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Guidelines for the Use of Visualization

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CTE/NCDOT Joint Environmental
Research Program

Guidelines for the Use of Visualization

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16. Abstract

This document is the product of a research project into visualization in the design and public review of transportation facilities. The project's goal was to provide NCDOT engineers and managers with a basic primer on this relatively new technology in transportation. The project examined current NCDOT visulization applications and capability, desired or potential applications, advantages, disadvantages, and the appropriate visualization levels in a variety of situations. The objective of these guidelines is to provide transportation project engineers with basic, introductory information on visualization including terminology, available capabilities within NCDOT, advantages and disadvantages, types and examples of visualization, and effectiveness. These guidelines are not meant to provide an in-depth tutorial, but to familiarize the reader with the basic terms, concepts, and applications of visualization as related to the design and public review of transportation facilities.

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Introduction

The ability to 'picture' the final product of a transportation system development project and how that product will function is essential not only to the public involvement process but to the design process as well. Engineers, architects, designers, and planners alike are relying more and more on the use of visual simulations and computer generated models as a means of improving their ability to communicate more effectively, not only with the general public, but with their colleagues as well.

Rapid advances in the areas of information processing and computer graphics are quickly narrowing the gaps between the computer aided design (CAD) environment of the engineer, the traditional 'rendering' environment of the graphic artist, and the real time, ‘virtual' environment of the mutli-media practitioner. The result is that modern approaches to 'visualization’ with their ability to retain both the characteristics of *technical accuracy* and *photorealism*, are more and more providing the 'common ground' upon which consensus and mutual agreement are built.

The North Carolina Department of Transportation (NCDOT) is recognized as a leader in the field of visualization and its integration within the areas of design and public involvement. One of many examples of the NCDOT's successful use of visualization is its 1996 application of photo simulation methods to help the community of Valle Crucis, NC to evaluate alternative designs for the proposed replacement of a deficient two lane bridge on NC 194 over Crab Orchard Creed in Watauga County.

Figure 1. Valle Crucis Project (B-2179) Showing Roadway Approach to Bridge. Courtesy of NCDOT Roadway Design Unit

NC 194 is a North Carolina Scenic Byway through the beautiful countryside and historic areas north of the community of Valle Crucis. The location of the bridge was not a

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significant issue; however, the appearance and visual impacts to the community and adjacent property owners was a major concern. An earlier bridge replacement project over nearby Bairds Creek had erupted into a major controversy between the NCDOT and the local community. Media coverage was extensive, resulting in significant negative publicity. The Department was able to use easy-to-generate photo simulations to portray to the community how special enhancements to the conventional features of a standard bridge (e.g, special coloration of the bridge rails, beams, roadway guardrail, and landscape plantings) could result in a structure ideally suited to the ambiance of the historic community of Valle Crucis. Visualization permitted both the local citizens and members of the State Historic Preservation staff to easily recognize and appreciate the special de sign features. Construction was completed without any of the controversy and negative publicity that had been associated with the nearby Bairds Creek project.

Figure 2. Valle Crucis Project (B-2179). Existing Side View (Courtesy of NCDOT Roadway Design Unit)

Figure 3. Valle Crucis Project (B-2179). Side View (Enhanced) of Projected Design. (Courtesy of NCDOT Roadway Design Unit)

Figure 4. Valle Crucis Project (B-2179). Side View (Standard) of Projected Design. (Courtesy of NCDOT Roadway Design Unit)

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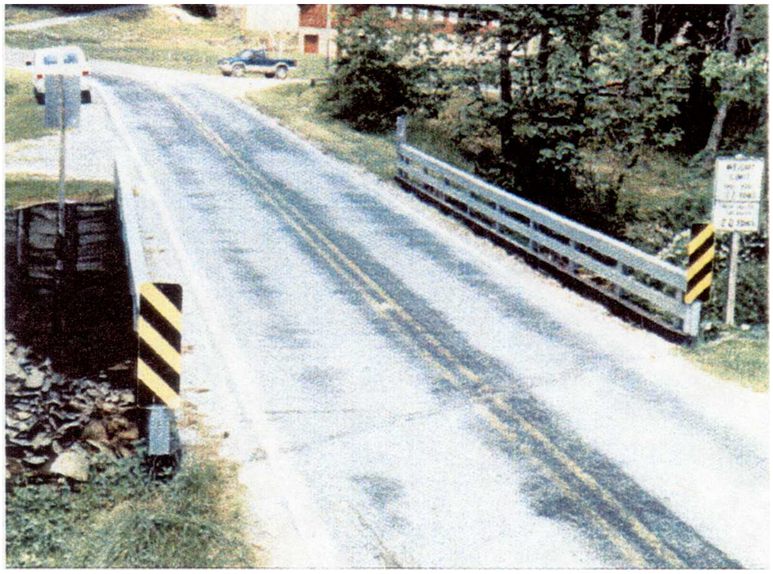

Figure 2. Valle Crucis Project (B-2179). Top View of Existing Condition. (Courtesy of NCDOT Roadway Design (Unit)

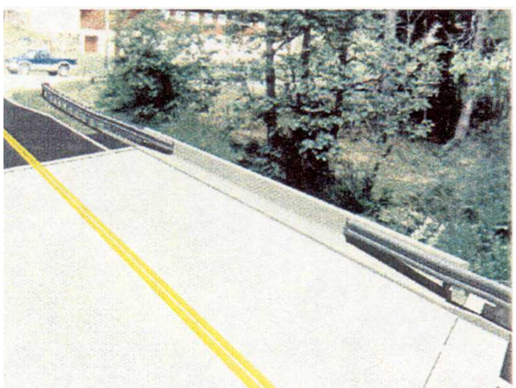

Figure 6. Valle Crucis Project (B-2179). Top View (Standard) of Proposed Design. (Courtesy of NCDOT Roadway Design Unit)

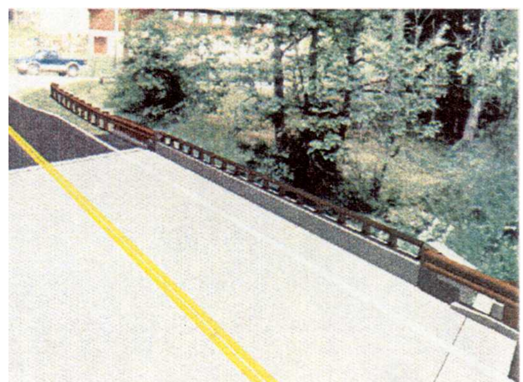

Figure 7. Valle Crucis Project (B-2179). Top View (Enhanced) of Proposed Design. (Courtesy of NCDOT Roadway Design Unit)

While photo simulations such as those used by the NCDOT on the Valle Crucis project will continue to be cost effective adjuncts to the Department's design and public involvement efforts, the term 'visualization' is taking on a much broader meaning. As we are now beginning to use the term, visualization refers not only the generation of photo realistic images but to the visual representation of *spatially-defined* data in all its varied formats. Depending upon whether ones orientation and area of expertise is Geographic Information Systems (GIS), the acquisition and use of aerial and satellite imagery (photogrammetry), computer aided design (CAD), or the development and use of real time, virtual environments, visualization is becoming more than simply the generation of the 'picture' but an area having responsibility for the collection, manipulation, and

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management of all sources of spatially referenced data. In the future, the NCDOT project engineer will not only be required to be familiar with each of these areas of spatial data representation, but will increasingly be required to understand how these various forms of spatial data can be effectively integrated. . . for design as well as public involvement.

While the term 'visualization' is quickly taking on a broader meaning, the goals and objectives of the visualization 'Guidelines' document listed on the next page are far less broad in scope. In essence, the purpose is to take what we have learned thus far about visualization (largely in the context of roadway design applications) and to put this information into a format that will permit those outside the immediate roadway design area (e.g, planning and environmental, traffic engineering, etc.) to develop effective applications in their own areas of expertise.

There are sections in the Guidelines that are important in helping the user develop a better understanding of *effectiveness* and the role played by visual and operational fidelity (realism), cost, and development time. As with all new technologies and engineering methods, visualization needs to be continually monitored and evaluated in order to identify its true contribution to the overall goals of the Department

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The Goal of the Guidelines

The goal of the 'Guidelines' *is not* to provide an in-depth tutorial on 'how it is done,' but rather to familiarize you with the basic terms, the concepts, and the applications you need to feel comfortable in

- ❑ Identifying where visualization may be helpful in your particular area.
- ❑ Developing and communicating the requirements for visualization support, and
- ❑ Understanding the key dimensions along which the effectiveness of visualization might be evaluated in actual applied settings.

