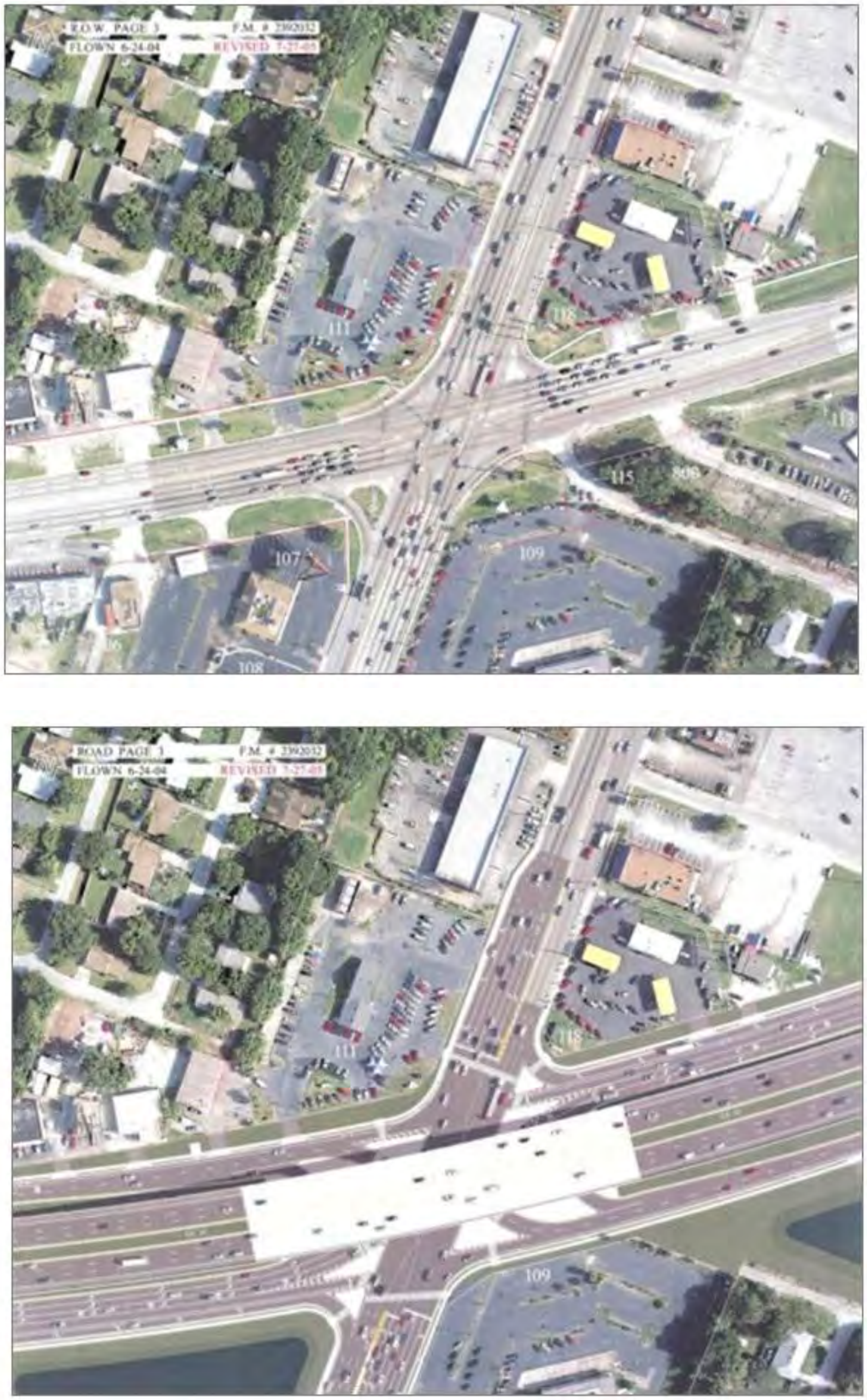


Figure 9. Two-dimensional aerial visualization of existing (top) and proposed overpass conditions (bottom). Source: FDOT.

4. RECOMMENDATIONS

The use of visualization has not been as widespread in the ROW acquisition process as in other stages of transportation project delivery because there has been a lack of awareness among ROW practitioners of visualization's potential ROW acquisition applications. Visualizations have also been perceived as too costly to produce unless the project was confronted with complex property issues. Some ROW practitioners expressed concern that visualization presentations might not exactly replicate the look of the actual project, thus potentially damaging public opinions about a particular project.

However, there was general agreement among stakeholders and in the literature that the use of visualization for ROW acquisition purposes will continue to grow. This is especially true as the demand for information that is accurate and easily communicated (e.g., via maps and visual displays) increases, and funding and timelines are scrutinized more rigorously. According to those interviewed, visualizations can offer a cost-effective way to enhance the ROW acquisition process. Communication with property owners and other stakeholders about project impacts can be improved, potentially lowering condemnation rates and associated fees or damages. The amount of land to be acquired can also be reduced in some cases. Project coordination among transportation disciplines is encouraged, potentially reducing the likelihood of design or construction errors further along in the project delivery process.

Determining which visualization techniques are most suitable for ROW acquisition is less clear. Current literature and the stakeholders interviewed for this report indicate that there may not be one universally preferred technique.

The technical level of a visualization that would best serve a ROW official in the acquisition process is highly dependent on the issues and concerns of the acquisition. For purposes of negotiation with property owners, simple visualizations, including ROW maps overlaid with aerial photography that are geometrically corrected or sketches created with CAD software, are likely sufficient. This does not suggest that more sophisticated techniques be overlooked, but the simplicity and scope of some negotiations may not warrant the investment of time and resources that complex visual aids can require. Traditional visualizations might also be better suited for situations that demand extra flexibility, as making changes to advanced visualizations, such as 3-D simulations or video flyovers, can be costly and complicated. An advanced computer-generated video exhibit that guides viewers through multiple scenarios might confuse, rather than clarify, a project when presented to a jury due to the potential number of issues displayed in the video.

In instances where the scrutiny of court proceedings are a concern, software that can provide for high degrees of accuracy and easily incorporate new changes or present new views are likely better than photo-editing software. Similarly, advanced visualizations also offer useful means to demonstrate less complex scenarios, such as on-site traffic maneuvers, grading changes, partitioning of remaining parcels, or simple renderings of the completed facility, to many people over longer periods of time (e.g., looping video at a public meeting or presentation to a home-owners association).

NCHRP Synthesis 361: Visualization for Project Development[16] reports that the current state of visualization within the transportation community is one of eagerness to use the technology but of minimal organization for its implementation. According to the study, transportation agencies nationwide were looking for guidelines and best practices for its use. To begin to address this gap, as well as the

[16] NCHRP Synthesis 361: Visualization for Project Development is available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_361.pdf.

barriers identified in this research, the project team proposes the following recommendations for using visualization techniques in ROW acquisition.

Barrier addressed: Lack of awareness of visualization's potential uses in the ROW acquisition process

- **ROW offices within state DOTs should reach out to visualization staff to learn about visualization techniques available.**
  It is important to instill an understanding of the range of visualization tools available for ROW acquisition. Potential visualization users, especially novices, may not know what to ask for or how to write a task order for visualization services.

  In state DOTs where visualizations are developed in-house, ROW practitioners should consider approaching visualization staff (and vice versa) to discuss potential visualization needs and capabilities. DOT leadership can help initiate these conversations, if necessary. In situations where visualization development is outsourced, real estate staff should request that consultants or agency ROW project managers present the agency with various visualization possibilities that could be specifically tailored to the ROW acquisition process. In both cases, the first topic of discussion should be to define the term "visualization." There are a variety of different visualization techniques, and not all involve sophisticated computer modeling or require digital graphics expertise. It is important for visualization staff to adapt the visualization technique to the need. Overlaying an ortho-rectified, or geo-referenced photo would likely facilitate the ROW acquisition process and not necessarily be expensive. "Home use" modeling software packages, such as Google SketchUp, are often free resources for those wanting to explore computer visualizations without learning specialized engineering tools. At a minimum, ROW staff should engage in early consultation with aerial photo and mapping personnel to understand how the most appropriate technologies might be utilized and best mapping products obtained. Without comprehension of the spectrum of options—from hand drawings to technologically-sophisticated computer renderings—this might not be feasible. See Appendix C for an example visualization request form that NYSDOT developed, which includes a synopsis of visualizations offered internally, as well as a listing of other relevant outreach and educational resources on visualization topics.