Specific Objectives

The main objective of the "Guidelines" is to provide ***the NCDOT project engineer,*** enough information to feel comfortable in addressing each of the following questions or issues having to do with the use of visualization.

- ❑ What do we mean by 'visualization'?
- ❑ What visualization capabilities are available within the department?
- ❑ What types of visualization products and approaches are currently feasible
- ❑ What's the difference between 2D, 3D, and 4D?
- ❑ What's involved in using animation?
- ❑ What's the difference between 'real time' and 'non real time'
- ❑ What are the perceived advantages and disadvantages of visualization
- ❑ How do I balance effectiveness, cost, and time to develop considerations,
- ❑ Are 'realism' and 'technical accuracy' the same thing?
- ❑ How to distinguish between the need for visual fidelity and operational fidelity.
- ❑ Does visualization 'guarantee' public support?

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Remember

Because most of your initial efforts to use visualization will be in the area of public involvement, keep in mind these things:

- ❑ The 'facts' alone are not sufficient to ensure public acceptance of a proposed design

- ❑ The user will be favorably disposed to the '*facts*' only when they are consistent with the user's values (e.g, people do not give up smoking based upon the facts that link smoking to lung cancer). The public will not support a design simply because the design meets Department 'standards.'

- ❑ Think 'function' not just form. The user wants to be assured that the proposed design or improvement will not only 'look better' but will also 'work better' than the existing design.

- ❑ Remember to use visualization not only to show the physical details of the proposed design, but to convey the proposed '*benefits*' as well. For example, don't just show a median. . . show a pedestrian 'refuge' island. Don't just show trees, show how shade provides the traveler protection from the elements. Don't just show an empty sidewalk. . . show a family taking a walk.

Visualization, alone, is not a guarantee of public support, but it can go a long way toward fostering the type of cooperative, working relationship being sought between the NCDOT and the public which it supports.

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Section II

Section II provides you with actual ***examples*** of the types of visualization products that can be developed. This section shows you examples of visualization work done by the NCDOT as well as other state DOTs and firms in the private sector. An excellent source of other visualization examples, in particular the application of animation, is the Federal Highway Administration CD-ROM, FHWA-RD-98-173. The names of contact points for visualization at the different state DOTs are included in Appendix A at the end of the report. An inventory of the 'tools' used by the Minnesota and Washington DOTs is included in Appendix C.

For capabilities available within the NCDOT, and for additional advice on the feasibility of specific visualization products, your point of contact is:

Mr. Jimmy Norris
Roadway Design Branch
919-250-4016
JNorris@doh.dot.state.nc.us

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Section II

Examples of Different Visualization Treatments and Products

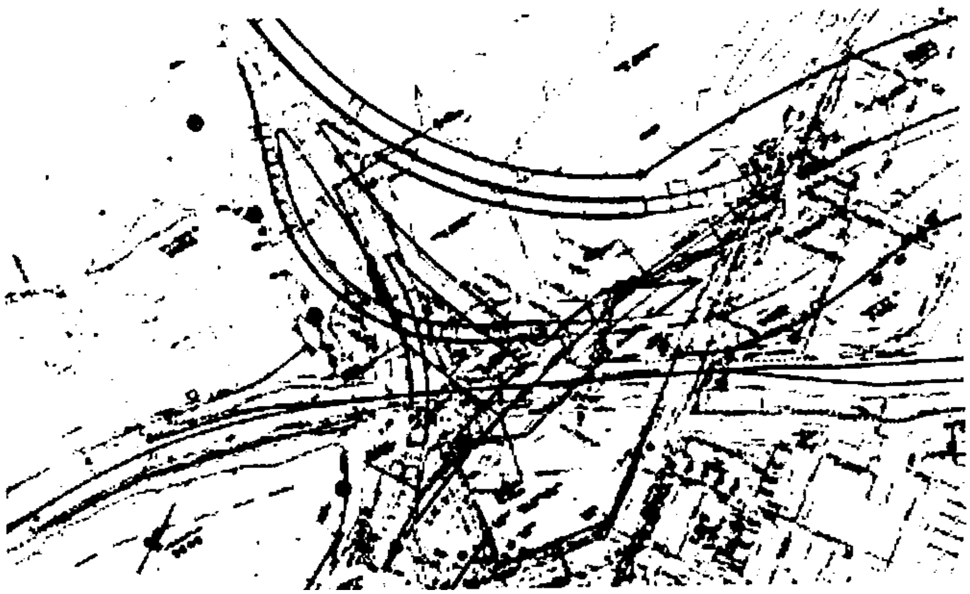

Figure 8. Example of 2D Engineering Drawing

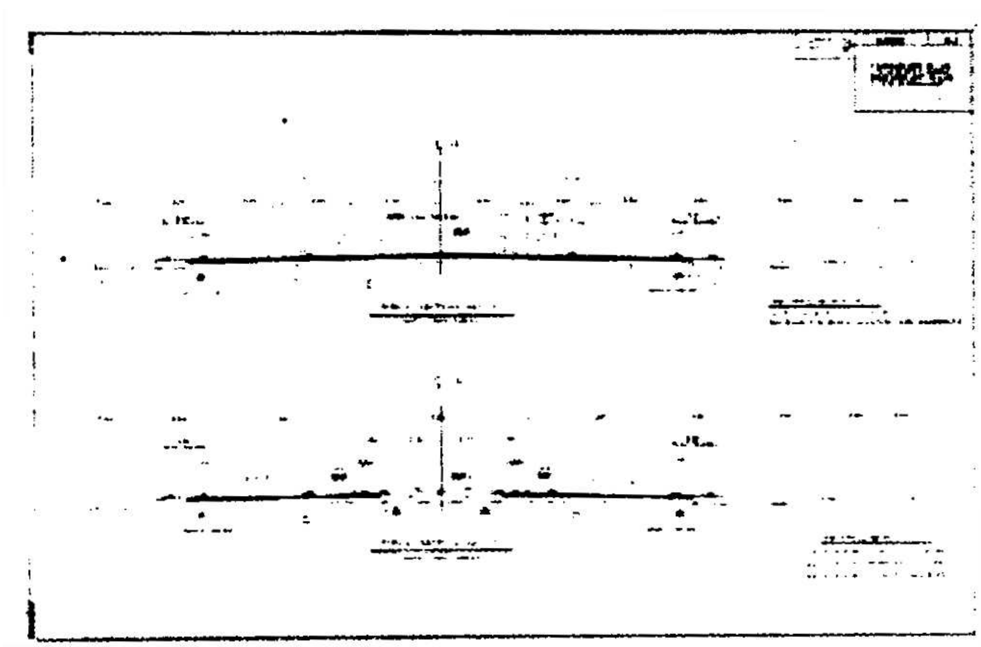

Figure 9. 2D 'Typical Section' Drawing

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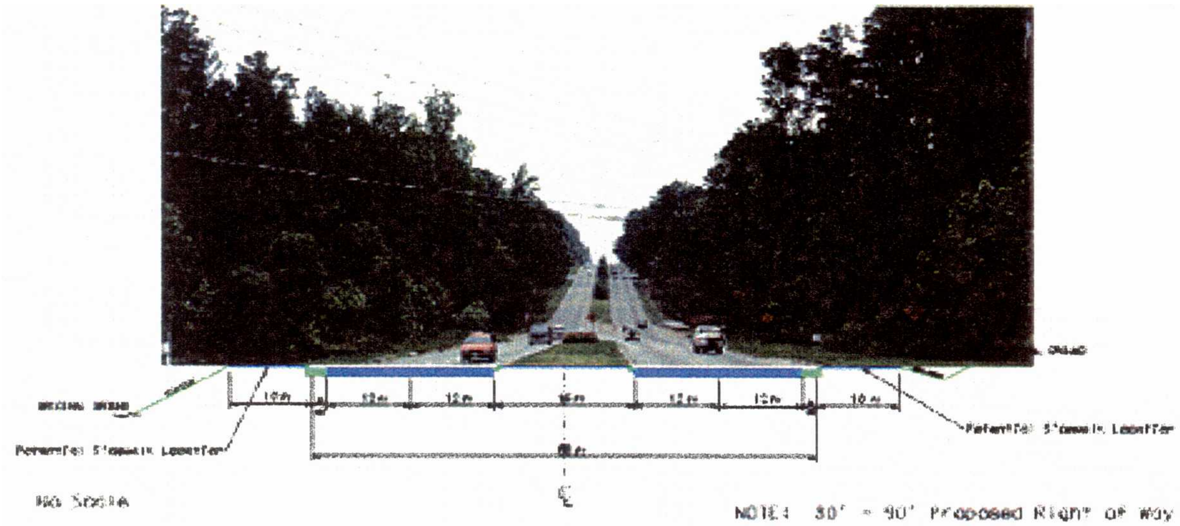

Figure 10. Example of "Modified" Typical Section Drawing With 2D Photo-Simulation of Project From Fixed Vantage Point.

Figure 11. Example of 2D Photo-Simulation Without Typical Section Information Included

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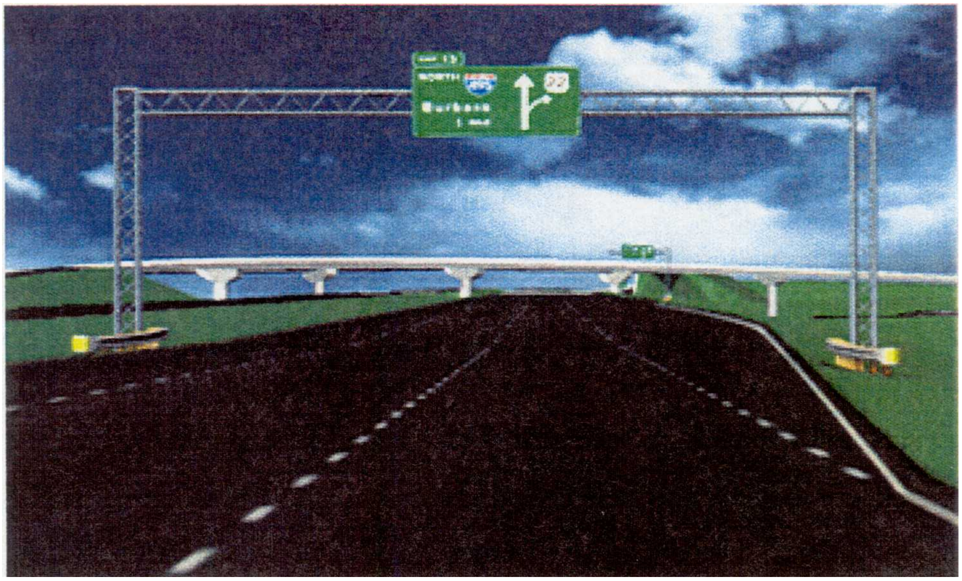

Figure 12. Visualization of Roadway Signs and Markings

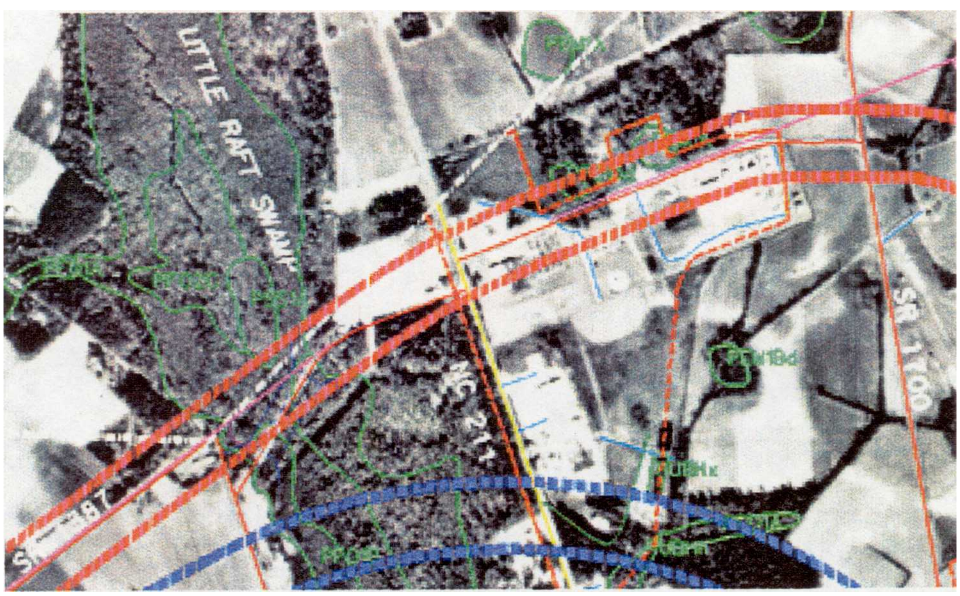

Figure 13. Example of 2D Aerial Photograph With Alignment Overlay

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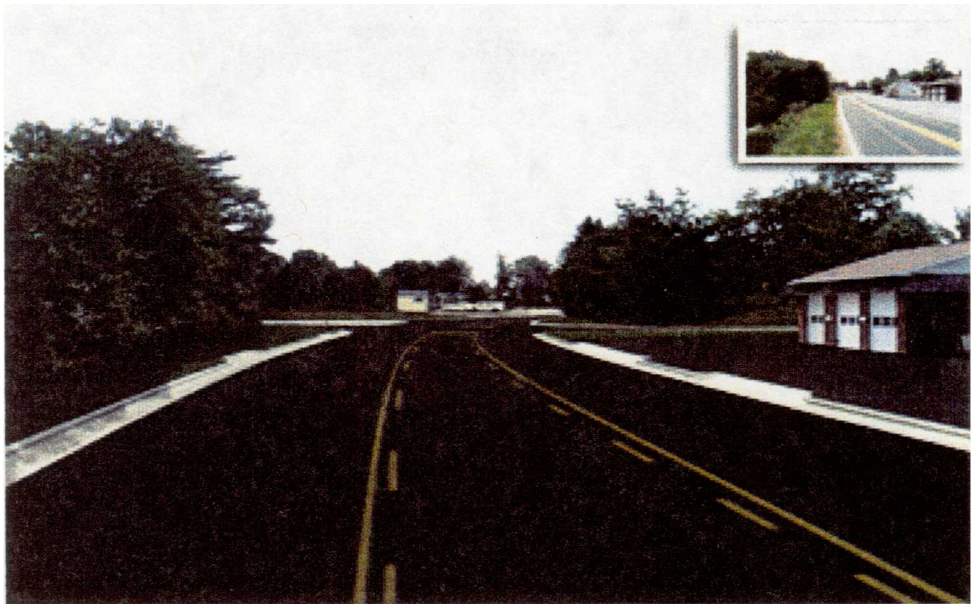

Figure 14. Example of Photo-Simulation or Photo-Composite Made by Blending 3D Model (of Roadway) Into Photographic Background. Insert Shows Existing Condition.

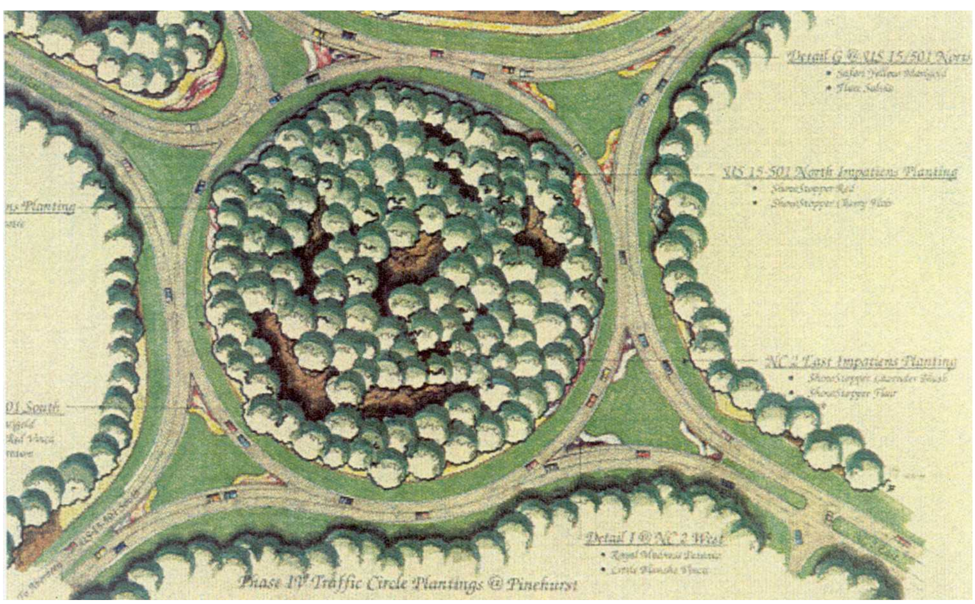

Figure 15. Rendered Plan View of a New Traffic Circle Design and Landscaping in Pinehurst, NC (Courtesy of NCDOT Roadside Environmental Unit)