- **Use visualizations to supplement, not replace, existing practices or tools**.
  As visualizations are integrated into the ROW acquisition process, it is important to use them to complement existing practices, such as a property walk-through. Before visualizations were used, negotiators would often take property owners to the actual site of where the proposed property change was to occur so that the property owners could mentally visualize the impacts to their properties and ROW practitioners could more easily stake the owners' land. To the extent possible, a site visit with property owners should accompany visualizations, regardless of the technique used. Project managers should continue to offer owners the opportunity to do a walk-through of properties being acquired. Negotiators should allow owners to compare plans and visualizations of the parcels in question with the actual property. In these cases, more simple visualizations, such as aerial images and ROW plans, might be more effective since computer simulations cannot replace physically being at a property. Visualizations would continue to be beneficial for more complex landscape alterations, grading changes, or the addition of structures such as walls.

Barrier addressed: Perception that visualizations are costly to produce or only useful for complex projects

- **Identify opportunities to spread the cost of visualization development**.
  During the initial stages of project development, each functional discipline on the project team should consider whether a visualization presentation would enhance its role, for example, through improved

communication with affected landowners and other stakeholders at public meetings or through enhanced ability to assess environmental impacts. Additionally, some visualization techniques, such as interactive 3-D modeling, can be a by-product of the design or other project development process (e.g., 3-D surface models are frequently developed for automated machine guidance during construction) and do not always need to be rendered with a high degree of realism to convey basic project concepts or certain effects such as the geospatial proximity of the project to the ROW or adjacent property. By having multiple disciplines involved in communication early on, the costs of developing the visualization(s) could likely be spread among all the groups poised to benefit from the presentation. More low cost visualization techniques could be applied to more projects.

Another pragmatic approach is to show existing ROW lines faintly in all visualizations created for project development purposes. This minor addition can enhance the usability of a presentation and demonstrate the added value of visualization.

- **State DOTs that are already utilizing, or plan to use, visualizations for ROW acquisition should develop a standard process for evaluating the visualizations, preferably before the visualization is produced and used.**
  State DOTs would benefit from a consistent method to record the benefits of visualization for ROW acquisition, as well as from documentation of the actual costs expended for visualization. Though the interviewed DOTs using visualization for ROW acquisition purposes recognize the value of establishing standard evaluation procedures and measures, none have been effectively implemented and shared. While one interviewed state DOT did indicate that it surveys property owners at the end of a negotiator's visit, the survey does not specifically solicit feedback on visualizations that may have been presented, nor are survey results between acquisitions completed with and without visualizations compared.

  Potential criteria for evaluating visualization for ROW acquisition include:
    - Time to complete acquisition compared to historical trends
    - Acquisition cost relative to visualization development cost or historical acquisition costs, when corrected to current dollars
    - Condemnation rate trends
    - Settlement rate trends
    - Initial property owner reaction to visualization(s) presented
    - Level of comprehension of proposed acquisition and improvements based on post-appraisal or negotiation property owner feedback
    - Satisfaction with the acquisition process based on post-acquisition property owner feedback (e.g., via confidential questionnaire)
    - Effect of visualization on property owner's attitude toward the acquisition process or DOT
    - The number of other uses (e.g., in the project development process) for the visualization

Barrier addressed: Lack of internal resources to develop and display visualizations

- **Make laptop computers and media software available for mobile use**.
  In order for appraisers and negotiators to make best use of visualizations during ROW acquisition, they need to present the visualizations to property owners in the field. Some interviewees indicated that equipping staff in the field with laptops had been a challenge due to budget constraints. Given visualization's potential benefits in the ROW acquisition process, DOTs should modernize appraisers' and negotiators' field equipment and maintain up-to-date visualization software to the extent practicable. ROW officials in the field could find additional uses for laptops beyond showing visualizations, such as changing and printing documents on-demand, thus saving a trip to the office

and potentially days in the process. These additional uses further justify the financial investment in laptops.

Barrier addressed: Concern that visualizations might not look exactly like the actual project

- **Keep the complexities of the parcels in mind**.
  Conveying a partial or complete project rendering in the ROW acquisition phase of project development can be challenging given that actual project completion is likely years away, during which substantial changes may occur. State DOTs interviewed, as well as existing literature, emphasize the importance of creating visualizations that are realistic rather than idealistic. Given the range of possibilities that visualization tools present, it is tempting to create a vision of what a finished project could look like, rather than what it will actually look like, as discussed earlier in the example where seedlings were planted onsite rather than the mature trees depicted in the visualization. Sharing visualizations that depict unfinished projects can foster public involvement by conveying that the projects are still in development, and that public feedback is welcome. In contrast, sharing a "finished" project plan may alienate stakeholders who believe that the project was finalized without their input.

Other Recommendations

- **Use visualization tools to improve the ROW acquisition process and, by extension, accelerate the overall project delivery process**.
  FHWA's "Every Day Counts" initiative is designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of roadways, and protecting the environment. The ROW process, which includes the ROW acquisition process, is a major part of project delivery, and significant time savings can be achieved. Visualization is an innovative tool that land acquiring agencies should consider in their efforts to expedite ROW acquisition.

Going forward, FHWA should:

- **Conduct a test study on the degree to which visualization can expedite ROW acquisition**.
  To quantify advantages of advanced visualization techniques over traditional approaches, the FHWA should support a project to test the effectiveness of visualization in expediting ROW acquisition. Although this experiment would not have a "control" case, it would allow for a comparison of visualization techniques on presumably similar properties related to one transportation improvement. The project should track the dollar and labor hour costs of producing the visualizations, and should compare traditional versus advanced visualization techniques in terms of time to develop, time to settle the acquisitions, settlement and condemnation rates, and any effect on damage payment that may be necessary.

- **Establish a working group to collaborate and share state of the art techniques and information on visualization for all aspects of the ROW process.**
  A working group could collect and disseminate best practices and lessons learned to maintain accurate cost data and share visualization techniques. The group, which could be organized as an AASHTO ROW committee focus group, could organize webinars, conferences, or sessions at semi-annual meetings to update visualization and ROW experts, as well as individuals who may need visualization assistance. The working group might also provide DOTs with up-to-date information on software and hardware capabilities and requirements or work with software companies to develop software packages appropriate for ROW offices.

- **Conduct research on the use of visualization tools in other core ROW process areas, such as appraisal, relocation, property management or asset management, and outdoor advertising control.** This research primarily focused on the acquisition aspects of the ROW process. Although other core ROW process areas were mentioned, an in-depth evaluation and analysis of the benefits and costs of visualization in the other areas was not conducted. Future research on these topics could yield useful information for practitioners seeking lessons learned in applying visualization for ROW purposes other than ROW acquisition.

- **Create guidelines and contract templates for visualization agreements**. In coordination with visualization firms, traffic engineers and appraisers often develop the terms in ROW visualization contracts in the parlance of their respective fields, potentially predisposing a visualization product toward one particular use, and away from a more holistic application. The project team also found that the contracting language used often varies depending on a project's scope. For example, sometimes language will be added to include preparation for and testifying at a court hearing. Going into a visualization project, some companies require the following:
    - Auto-turn data
    - High-resolution ground photography
    - 3D topography
    - Road geometry and schematics
    - Striping plans
    - Planometrics
    - Aerial data
    - Grading plan
    - Any state specific design standards
    - Traffic counts

  Other companies ask for more basic information, such as whether the DOT wants an advanced visualization versus a basic visualization, or whether additional details (e.g., people, buildings, and vehicles) will be included.

  FHWA should work with a select group of ROW offices within DOTs to produce guidelines and sample language for contracts between state DOTs and visualization consulting firms, should a visualization contract be necessary. Appendix F offers sample specifications, parameters, and deliverables that could be included in a scope of work for visualization services.

Sources Consulted and Literature Review

Hannon, Jeffrey John and Tulio Sulbaran. NCHRP Synthesis 385: Information Technology for Efficient Project Delivery. University of Southern Mississippi. October 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_385.pdf. Prepared for TRB.

The National Institute of Standards and Technology (NIST), the U.S. Department of Commerce, the General Services Administration, the Construction Industry Institute consortium, the International Alliance for Interoperability, and the Construction Sciences Research Foundation (NCHRP) commissioned this synthesis report to study interoperability issues specifically related to state DOTs. The scope aimed to identify sharing of information throughout all phases of the project delivery process, including procedural, institutional, human, and technical constraints and mechanisms.

American Association of State Highway and Transportation Officials Task Force on Environmental Design. July 2003. *Visualization in Transportation: A Guide for Transportation Agencies*. http://cms.transportation.org/sites/design/docs/VisualizationGuideJuly2003.pdf

The AASHTO Task Force on Environmental Design presents the different types and uses of visualization in transportation and associated benefits and constraints. The purpose of visualization in transportation is to sufficiently convey to the public the full extent of proposed improvements without the need for specialized technical knowledge. Since visualizations are often created during the early stages of a project when final details are not certain, it should be clear that they only represent preliminary designs, which may ultimately change before the project is completed. In certain cases, where the appearance of a project may change between the time of its completion and a future date (for instance, based on the growth of vegetation planted during construction), these anticipated changes should be communicated to the public or documented in additional visualizations. Visualizations have the potential to accelerate the process of reaching a consensus on the design of a project with stakeholders, the public, and communities directly affected by the construction and ultimate operation of a project. However, AASHTO warns potential users of visualization technology for transportation projects against misrepresenting the ultimate intent of a project by augmenting images with features that will not be included in the actual improvement. Adding features purely for visual appeal can introduce bias, and may ultimately necessitate the inclusion of any superfluous visualized features into the end design.

Cambridge Systematics, Inc. December, 2006. "U.S. Domestic Scan Program: Best Practices in Right-of-Way Acquisition and Utility Relocation, Final Scan-Tour Report." http://onlinepubs.trb.org/onlinepubs/trbnet/acl/FR1_NCHRP2068_Right-of-Way_all-in-one.pdf

In July 2006, the NCHRP initiated a scanning tour of three state DOTs to highlight successful practices in right-of-way acquisition and utility relocation. In Florida, the scanning team noted that FDOT employs aerial photographs with the existing and proposed alignments superimposed during the ROW acquisition process to communicate to landowners the projected impact to their property. The use of these maps, which cost about $10,000 per mile, have been particularly useful in highly developed urban areas, where business use the ROW for parking and other commercial-based activities. Minnesota DOT employs a more sophisticated form of visualization in its ROW acquisition process, presenting landowners with a 3-D video depicting the proposed improvement and the adjacent property. At an estimated cost of less than $500 per parcel, this practice is

intended to help landowners understand the impact of a project on their property while they consider the fairness of an acquisition offer.

Campbell, John *et al*. June 2009. "Streamlining and Integrating Right-of-Way and Utility Processes With Planning, Environmental, and Design Processes in Australia and Canada." Federal Highway Administration. http://international.fhwa.dot.gov/pubs/pl09011/execsum.cfm

In September 2008, a group of state DOT and FHWA staff sponsored by FHWA, AASHTO, and the NCHRP conducted a scan of innovative ROW practices in Australia and Canada. The scanning team found that certain Australian states are beginning to employ visualization technology in the ROW acquisition process, posting three-dimensional animations of proposed projects online. Although the tools to create the animations were expensive, the higher level of public engagement the tools allowed sufficiently offset the tools' costs. As a result, the scanning team recommended that DOTs in the United States begin to research and promote a similar use of the technology.

Charles L. Hixon III. 2006. "Visualization for Project Development: A Synthesis of Highway Practice." NCHRP Synthesis 361. Prepared for TRB. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_361.pdf

The authors of this NCHRP publication define visualization as "the visual representation of proposed project alternatives and improvements and their associated impacts on the existing surroundings." They suggest that traditional 2-D technical documentation like design plans often exacerbate confusion among members of the public while newer CAD-based three-dimensional media hold potential for allowing the public to understand the proposed impacts of a project. They also find that visualization can aid transportation professionals during the design process by allowing them to view potential points of interference between project elements or comprehend complex construction sequences. The authors present case studies of the Utah, California, Minnesota, New York, and Florida DOTs and the FHWA to highlight common challenges in employing visualization in transportation. These include a lack of standards and guidelines, insufficient cost/benefit data to justify the use of visualization, limited knowledge on the potential of visualization, a shortage of qualified visualization technicians within agencies, and limited opportunities for training.

FHWA. 2007. Virtual Highways—A Vision of the Future. *Public Roads* article. www.fhwa.dot.gov/publications/publicroads/07may/05.cfm

This article appearing the May/June 2007 issue of *Public Roads* describes how FHWA demonstrated new visualization technologies for a roadway design process in Montana to improve project delivery time.

FHWA. 2010. Visualization's Next Frontier. *Public Roads* article. www.fhwa.dot.gov/publications/publicroads/10janfeb/02.cfm

This article appearing the January/February 2010 issue of *Public Roads* describes how visualization can be used as a tool in the engineering and design phases of project development. It includes descriptions of many 3-D, 4-D, and dynamic (animated or real-time simulation) technological tools for design visualization.

FHWA. 2008. Right of Way and Utilities International Scanning Tour—Australia and Canada: Summary Report. www.fhwa.dot.gov/realestate/scans/rowutilint08.htm

In September 2008, an International Scanning Study Team visited Australia and Canada to learn about innovative practices on ROW and utility processes that might be applicable for implementation in the United States. This report documents the findings of the scan.

FHWA. 2005. "Acquiring Real Property for Federal and Federal-aid Programs and Projects." Publication no. FHWA-HEP-05-030. www.fhwa.dot.gov/realestate/realprop/index.html

This brochure explains the rights of owners of real property to be acquired for a federally-funded programs or projects.

Federal Lands Highway Division. *Design Visualization Guide*. www.efl.fhwa.dot.gov/manuals/dv/manual/chapter1/1_0.aspx

FHWA's Federal Lands Highway Division defines design visualization as a "simulated representation of a design concept and its contextual impacts or improvements." Federal Lands Highway Division acknowledges that design visualization is not commonly used by transportation agencies for small- or medium-scale projects due to the perception that the techniques are expensive and require a highly-specialized skill set. Their Design Visualization Guide presents visualization techniques ranging from basic to advanced that utilize computer-aided design and drafting software. They also present innovative tools for communicating designs to a general audience, including 2.5-D animations that combine an aerial photograph with a 3-D model in a single video sequence, 3-D applications, and real-time interactive models, which allow stakeholders to navigate through an animation interactively. Finally, the guide depicts seven case studies in which design visualization techniques were used to communicate the effects of a proposed improvement on a Federal Lands Highway alignment.

Garrick, Norman W. *et al*. July 2005. *Effective Visualization Techniques for the Public Presentation of Transportation Projects*. Prepared for The New England Transportation Consortium. www.netc.uconn.edu/pdf/netcr48_00-6.pdf

Garrick, Miniutti, Westa, Luo, and Bishop identify the components of successful visualization techniques in the public involvement process of transportation projects, highlight the state of the practice in New England, and provide an overview of the techniques available to transportation professionals. The need for effective presentation methods has evolved concurrently with the availability of computer-based visualization techniques and technologies but transportation agencies need to be careful in order to ensure that visualizations are constructed accurately. In addition to involving the public more easily in the transportation planning process, visualization can be used to evaluate alternatives and identify problems early in the planning and design processes. Through their survey of visualization techniques, the authors found that, although available visualization techniques range from artist renderings to 3-D animations and simulations, New England DOTs generally use static image composites as their primary form of visualization. Furthermore, when the survey was conducted, visualization had not been fully integrated into the transportation design process at most of the DOTs that responded.