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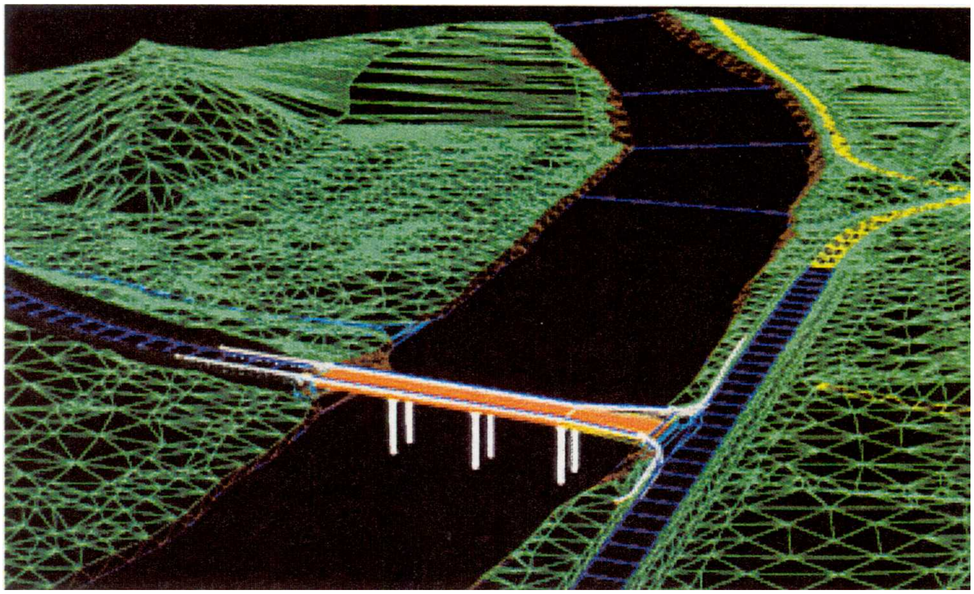

Figure 16. Example of CAD 'Wire Frame' Model

Figure 17. Dynamic 3D Model of Roundabout Traffic (Animation). Courtesy of FDOT and MPI, Inc)

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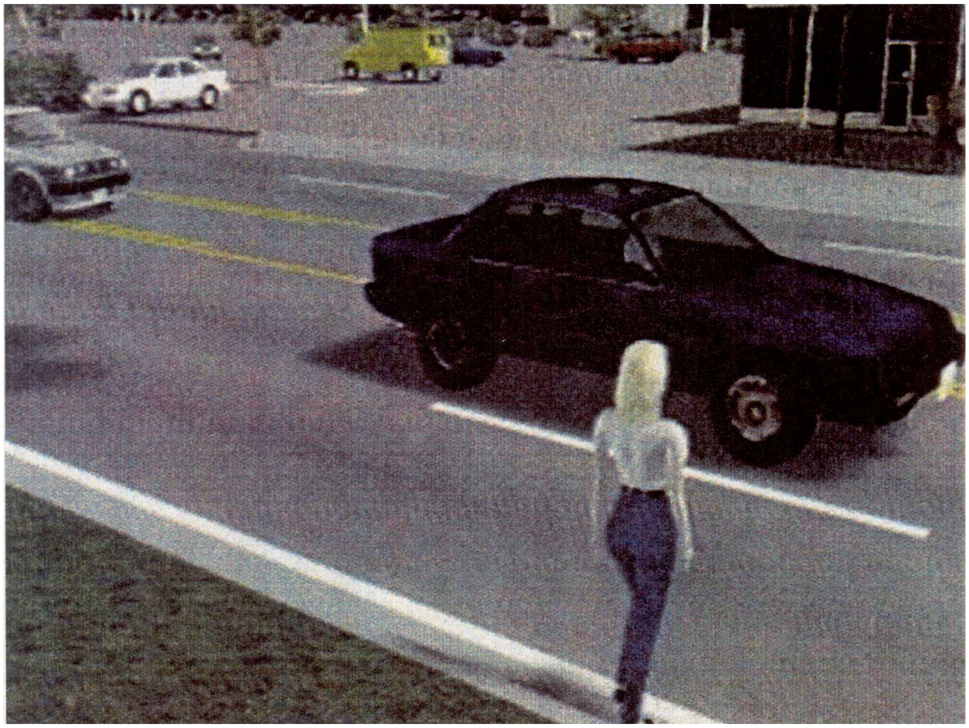

Figure 18. Dynamic Representation of Pedestrian Crossing Roadway (Animation Created Using 3D StudioMax Character Studio)

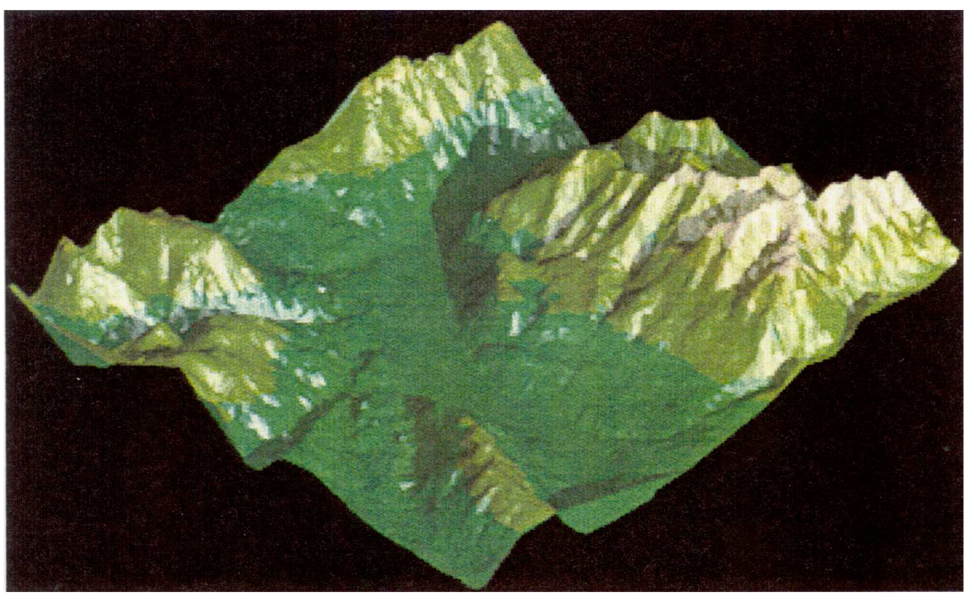

Figure 19. 3D Rendered View of Terrain Based upon Digital Elevation Data.

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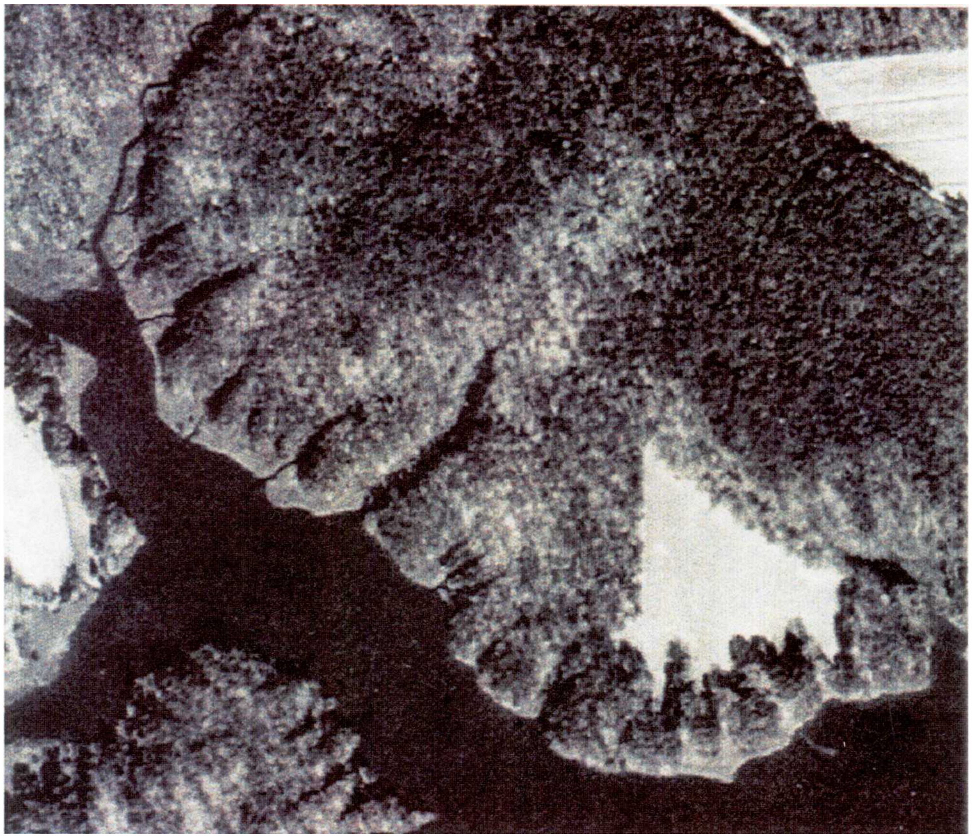

Figure 20. Example of 2-Meter Satellite Imagery of Pamlico Sound, NC (from Aerial Imagery, Inc., Raleigh, NC)

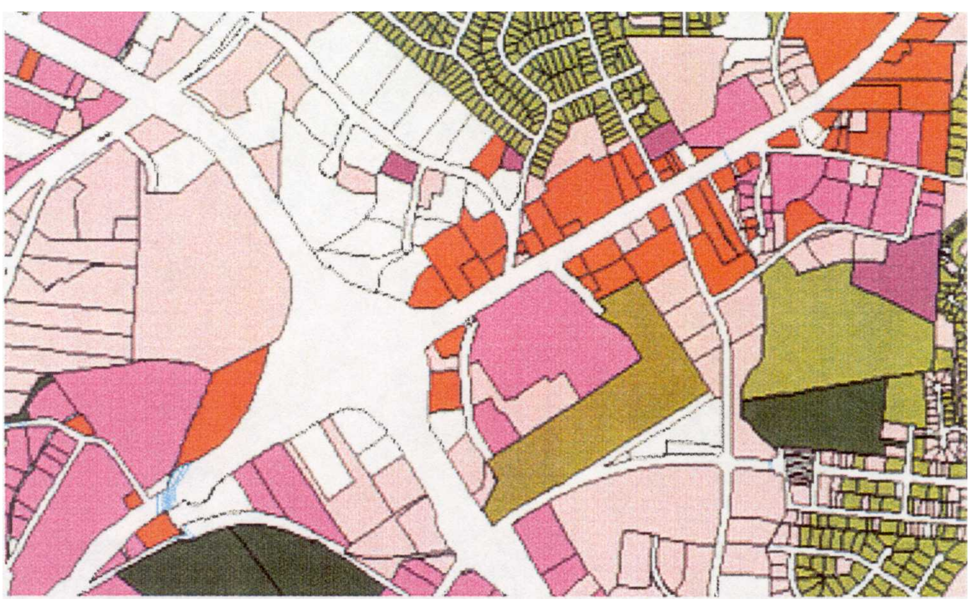

Figure 21. Example of 2D GIS View of Land Use Data

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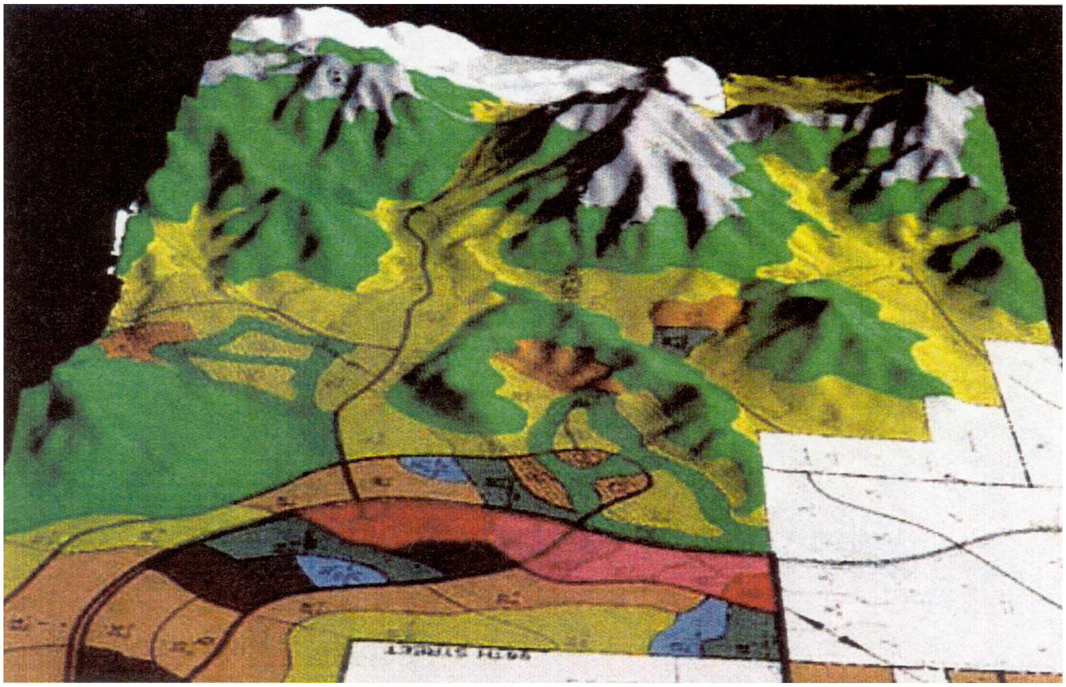

Figure 22. Example of GIS Data Overlaid on Digital Terrain Elevation Data (Courtesy of City of Scottsdale, Arizona)

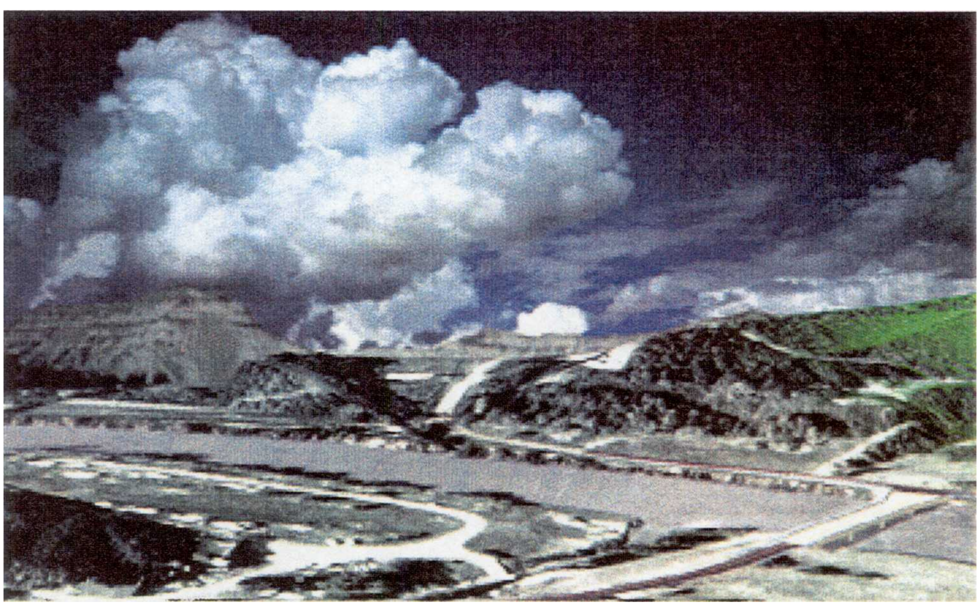

Figure 23. Aerial Photograph Draped Over Digital Elevation Data. Exposed Wire Frame Model Can be Seen at Right Center of Image.