Genesee Transportation Council. *An Introduction to Visualization.* www.gtcmpo.org/Resources/Topics/Visualization.htm

The Genesee Transportation Council provides an overview of the use of visualization in transportation, including reasons for its use, available techniques, and recommendations for using visualization appropriately. Since the public may not possess the same level of understanding of engineering concepts as transportation professionals, visualization can help translate and convey the intent of proposed transportation projects. Projects of all scales can impact surrounding communities, so it is important that some form of visualization is available to the public for all projects. However, given the predictive nature of visualization, transportation professionals should qualify any visual depiction of a potential project and its source data in order to avoid misrepresentation.

Gentry, Ann H. November/December 2000. "3-D Animations: Power Tools for the ROW Professional." *Right of Way Magazine*. Pgs. 12-17.

Ann H. Gentry, of Precision Simulations Inc. presents various uses for visualization technology in the ROW industry. She focuses, in particular, on its use in litigation, where a three-dimensional animation or simulation can convey to a jury what maps and engineering plans cannot. A three-dimensional model allows the jury to fully understand the nature of a condemnation case and understand visually the impacts to a property that a proposed project will have or has already made. In the latter case, visualization techniques can allow an attorney to depict to the jury the appearance of a property before the improvement in question was constructed.

Hakimi, Shadi and Kara M. Kockelman. Fall 2005. "Right-of-Way Acquisition and Property Condemnation: A Comparison of U.S. State Laws." *Journal of the Transportation Research Forum.* Pgs. 45-58. www.ce.utexas.edu/prof/kockelman/public_html/TRB05ROWCondemnations.pdf

Hakimi and Kockelman investigate the correlation between state ROW acquisition practices, demographic characteristics, and condemnation rates. They suggest that condemnation introduces uncertainty into estimates of cost and timeframes for ROW acquisition and, while fairly constant across years, condemnation rates represent a sufficient indication of success for ROW statutes. Their analysis found that states that allowed the acquisition of property prior to an agreement of compensation or acquisition of uneconomic remnants left over as a result of a partial acquisition experienced generally higher condemnation rates, while states that engaged in early, open, flexible, and explicit acquisition practices experienced lower condemnation rates. Their investigation of state condemnation rates also indicated that certain demographic variables like urbanization, high educational attainment, and certain political affiliations correlated with higher condemnation rates.

Hart, James M. June 29, 2009. "Integrating Modern Surveying and Mapping Technology into the Right of Way Acquisition Process." Presentation to 55th Annual IRWA International Conference, Indianapolis, IN. https://www.irwaonline.org/EWEB/upload/2009Conference/Monday/Integrating%20Modern%20Surveying%20and%20Mapping%20Technology%20into%20the%20Acquisition%20Process.ppt

James M. Hart of Towill Surveying, Mapping, and GIS Services presented to the 55th Annual Right of Way Association International Conference the benefits of modern mapping and surveying technology, including GPS, aerial photography, and Google Earth, in the ROW acquisition process. Hart expressed the effectiveness of aerial photography and Google Earth as tools for interacting with landowners, particularly highlighting the power of the latter when displayed on a GPS-enabled and wirelessly-connected laptop.

Heiner, Jared D. and Kara M. Kockelman. January 2004. "The Costs of Right of Way Acquisition: Methods and Models for Estimation." Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, D.C. www.ce.utexas.edu/prof/kockelman/public_html/TRB04ROW.pdf

Estimating Right of Way acquisition costs can be a difficult task, and one that has many variables that are difficult to predict. Agencies typically have little time or information to estimate ROW acquisition costs, which represent a significant portion of a project's cost. Heiner and Kockelman introduce models to help agencies estimate the cost of acquiring parcels. Their analysis indicates that in full property acquisitions, the value of improvements is typically more important than the value of the underlying land, while in partial acquisition, the size and shape of the remainder as well as characteristics like parking and access are significant in determining damages.

Linné, Mark R. and Michelle M. Thompson. 2010. Visual Valuation: Implementing Valuation Modeling and Geographic Information Solutions. Appraisal Institute. Chicago, IL.

The three sections of this book target readers at different levels of sophistication. Early chapters instruct the technological neophyte trying to get up to speed on the issues. Later chapters address the power user who is comfortable with practical applications of the technology. The final chapters explore the academic arena, where experts apply the most sophisticated modeling techniques in original research work.

Morgan State University, Institute for Transportation. July 2004. "Geographic Information System Implementation of State Department of Transportation Right-of-Way Programs." Prepared for the Office of Real Estate Services, FHWA, www.fhwa.dot.gov/realestate/rowsurvjuly04.htm

As part of its report for the FHWA Office of Real Estate Services, the Institute for Transportation at Morgan State University surveyed the use of GIS by eight state DOT ROW programs. The Maryland Department of Transportation utilizes ESRI ArcView GIS in the ROW acquisition process to display tax assessment data visually. Certain districts of the NYSDOT also use GIS to digitize the geographic features of properties being considered for acquisition. The Minnesota and New Mexico DOTs also indicated that they used GIS for ROW acquisition.

Transportation Research Board. NCHRP Synthesis 229: Applications of 3-D and 4-D Visualization Technology in Transportation. 1996

This NCHRP publication describes the application of computer graphics to transportation practice. The publication is intended for transportation planners, facilities design and construction personnel, and traffic engineers. The report of describes the use of 3-D and 4-D as well as the requirements of hardware and software, costs, production time, and issues of complexity.

Transportation Research Board. NCHRP Synthesis 372: Emerging Technologies for Construction Delivery. 2007.

Chapter 5 describes the use of 3-D modeling and visualization for Automated Machine Guidance purposes.

Transportation Research Board. January-February 2007. "It's About Decisions: Advancing Transportation Project Development with Visualization Technologies." *TR News*. http://onlinepubs.trb.org/onlinepubs/trnews/trnews248.pdf

This article provides an editorial perspective describing a leading intent of visualization technologies.

Transportation Research Board. September-October 2007. Visualization in Transportation: Empowering Innovation." *TR News.* http://onlinepubs.trb.org/onlinepubs/trnews/trnews252.pdf

TR News presents an issue that focuses specifically on the use of visualization technology in transportation, featuring articles by several transportation professionals. Michael A. Manore, Chair of the TRB Visualization Committee, generally defines visualization as "any progressive visual means of representing static or temporal spatial and geometric information." Alan E. Pisarski, a member of the Urban Transportation Data and Information Systems Committee, illustrates the growing need for visualization in transportation, suggesting that visualization allows the public to envision complex information, and facilitates their buy-in for investing in large, expensive, and necessary transportation projects. Doug Walker, president of the visualization software and consulting firm Placeways, LLC., echoes Pisarski's message, highlighting the importance of community concerns in the project development process and the need for visualization as a common language through which experts, stakeholders, and the community can communicate. Finally, Charles L. Hixon III, the consultant for NCHRP Synthesis 361: Visualization for Project Development, notes several considerations for transportation agencies interested in employing visualization technology. He recommends that visualization be fully integrated into the planning process so that the costs are amortized. He also suggests that transportation agencies should house visualization staff in a specialized unit to provide the greatest opportunity for training, and to spread the cost of visualization over the entire agency rather than only to specific projects.

USDOT. 2002. Acquiring Real Property for Federal and Federal-Aid Programs and Projects. FHWA Publication No. FHWA-PD-95-005.

Volpe Center. July 2009. Applications of 3-D Visualization: Peer Exchange Summary Report. Prepared for FHWA's Office of Interstate and Border Planning. www.gis.fhwa.dot.gov/documents/PeerEx_report_3-D.pdf

On July 8–9, 2009, The FHWA's Office of Interstate and Border Planning sponsored a peer exchange to promote the use of three dimensional visualization technologies within transportation agencies. The peer exchange included presentations from the North Carolina, New York State, Minnesota, and California DOTs as well as the Baltimore Metropolitan Council and the Volusia County Metropolitan Planning Organization. The presenting agencies noted common challenges, including a difficulty determining the effectiveness of visualization tools and gaining support from upper management, difficulty organizing visualization staff within the organization, and difficulty ensuring that visualizations are used in the most appropriate and effective manner. Certain participants also emphasized the importance of developing true-to-life visualizations rather than idealized versions of a project. The key themes highlighted during the peer exchange were that visualization techniques allow transportation agencies to converse with a wide range of stakeholders, but agencies need a way to evaluate the effectiveness of visualization, develop a channel for hiring and retaining qualified visualization designers, and facilitate training and information sharing between transportation visualization specialists and practitioners from the overall industry.