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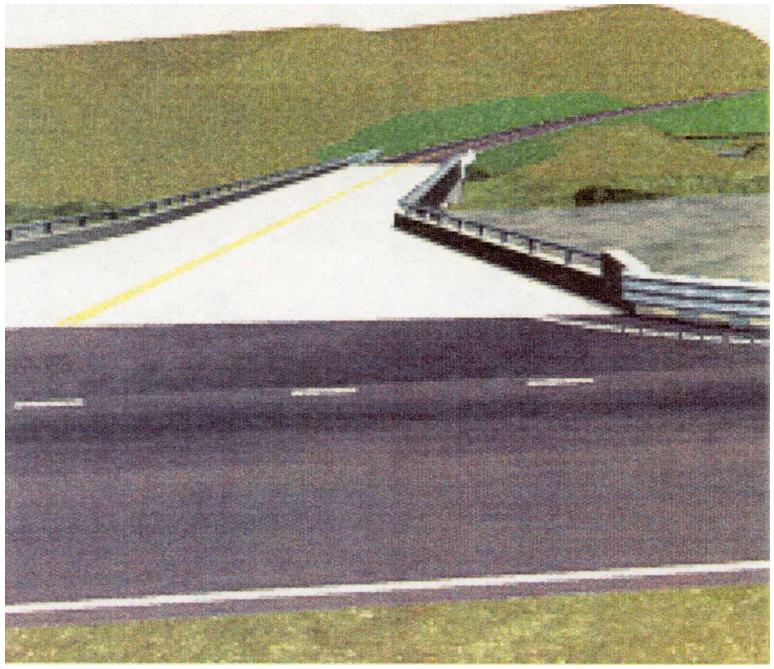

Figure 24. 3D Model of Bridge Displayed in 3D Virtual Environment.

Figure 25. Same 3D Model of Bridge Displayed in Photo-Simulation. Insert Shows Existing Condition

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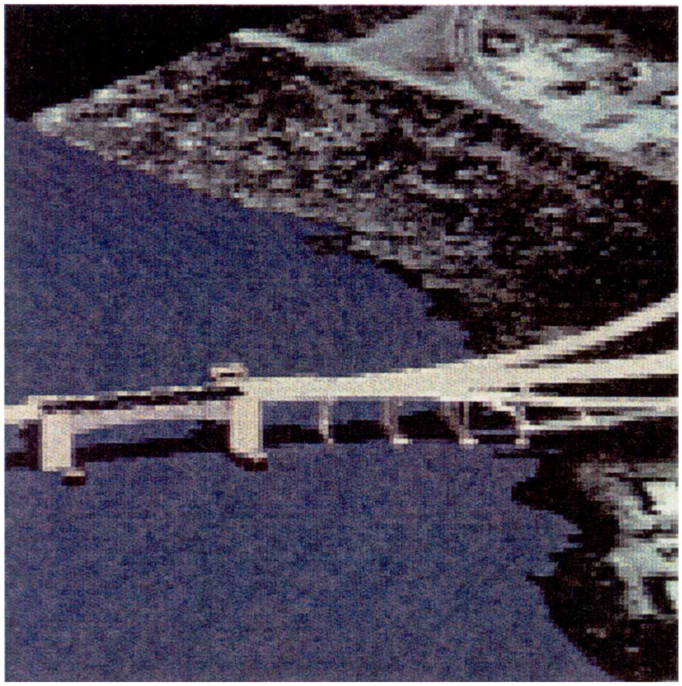

Figure 26. Simulated Aerial View of 3D Model of Bridge Design in Photographic Background (i.e, a 3D Model Within a Photo-Simulation)

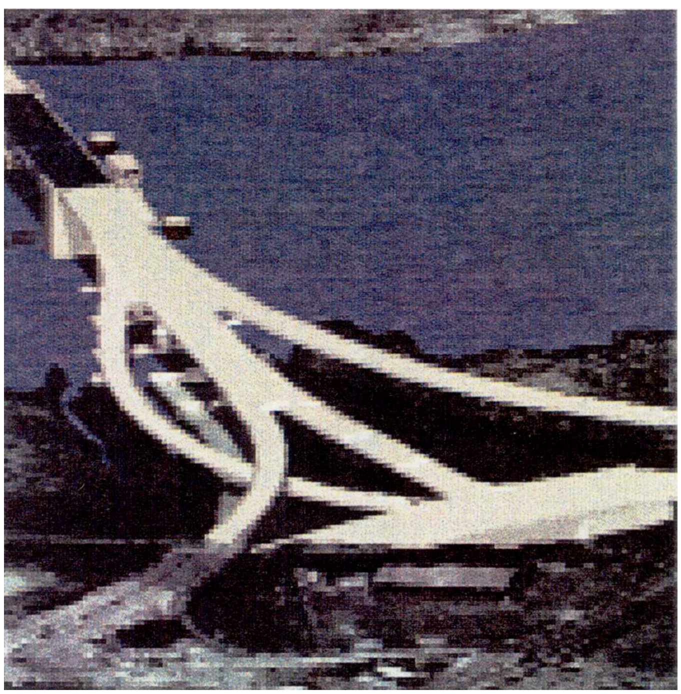

Figure 27. Different View of Same Bridge as Above Shown in Photo-Simulation.

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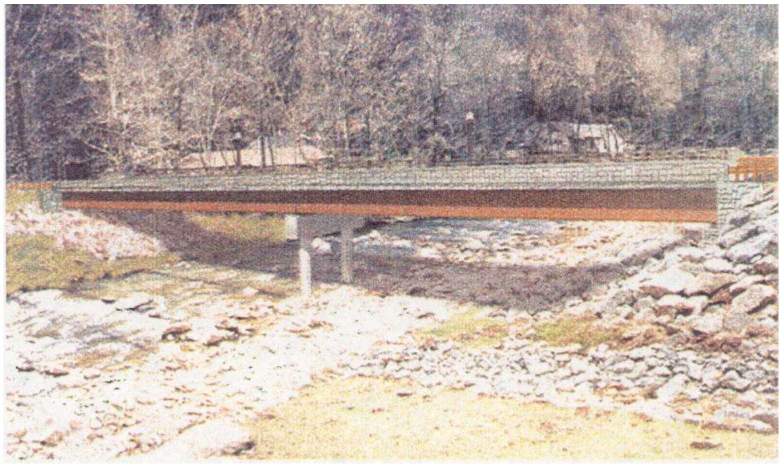

Figure 28. Side Rendering of a Proposed Bridge in Chimney Rock, NC. Courtesy of NCDOT Structure Design Unit

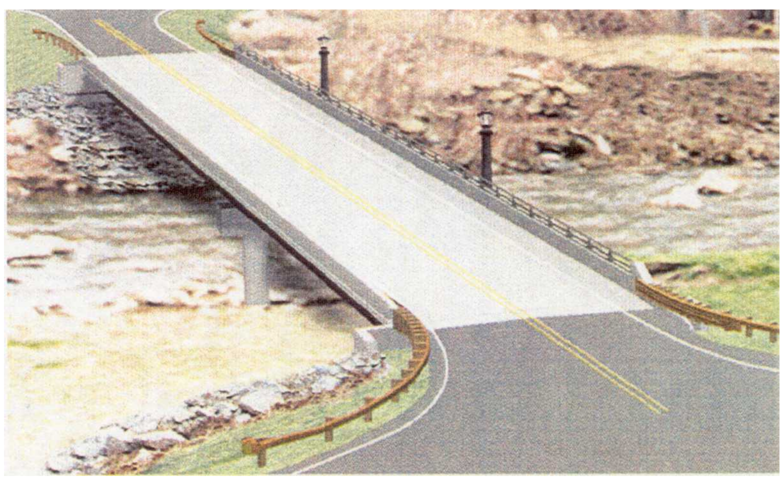

Figure 29. Elevated Rendering of a Proposed Bridge in Chimney Rock, NC. Courtesy of NCDOT Structure Design Unit.