Volpe Center. November 2007. Visualization Case Studies: A Summary of Three Transportation Applications of Visualization. Prepared for FHWA's Office of Interstate and Border Planning and Office of Project Development and Environmental Review. www.gis.fhwa.dot.gov/documents/visual_toc.htm

In 2007, the USDOT Volpe National Transportation Systems Center, in coordination with the FHWA developed three case studies on the use of visualization techniques by the Arizona, Ohio, and Wyoming DOTs (ADOT, ODOT, and WYDOT, respectively). As part of an improvement project for its Interstate 10 corridor, ADOT proposed replacing an existing interchange with a design that accommodates both express and local lanes. In order to communicate the complicated proposed design to the public, ADOT created a video simulation that it showed during three public meetings. Following the display of its visualization, ADOT noted that it was effective in engaging the public and increasing support for the project. ODOT employed visualization to quantify the impact of a proposed rail grade separation following a finding of adverse affect by the Ohio State Historic Preservation Office (SHPO). As part of a Visual Impact Assessment Report, ODOT created a drive-through simulation of its proposed project that enabled the Ohio SHPO to better understand the projected impacts of the project. Finally, WYDOT required the use of visualization in proposing alternatives for managing landslides along an existing alignment. It chose to enlist a consultant to create a series of photo-simulations and animations that would show the anticipated impacts of each alternative on the surrounding environment. The creation of these visualizations aided the U.S. Forest Service and the Wyoming Fish and Game Department in quantifying the impact of each alternative during the environmental review process.

Volpe Center. March 2009. "Visualization in Transportation: Five Case Studies." Prepared for FWHA's Office of Project Development and Environmental Review.

As a follow-up to its 2007 summary of three case studies in the use of visualization in transportation agencies, the USDOT Volpe Center, in coordination with the FHWA, developed five additional case studies to document the use of visualization techniques by state departments of transportation. The case studies focused on the Washington state DOT, the Idaho Transportation Department, the Vermont Agency of Transportation (VTrans), the NCDOT, and the Massachusetts Highway Department, all of which had used visualization for public and stakeholder involvement during the transportation planning process. VTrans, in particular, had used video simulations in evaluating alternatives for redesigning an especially contentious intersection. In addition to allowing the public to understand the operations of each proposed alternative, the visualization illustrated to the public the need for VTrans to acquire property to build each option, and even showed VTrans where they could afford reduce the acquisition of surrounding parcels.

Waltersheid, David. October 23-26, 2006. "Use of Visualization Technology for ROW Acquisition and Eminent Domain." Presentation to 5th International Visualization in Transportation Symposium and Workshop. Denver, CO. www.teachamerica.com/VIZ/08_Waltersheid/index.htm

David Waltersheid from the FHWA Office of Real Estate Services presented several examples of the use of visualization technology for the right-of-way acquisition process to the TRB 5th International Visualization in Transportation Symposium and Workshop. Examples included projects from Texas and Florida in which the acquiring agency used three-dimensional computer visualizations to communicate to landowners the projected impact of a project to their property. In one instance, a three-dimensional animation was used to communicate to a jury the anticipated effects of a project on a commercial property, which reduced the land owner's claim of just compensation from $2 million to an award of about $200,000.

APPENDICES

Appendix A. Stakeholder Contacts
Appendix B. Phone Discussion Guide
Appendix C. Additional Resources
Appendix D. Example Property Owner Feedback Survey
Appendix E. AASHTO Survey on Visualization for ROW Acquisition
Appendix F. Example Specifications and Deliverables for a Visualization Scope of Work
Appendix G. Caltrans GIS Marketing Documents

Appendix A. Stakeholder Contacts

Bentley Systems, Inc.	Jackie Cissell 828-505-2050 Jackie.Cissell@bentley.com
Caltrans	Don Grebe 916-654-4456 Don.Grebe@dot.ca.gov
FHWA Resource Center	Mark Taylor 720-963-3235 Mark.Taylor@dot.gov
Florida DOT	John Garner 850-414-4545 John.Garner@dot.state.fl.us
Halff Associates, Inc.	Jeff Christiansen 214-346-6365 jchristiansen@Halff.com Mark Janicki mjanicki@Halff.com
Missouri DOT	George Kopp 573-751-7886 George.Kopp@modot.mo.gov
New York State DOT	Marci Sammons 518-458-2442 msammons@dot.state.ny.us Bob Dudley rdudley@dot.state.ny.us
North Carolina DOT	Tom Childrey 919-571-4191 tchildrey@ncdot.gov David Hinnant 919-212-3126 dbhinnant@ncdot.gov
Office of the Attorney General of Texas	Cavitt Wendlant 512-936-1151 Cavitt.Wendlant@oag.state.tx.us
Ohio DOT	Wayne Pace 614-995-3541 Wayne.Pace@dot.state.oh.us
Transportation Research Services, Inc.	Brad Rodenberg 719-494-8067 Brad.Rodenberg@trscorp.us

Appendix B. Phone Discussion Guide

1. **Please tell us your title and describe your main project responsibilities.**

2. **In what capacities have you used visualization tools and techniques other than for ROW acquisition?**
    - o Who are the primary users and audiences?

3. **How did you first learn/think about using visualization for ROW acquisition? How were you introduced to the concept?**

4. **Did you do/review any research on other agencies' use of visualization for ROW acquisition?**

5. **Can you describe some specific situations/circumstances that called for using visualization for ROW acquisition purposes? What ROW acquisition need does/can visualization fill?**

6. **Before you used visualization for ROW acquisition, how did you carry out the uses or communicate the relevant information/concepts to stakeholders? What, if anything, did visualization replace?**

7. **Do you develop the visualizations in-house or do you hire consultants? If consultants, who?**

8. **Can you estimate the development costs for a typical visualization application for ROW acquisition purposes?**
    - o When you consider the costs of visualization for ROW acquisition, do you view it as a cost associated primarily with the ROW process, or have you analyzed how the cost is spread over the entire project development spectrum?
    - o What was the cost of developing/purchasing the visualization application relative to the total project development cost, or overall project delivery costs?
        - E.g., can you comment on the cost of developing a visualization tool compared to the potential increase in project costs due to construction delays?
    - o Do you include staff training or maintenance costs in your calculation of the total cost of developing/purchasing the visualization application?

9. **What lessons learned/best practices can you share about <u>pricing/costing/investing</u> in visualization applications/tools/services based on your experience?**

10. **Have you evaluated the benefits (actual cost-benefits or other) of using visualization?**
    - o Have you compared and contrasted different visualization methods/techniques for relative effectiveness? How have you done so?

11. **As a user, what have been the <u>challenges</u> of using visualization for ROW acquisition?**
    - o If you could do it all over again, would you have invested in the same tools for the same purposes? If no, what would you change?

12. **Have you received feedback from <u>stakeholders</u> about the relative benefits/advantages or disadvantages of using visualization for ROW acquisition?**
    - o How did you collect their feedback? What did they say?

13. **Do you have any ideas regarding what makes ROW acquisition so different such that visualization uses have not seeped over into the field yet as much as in other areas?**

14. **Do you believe there is value in posting visualizations to social networking websites?**

15. **What advice would you give to other states that are thinking of undertaking a similar project?**

Appendix C. Additional Resources

NYSDOT Visualization Request Form

Instructions:
Fill out the information below and e-mail or fax your request to: mshaul@dot.state.ny.us
fax: 518-457-6887 The Visualization Section may be reached by calling 518-485-2442.

General Information:

Project Name:

Contact Name: PIN #:

Phone Number: Date Needed:

Regional Data Manager:

Visualization Objective:
What are your visual communication needs? Who is your audience?