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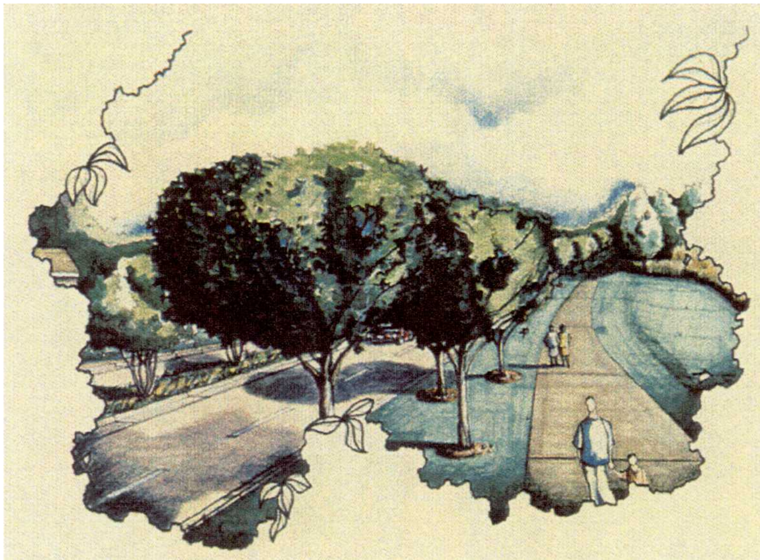

Figure 30. Artist's Rendering of Bicycle Path Median and Landscaping Along Cook Rd at Elon College (Courtesy NCDOT Roadside Environmental Unit)

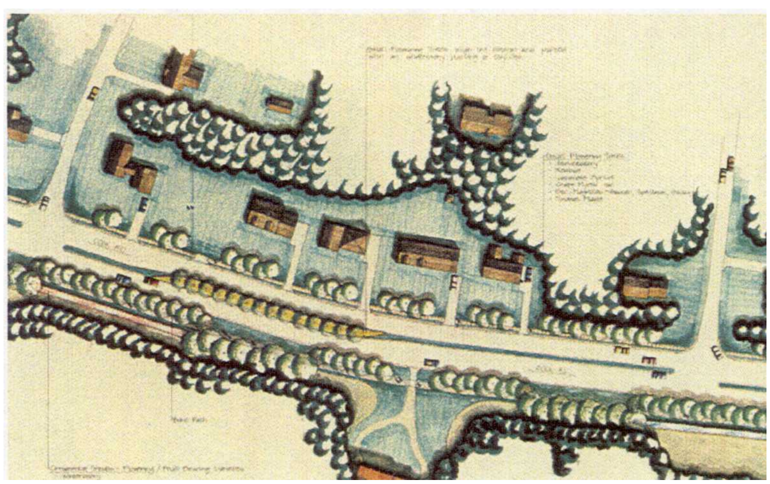

Figure 31. Artist's Rendering Showing Plan View Along Cook Rd at Elon College (Courtesy of NCDOT Roadside Environmental Unit).

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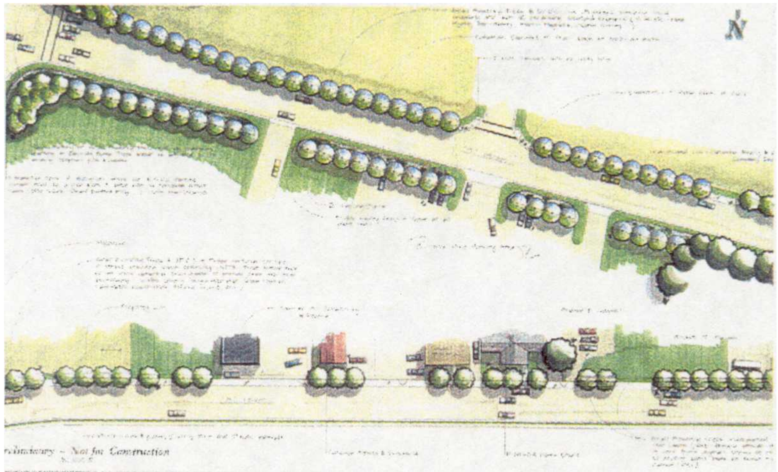

Figure 32. Artist's Rendering of an Entire Entrance Enhancement in Newton, NC (courtesy of NCDOT Roadside Environmental Unit)

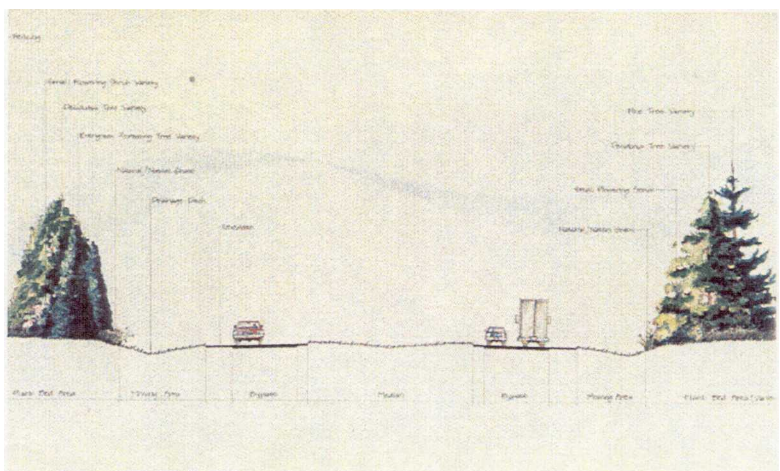

Figure 33. Artist's Rendering Showing Cross Sectional View of Wilmington Bypass With Median and Vegetative Barriers (Courtesy of NCDOT Roadside Environmental Unit)

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Section III

Getting Started

Section III of the Guidelines provides an initial 'checklist' for use in making a preliminary assessment as to whether or not visualization may be beneficial to your project. The checklist is not intended to provide you with a simple 'cut-off' score. Neither the checklist in Section III nor the more detailed questions provided in Section IV are intended to provide you with the equivalent of an 'expert system.' It's not that simple. Use of material in these two sections will, however, lead you to consider the types of issues that are recognized to be important both in a decision to use visualization as well as in evaluating the requirements associated with different visualization applications.

Use the checklist as it is intended. . . as a preliminary 'tool' in helping you assess whether visualization may be a helpful adjunct to your project. . . both from a design standpoint as well as from a public involvement standpoint.

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Section III

Getting Started (An Initial Checklist)

Making the Decision to Use Visualization

❑ Has a decision already been made by NCDOT management to use visualization on this project?

❑ If the answer is YES, did the decision to do so adequately address ***requirements, cost, and schedule***? Use the information in the following 'checklists' to see if anything has been overlooked.

❑ If a decision as to whether or not to use visualization has ***not*** been made, begin by considering your answers to the questions in the table on the next page.

Figure 34. 3D Model View Developed by FDOT as part of North and South Roosevelt Boulevard PD&E Study in Key West, FL (1998)

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The Initial "Checklist"

At the outset of a project, ask the following questions to gauge whether or not visualization may provide a worthwhile benefit. Remember, a late decision to use visualization will significantly limit your possibilities.

Will the complexity of the design concept and design alternatives be difficult for the user or client to understand?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Will the design team benefit from sharing a common visual image of the final product?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Will failure to achieve consensus at the outset of the public involvement process have serious impacts on overall project costs and schedule?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Will the use of visualization make it easier to respond to differences in design alternatives or to subtle, but important changes, in a design?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Will the use of visualization aid the design team in identifying errors or inconsistencies that might not otherwise be apparent from the use of conventional 2D graphical and numerical approaches?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Can the overall design requirement be conceptualized in terms of a limited number of specific locations, typical sections, etc.?

Definitely Not	Probably Not	Don't Know	Probably Yes	Definitely Yes

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If different parts of the project have significantly different design requirements, can visualization be used to 'pull together' the project as a whole?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Has the public or other agencies expressed, or are they likely to express, concerns regarding the appearance of the proposed project?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Does the project have the potential to affect the view from a historic site or change the character of the surrounding area?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Yes

Does the project contain innovative or complex design features which might not be familiar to the general public from an operational standpoint (e.g., a roundabout, single-point diamond, etc.)?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

Has the public or other agencies expressed concerns regarding the proximity of the proposed facility to existing homes, businesses, historic sites, parks, natural areas, or other properties?

Definitely Not	Probably Not	Don't Know	Probably Will	Definitely Will

As yet, there are no hard-and-fast rules for deciding *when* to use visualization or for deciding how much visualization will be *enough.* In general, if visualization helps you and your project team get a better 'picture' of what the final product will look like and how it will function, then it will also be of help in communicating those same issues to the public as well as to agencies whose approvals are required to proceed.

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Section IV

Working on the Details

Now that you have made at least a preliminary decision to utilize visualization as part of your project, you need to consider the more detailed issues involved in its application.