Project Phase:

- ☐ Planning (IPP or EPP)
- ☐ Prelim Design (Phase I-IV)
- ☐ Final Design (Phase V-VI)

Project Type:

- ☐ Intersection/Roundabout
- ☐ Highway
- ☐ Bridge Structure
- ☐ Planning
- ☐ Visual Impact
- ☐ Other (explain)

Visualization Type:

- ☐ 2D Quick Photosim
- ☐ 3D Photosim
- ☐ 3D Rendering
- ☐ 3D Animation
- ☐ 3D/4D Content

Deliverable Form:

- ☐ Image File(s)
- ☐ Video File(s) - playback method: ☐Web ☐PC ☐TV
- ☐ Interactive Multimedia

Visualization Products

2D Quick Sim
Used for quick, illustrative purposes, this product does not claim to be highly accurate, but it can convey a design intention quickly without relying on accurate 3D geometry. This product relies predominately on image editing and hand rendered perspectives.
Time requirement: 2-4 days* each

3D Rendering
3D renderings are images generated entirely from three dimensional geometry (models). Usually, the geometry will have patterns (images) attributed to them to make them appear more photorealistic. Once a model is render ready, subsequent images are easily created from other locations.
Time requirement: 1-2* weeks each

3D Photosim
Excellent for depicting multiple design alternatives, this product requires a high resolution photo, from a known location, as the foundation. Once a 3D model has been created and patterned with photorealistic materials, a virtual camera is then positioned from the same coordinate location, and a rendering of the geometry is made. Support photos may be required if substantial portions of the photo are being removed (ie. foliage, buildings, etc.) Combining the photograph and the rendering makes it nearly complete. Some image editing is usually required to complete the final montage.
Time requirement: 1-2 weeks* each

3D Animation
Once a 3D model has been created and patterned, a virtual camera can travel through a modeled environment, down a defined path, to capture what is seen, or a still virtual camera can record the animated motion of discrete objects. Thirty images per second are recorded, saved and compiled to a video file. Changing the defined path or camera location requires a regeneration of animation frames.
Time requirement: 2-6* weeks

3D/4D Model Content
To populate a 3D computer grahics model, virtual content is used to represent real world objects. Examples could be buildings or other structures, lighting, signage, automobiles, or 3D terrain. Content can be created to populate Microstation and VISSIM 3D environments. Comprehensive 3D environments require considerable more time than simple discrete 3D objects.
Time requirement: 1-3* weeks

Appendix D. Example Property Owner Feedback Survey

***INSTRUCTIONS**: The cover letter below could be used as a guide to introduce a survey intended to collect feedback on the experience of showing property owners a visualization presentation.*

[State] Department of Transportation
[Date]

Dear Property Owner:

You are receiving this letter because you were contacted at your home or business by a representative from the *[Right of Way]* office from *[State]* DOT. This meeting was regarding the agency's need to acquire private property for the upcoming *[project]*.

[State] DOT would like to ensure that property owners have a clear understanding about the purchase of private property for Right-of-Way. *[State]* DOT is testing current methods of presentation tools to make it easier for a property owner to comprehend a proposed change. *[State]* DOT would like to continue to improve on our site visits and discussions with property owners.

Please respond to the enclosed survey so that *[State]* DOT can better serve the public *(The survey could be made available online)*.

Please call if you have any questions.

Thank you,

[Name]

[State DOT contact name and contact number]

INSTRUCTIONS*: The survey below could be used as a guide for developing your own feedback-collection survey.*

State **DOT Right of Way Representative Site Visit Survey**

Please answer the following questions about the ROW staff visit to your home or business.

1. Please indicate if you had a DOT right of way representative visit you in the past year. If yes, during which month?

2. Please state if the DOT representative visited you about your home or business.
   a. Home
   b. Business
   c. Other, please state here

3. Please state if this is the first visit by a DOT representative?
   a. Yes
      If yes, how many visits have you received from a ROW representative?
   b. No

4. How well did you understand the impact to your land that will result from the DOT's planned right of way purchase after the visit?

Not at all		Neutral		Completely
1	2	3	4	5

5. How did the representative communicate the project and the planned take to you? Circle all that apply.
   a. Aerial photos
   b. Plan drawings
   c. Site walk through
   d. 3-D physical model
   e. 3-D images on paper
   f. 3-D images on a computer
   g. Video played on a computer
   h. Other, please explain below
   i. Not sure

6. Did you feel that this method(s) was informative?

Not at all		Neutral		Completely
1	2	3	4	5

7. How positive did you feel toward the DOT representative after the visit?

Not positive		Neutral		Positive
1	2	3	4	5

8. What could the DOT representative do differently to improve future visits?

9. Please provide additional input about the visit to your home or business.

Thank you for your input on this survey. Your answers will inform *[State]* DOT of their current practices and inform our staff on how to improve on future site visits.

***NOTE**: The example survey above was adapted from a Mn/DOT survey that was offered to property owners after Mn/DOT made initial visits to the owners' places of residence or business. The Mn/DOT survey was distributed as part of a pilot project to assess the effectiveness of using visualization for ROW acquisition.*

Right of Way Initial Visit Survey

Please answer about the **initial visit at your place of residence or business**, as best you can recall.

1. In which month were you visited by a Mn/DOT Real Estate Representative?

   ____________________ (please write in month)

2. For the following, please circle a number from 1-5, with 1 meaning "not at all" and 5 meaning "completely." A 3 means "I am neutral," and write in "Don't know" if that applies.

	Not At All		Neutral		Completely
a. How well did you understand the impact to your land that will result from Mn/DOT's planned Right of Way purchase, after the visit?	1	2	3	4	5
b. How clear (not confusing) were Mn/DOT's maps and layouts?	1	2	3	4	5
c. How positive did you feel toward Mn/DOT, after the visit, in light of the need to purchase some of your property?	1	2	3	4	5

3. Did Mn/DOT's Real Estate Representative show you a video representation of what the project will ultimately look like, or not?

   (circle): YES - NO - DON'T REMEMBER

4. Please provide any input you may have about this first visit to your home or business by the Mn/DOT Real Estate Representative.

   ____
   ____
   ____

We very much appreciate your time and willingness to give us input.
We know this may be a difficult transition, but your answers will help Mn/DOT understand the clarity of materials as presented to property owners.

Please return this survey in the envelope provided.

Appendix E. AASHTO Survey on Visualization for ROW Acqusition

2008 International Scan Identified visualization

Requested by: **State of Texas**
Survey Deadline: **February 28, 2010**

The 2008 International Scan identified visualization as having potential to improve the ROW acquisition process and build relationships with property owners.

1. May we contact you in regard to your experience with Design Visualization as a suitable tool for ROW acquisition? Please provide contact information for a good resource to contact. Name, agency, phone number:[17]
2. Briefly describe how Design Visualization can be a cost effective tool to facilitate ROW acquisition?
3. Are procedures or methods available that can help determine best practices for the specific application of acquiring ROW, or for other Realty related purposes?

Thank you for your time and assistance.

ARKANSAS

The Department uses simulation models to analyze how well the traffic will flow, not anything that relates to ROW Acquisition.

GEORGIA

We are not use Design Visualization; however it looks like a tool to look into.

MICHIGAN

We are beginning to use visualization for some major projects but it is not yet the norm.

MINNESOTA

We have tried this on a very limited basis, and cannot meaningfully contribute on this.

MISSOURI

1) Design Visualization is fairly expensive and would only be cost effective on projects where the property values are very high or in areas where there are several contentious property owners. For an average project, we have not found Design Visualization to be cost effective.

2) We consider the use of Design Visualization on a project-by-project basis.

NEW YORK

1) Design Visualization can be a cost effective tool to facilitate ROW acquisition by providing better service to the public and save negotiations time. The benefits would include less time in using traditional methods, maps, cross sections and specially prepared exhibits, to negotiate damages; reduce the confusion of how to anticipate changes to their properties; result in higher quality appraisal products through more accurate analysis of impacts, thereby reducing the need for settlement justifications later on in the process once the project is completed and the impacts fully understood, and, ultimately saving on negotiations breaking down and cases ending up in the Court of Claims.

[17] Names and contact information have been removed from the states' responses.

2) Are procedures or methods available that can help determine best practices for the specific application of acquiring ROW, or for other Realty related purposes? No – none as a standard at NYSDOT, but I strongly condone implementing this method.

OHIO

1) The cost effectiveness for ROW acquisition can reduce the appropriation rates because property owners would have a better understanding of the impact to their property. Reduce the unknown for property owners by providing a post construction visual of their property. To aid the Appraiser in the evaluation of impact for the damage to the residue, as well as assist the Review Appraiser to determine the recommended FMVE. Improve public relations at public information meetings to show what the project will look like at post construction. Have a better understanding of the actual construction plans to see the elevation changes to a parcel.

2) Yes, ODOT uses Personal Service Contracts as a method to hire consultants that are able to perform the visualization task.

A best practice to determine the need for this application is based on the complexity of the project or parcel and anticipating if the parcel would be appropriated. It is not recommended to use on every parcel because of the time commitment and the cost per parcel for preparation.

PUERTO RICO

Currently we only use aerial photos with cadastral layers, and some time with row plan sheets with Arc map (GIS). I will love to have more information about this kind of technology because we are trying to bring it to this area but so far with no luck.

SOUTH DAKOTA

South Dakota does not use visualization for ROW activities.

Appendix F. Example Specifications and Deliverables for a Visualization Scope of Work

The list below includes example considerations that should be made when determining and negotiating what visualization services are sought. It should be noted that not all of the example specifications and deliverables listed below apply to all visualizations.

Potential Specifications and Considerations

- **Purpose of Visualization.** Identify the purpose of the requested visualization. For example, is the purpose to convey what the future experience could be like or to identify particular facilities and precisely where they will be located?

- **Scale and Accuracy**. Scale is the size of features in a visualization relative to those features' actual size. Similarly, accuracy is the degree of closeness of measurements of features to their true values. These concepts hold whether the visualization is traditional or advanced. Include specifications on the scale and minimum accuracy of the presentation requested in statements of work for visualization services.

- **Duration**. Include durations for the visualizations required. If different visualizations will be created (e.g., one to post on the Internet and one to use on laptops in the field), durations for each should be specified.

- **Perspective**. Include indication of the number of view angles that are expected. For advanced visualization, the scope might also indicate whether more advanced functionalities, such as being able to observe relevant details in a 360º environment, are required.

- **Should users be able to modify the viewpoint of the visualization?** In an animation, the viewpoint or path is chosen ahead of time. Once the animation has been developed its viewpoint cannot be modified without completely recreating the animation. Real-time simulations do not have this limitation; however, they can be more costly.

- **Aspect Ratio**. The aspect ratio of an image is the ratio of the width of the image to its height. Include information on the desired or required aspect ratio.

- **Will additional nearby features be included?** Include specification of whether the visualization will incorporate features such as people/pedestrians, moving water, lighting, and textures, colors, materials, or finishes consistent with the plans, concepts, and designs provided. Articulate whether, and to what degree, areas adjacent to the project site(s) will be modeled and displayed. This is especially important in advanced visualizations, as some viewers may expect those types of models to reflect reality to a greater degree than with traditional visualizations. Viewers may also expect each element depicted in a visualization to be rendered with extreme realism, regardless of its relevance to the focus of the visualization (e.g., power lines along a roadway). Therefore, it may be necessary to omit certain features that do not need to be portrayed in the interest of reducing the amount of measurement and rendering necessary, and eliminating potential points of distraction.

- **Will existing and proposed features both be displayed?** Describe the degree to which features or visual cues, such as interchanges, buildings, landscaping, and related structures will balance realism (the existing built environment) with future project phases. A visualization might be developed to show only existing conditions, only future conditions, or both, as in a 3-D flyover where a transition to future conditions might be seamlessly simulated.

- **Interactivity**. In the case of advanced visualizations, describe whether the visualization will include "hot spots" where the user is able to zoom and pan at a specific location. The scope might also describe whether users should be able to accelerate or decelerate the visualization.

- **Data Already Available**. Include a list of the data already on hand. A project manager could inventory and report whether the following data, for example, are available to the entity developing the visualization: auto-turn data; high-resolution ground photography; 3-D topography; road geometry and schematics; striping plans; planometrics; aerial data; grading plan; any state specific design standards; traffic counts; current site plan; digital terrain map; CAD files of the existing and proposed structures; information on landscaping.

- **Environment Required**. Include a discussion of whether specialized computer hardware or software programs will be required to view the visualization. It might also include the environment or medium (i.e., computer, hardcopy, or physical model) that the visualization is ultimately to be displayed in. For visualizations to be displayed in a computer environment, describe whether the project manager is requesting the visualization be navigable in a web-based environment, a laptop environment, both, or some other environment. A deliverable could be information on minimum hardware and software requirements. Another specification could be to require the visualization developer to provide installation packages for a variety of computing environments (e.g., Windows XP, Mac OS X, Linux, etc.). Alternatively, web-based dissemination where the visualization runs through a web browser would eliminate the need to download and install the visualization.

- **Technical Support Required**. Include a description of whether ongoing technical support will be required once the visualization has been produced and approved. Example technical support activities include running or demonstrating the visualization on a computer or troubleshooting problems with playback. Consider including language that allows for the preparation for and testifying in court hearings as an expert witness to attest to the accuracy of a visualization and the methods used to create it. An organized training program that transfers knowledge about using the visualization to practitioners in the field would also be helpful. A multifaceted education, outreach, and training program can be an important component to effectively using visualization for ROW acquisition.

- **Revisions Required**. Include indication of how many draft versions of the visualization are necessary. Some common points of review are at 50 percent and 90 percent completion. Indicate whether the visualization should be editable to accommodate for the following at a future date: changes to the structures as future phases are constructed or modifications occur at the visualized site; the ability for a production house to incorporate background music, narratives, and other media throughout the visualization. A deliverable could be an intermediate, draft visualization(s), including an agreement on the number of revisions to be provided.

- **Ability to Accommodate "Add-ons."** Include a description of whether the visualization should be developed with the ability to be integrated with other components or services in the future. For example, the scope might describe whether the visualization could be made viewable in a real-time Google Earth or whether project timeline animations could be added. A project timeline animation might identify project phases or funding expended as the user travels in the virtual tour.

- **Method of Visualization Delivery**. For advanced visualizations, include requirements for how the visualization will be delivered. Some examples formats are physical model, hardcopy print out, visualization in a zip file, visualization on a CD-ROM or DVD, or visualization on a website. Request that documentation of the visualization development methodology be delivered.

Appendix G. Caltrans GIS Marketing Documents

The following could be used as a model for a marketing document for visualization services.

Implementing an Information Management System in Right-of-Way Offices
An Overview for Executives

Increasing responsiveness and maximizing resources are important factors in how transportation agencies improve their business in today's data-driven, performance-based environment. The ability to deliver projects on time and within budget is one measure of a transportation agency's performance. The effective delivery of real property by the right-of-way office is fundamental to achieving this agency objective. A well designed and implemented information management system can substantially improve this capability. Adding geospatial capabilities (GIS) to the system to replace reliance on hardcopy maps and tabular information and to give additional management and analysis functions can significantly increase its usefulness.

Understanding the critical factors necessary to successfully implement an information management system can ensure the best value for the necessary outlay in resources and can substantially improve the realization of the system's full potential. Obtaining strategic buy-in from agency executive-level decision makers to pursue implementation will provide the necessary foundation for system.

Implementing a System

The process to implement an information management system is well documented and follows standard procedures:

- Formalize support
- Assess requirements
- Assess capabilities
- Define the system
- Develop an implementation plan
- Implement the system
- Maintain the system

Implementation is typically considered complete at the point when the system being implemented has transitioned to "business as usual" for its users.

Implementation Responsibilities

- ***Project champion:*** This person is typically known and trusted by agency management and is responsible for marketing and promoting the system both inside and outside the agency.

  Without an identified champion, history has shown that projects flounder at the first major challenge.

- ***Steering group:*** The steering group is responsible for ensuring that there is active and appropriate input and feedback to the system during the implementation process.

  Transportation agencies consist of multiple departments and offices responsible for different aspects of doing business. Without representation from each group that will be impacted by the system, the system will face numerous challenges including: a) meeting agency information technology (IT) requirements, b) obtaining buy-in from stakeholders, and c) coordinating data sharing between data owners and users, as well as performing the tasks necessary to support right-of-way activities.

- ***Project manager:*** The project manager is responsible for the day-to-day management of the process.

This person must have the necessary skills, authority and resources to coordinate sometimes conflicting input from the groups and individuals involved in the process. The project manager must also have the organizational skills to ensure that the process stays on track and within design boundaries and sufficient technical understanding of the right-of-way process and individual functions to reasonably evaluate input during the development process.

- ***Development team:*** The development team consists of the people who will actually be developing the system.

  They can be wholly from within the agency or wholly contracted from outside or a combination of both. The importance, at the proposal stage, is that the skills necessary to the project be clearly identified and articulated.

Implementation Factors

- ***Assessing requirements***: Any proposal for a new information system should include a clearly stated understanding of the scope and goals of that system. As these requirements are refined, consideration should include the business areas to be included (often referred to as the *enterprise*), the functions that should be performed, the data needed to support these functions, other systems that should interact with the proposed system, security issues, and any legal and regulatory requirements.

- ***Assessing capabilities***: An understanding of the capabilities in the right-of-way office and across the agency is critical to successfully implementing a system. Considerations include available or required hardware and software, existing applications including database management systems and GIS, datasets along with who is responsible for them, and agency policies and procedures related to IT including application development, data and data standards, and hardware and software acquisition. Knowing who will be responsible for maintaining the system and any corresponding data and output is also necessary. Availability of funding for development and continued maintenance is critical to the project's success.

- ***Defining the system***: This is the core of the system and will be the basis for the tool that manages the information associated with right-of-way offices. The technical considerations will be included in the detailed implementation plan. An important aspect of this definition is knowing the starting point for system development. Three common starting points include:
  - ♦ The system is being developed from scratch with no existing information management system or GIS.
  - ♦ The system is expanding on an existing information management system to include GIS.
  - ♦ The system is being developed to take advantage of existing GIS capabilities.

  Knowing this information will ensure that appropriate coordination is considered in the design.

Additional Considerations

The current evolution and expansion of technology is extremely rapid and most transportation agency policies and procedures are not designed to operate at the same rate of change. Innovative and flexible approaches to supporting improved information management tools could save money and time both in their implementation and use.

From concept to operation, a comprehensive information management system can take 12 to 24 months or longer, and, during that time, technology will become more powerful, faster, and more flexible at the same time that the general public will become more technologically sophisticated with fingertip access to information through smart phones and other similar devices. A flexible design can readily take advantage of this changing technology without requiring major modifications. However, waiting for the next advancement before initiating the process can, and often does, result in never starting.

Many transportation agencies are in the process of either designing or building an agency-wide infrastructure for sharing data and/or integrating computer systems. Although, the desire to fold individual systems into this larger initiative is compelling, the reality may be more problematic given the scale, complexity, and cost of the larger effort. With current technologies, consideration should be given to supporting individual systems if they provide the necessary connections to and support for integrating with the larger initiative.

For More Information

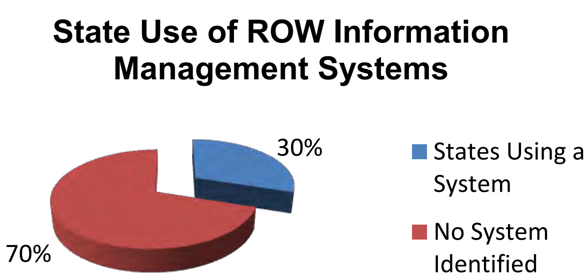
This document is part of the National Cooperative Highway Research Project 8-55A "Developing a Logical Model for a Geo-Spatial Right-of-Way Land Management System". The project was managed by Ed Harrigan EHARRIGA@nas.edu and was performed under Kathleen Hancock hancockk@vt.edu at Virginia Tech and was completed in 12/10. A detailed implementation guide was developed as part of this project and will be available through TRB.

Results of the first phase, 8-55 "Integrating Geo-Spatial Technologies into the ROW Data-Management Process", including the documented savings reported here, are available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_310.pdf and http://www.trb.org/news/blurb_detail.asp?id=7308

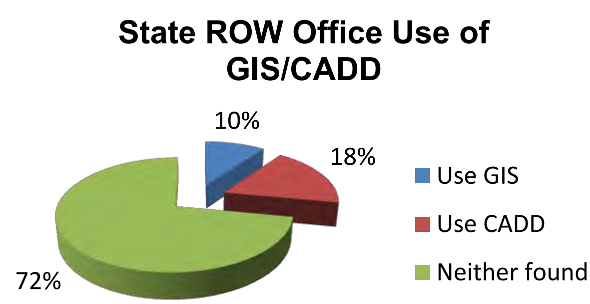
Improving Resource Management and Operations in Right of Way Offices with Right-of-Way Information Management Systems

A well designed and implemented information management system can substantially improve management of resources – **personnel**, **money**, **information**, and **time** – which is critically important to successfully meeting state performance goals and budgets. Adding geospatial capabilities (GIS) to the system to replace hardcopy maps and tabular information and to give additional management and analysis functions can significantly increase its usefulness.

In the Right-of-Way office, this is particularly



important because of the resources required to



deliver real property for transportation improvements and manage state-owned land.

BENEFITS

- **Improved on-time delivery of project real property**
- **Expedited project award**
- **Reduced staffing and/or improved staff efficiency**
- **Improved scheduling**
- **Improved access to information both internally and by the public**
- **Improved customer service and public relations**
- **Improved documentation and reporting uniformity**
- **Reduced time to perform tasks**
- **Reduced redundancy, primarily in data entry**
- **Increased management flexibility**
- **Improved oversight capabilities**
- **Improved integration, use, and sharing of information**

DOCUMENTED SAVINGS

- ***A return on investment of more than 21%***

  Pennsylvania invested $829,000 on a ROW information system that ***reduced annual operating*** costs by nearly $680,000 while providing ***greater convenience*** to users. Because the system integrates with their financial system, the time to process payments ***reduced from several days to several minutes.***

- ***Staffing reductions and improved on-time performance***

  In Virginia, the ROW information system provides over 500 staff and contractors all information on ROW projects, providing ***exceptional customer service***. Information is entered only once, ***eliminating duplication of effort***. ***Clear project tracking*** provides staff with a comprehensive understanding of the status of each project including resource allocation.

  In Maryland, ***research staff has been reduced by half*** because parcel and other geospatial information is available through the intranet. ***In-person courthouse research and travel time have been eliminated***.

  New Mexico uses GIS to generate summaries on excess property for sale to the public, ***reducing the time required*** to provide this information from several hours to several minutes. The information includes a map with an aerial photograph image background resulting in dramatically **reduced questions from the public**.

  Using GIS, the San Antonio district of Texas provides its staff with electronic access to project drawings, thus **eliminating the manual locating and reviewing of large drawing sets**. Drawings are accessed by simply clicking on a desired section of road.

- ***One-person project oversight and management of real estate activities***

  In Illinois, a multi-million dollar airport project is managed by a single person who has desktop **access to near real-time information** about the project.

RISKS OF NOT IMPLEMENTING A SYSTEM

A primary purpose of this type of information management system is to facilitate standard business operations and support information and decision making by providing easy access to both internal and external information relevant to meeting the goals and operational needs of the transportation agency and the real estate office.

Without such a system, decision makers are limited in their ability to monitor performance and identify opportunities quickly and make strategic adjustments to resource allocation as needed. The real estate office will be limited in its ability to respond to the rapidly increasing reliance on digital information exchange to perform its functions.

Expectations in the current technological environment are for faster, more accurate information with fingertip access to on-line maps. Without a geospatially enabled system, these expectations cannot be met for staff or the public.

FOR MORE INFORMATION

This document is part of the National Cooperative Highway Research Project 8-55A “Developing a Logical Model for a Geo-Spatial Right-of-Way Land Management System”. The project is managed by Ed Harrigan EHARRIGA@nas.edu and is being performed under Kathleen Hancock hancockk@vt.edu at Virginia Tech and is scheduled to be completed in 2/10.

Results of the first phase, 8-55 "Integrating Geo-Spatial Technologies into the ROW Data-Management Process", including the documented savings reported here, are available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_310.pdf and http://www.trb.org/news/blurb_detail.asp?id=7308