In some cases, you will be able to get help from an in-house visualization unit who will provide you with additional help in defining scope, requirements, etc. In other cases, you will have to develop your own scope of services and obtain visualization support from outside firms. In either event, there will always be more options and alternatives than available funds. So, decisions to limit the scope or extent of your visualization support are inevitable. As you become more experienced in the use of visualization, you will begin to associate certain applications and levels of effort with the unique needs of your particular project(s).

A 'table of contents' listing the major questions/issues addressed in this section is given on the following pages. Use these major questions and issues to help to organize your thinking about visualization requirements and applications.

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Major Issues Addressed in this Section

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Who will be responsible for actually developing the visualization?

- ❑ Do-es the DOT possess an in-house capability for visualization? Is there a special visualization unit? Does visualization support reside primarily in roadway design, P&E, etc? What is the mechanism for making this support available to the project?

- ❑ Are in-house resources available at the level you require? Can visualization support be developed within the time constraints of your project schedule?

- ❑ Are there outside resources that can support your visualization needs? Do they have experience with DOT projects? Are they able to work with DOT data sources and formats? What is the availability of outside resources?

Figure 35. Portion of 3D Model Being Developed by Bentley Systems for "Model City Philadelphia"

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Defining What is Needed

❑ Regardless of whether the work will be done in-house or through an outside contractor, are members of the project staff familiar enough with the use of visualization to develop a ***statement of work/services*** to which in-house personnel or an outside contractor can respond? Before you say, "Just do what was done on Project-X," consider the following:

❑ Will visualization be used to support design, public involvement, or both?

The consideration here is primarily in terms of the level of fidelity ('realism') of the visualization products that will be needed. Design oriented applications need not have the level of realism required for public involvement use. When visualization is used to support design, the ***visualization support function should be integrated and function as part of the design team***, otherwise the tendency is to simply use visualization to create images of the preferred design only, thereby minimizing its use during conceptual design and the evaluation of preliminary design alternatives. Get the visualization support personnel on-board EARLY.

❑ Do in-house staff have sufficient experience with contractor-supported visualization to accurately estimate the cost associated with the level of visualization support that is desired? Remember, this is a relatively new field. You are not alone in feeling that you are unable to accurately associate costs with different types of visualization 'products.' Advice: Use the Guidelines to become informed about the different types of products that are available and which might be effective for your particular project. Learn how to describe what you want in terms that multiple providers of visualization support services can respond to (i.e., 'bid'). Describe your needs and put out a Request for Quotes (RFQ). Use the replies to narrow the field to where you can negotiate for services that are within your budget. Be prepared to accept a compromise solution.

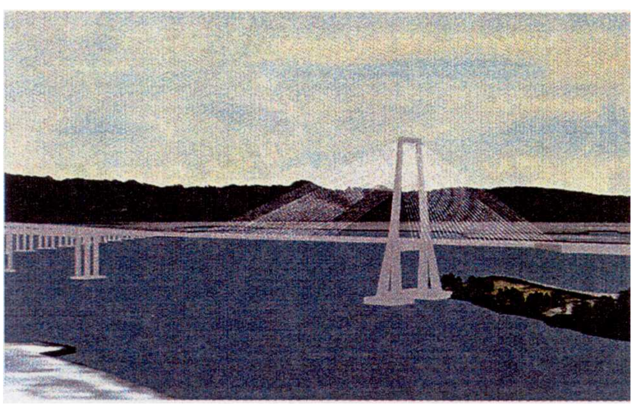

Figure 36. Candidate Bridge Design Considered in Oakland Bay Bridge Replacement Project (from CALTRANS web site).

What forms of spatially referenced data will be required?

- ❑ Will the use of conventional artist renderings be sufficient?

  If technical accuracy is not essential; if the client understands that what he/she is viewing is preliminary or conceptual; if the time and cost to develop the visualization are limited; if walk-thrus or drive-thrus are not required; if requirement to visualize the design can be satisfied through a single or limited viewpoints

- ❑ Will the use of photo composite images be sufficient? Who will develop the image of the proposed facility? Who will provide photos of the area? Who will blend facility image into photo;

  Photo-composites or photo-simulations are relatively quick and inexpensive to produce; can be done either by inserting either an artist concept/rendering of the proposed facility or a CAD-generated view; effective if the requirement can be satisfied with a single viewpoint

- ❑ Will the visualization require aerial or photographic data? (e.g, photographic data for developing photo composites; or aerial photography for overlaying alignment information from CAD or GIS or raster (photo) images)

  Will it be desirable for the client to visualize the alignment against an aerial photo? Are aerials available at the appropriate scale or will they have to be arranged? If currently available, are they recent enough to show present situation?

- ❑ Will the visualization require the integration of GIS data?

  Is there a requirement to visually define the boundaries of certain types of information typically contained in GIS files; for example, wetlands, areas with certain socio-economic characteristics, etc.

- ❑ Is there a requirement to use satellite imagery to visualize land use and/or environmental impact issues?

  Is satellite imagery of the area available; how recent is the imagery; will you require black and white, color, multi-spectral images; what resolution is required; will you have to utilize satellite imagery in conjunction with other sources of spatially referenced data such as GIS, CAD, virtual/synthetic, etc.?

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How critical is an *accurate representation* of terrain contours?

❑ Is there a requirement for a 3D digital *terrain model* as part of the visualization? Can I assume that the earth is essentially flat or is terrain contour a major issue?

- Is a digital elevation model of the terrain available? Does the model/data have sufficient resolution/accuracy for the present project?

- What is your source of digital terrain elevation data? Will visualization based upon this level of accuracy for design? for public involvement?

- Is there a requirement to overlay (drape) aerial or satellite imagery over digital elevation data?

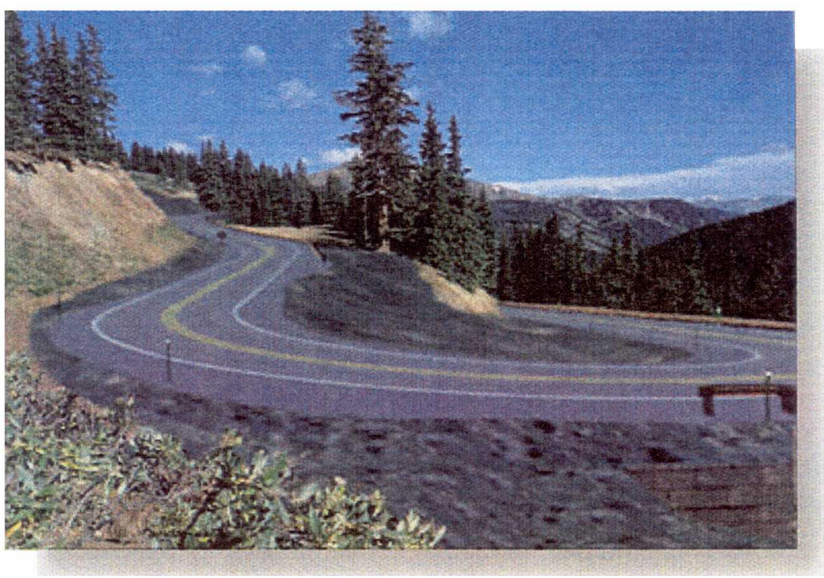

Figure 37. Photo Simulation from Guanella Pass (CO) Project as Displayed on Project Web Page

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Viewing the design from different eye points or vantage points?

- ❑ Will a single, or limited number of views or points of gaze, be sufficient to provide the client/user with an acceptable concept of facility design and operation?

- ❑ Is there a requirement to observe *operations* from different vantage points and/or different eye points (e.g, from driver, pedestrian, and or bicyclist eye points)?

- ❑ Can the requirement for different vantage points be limited to specific locations or must control of eye point be totally up to the observer? This may not be a problem unless there is a requirement for walk/drive thrus in which case non real time animations will have to be scripted ahead of time.

- ❑ Will a 3D wireframe (CAD) model of the proposed facility be sufficient for conceptual design, for the development of design alternatives, for public involvement, for final design, for the generation of construction plans?

- ❑ Is the area to be affected by the design so large as to make it difficult for an observer (either designer or client/public) to orient to his/her location? Would the capability for a 360 degree view from selected vantage points (such as that provided by Quick Time VR) be a helpful feature of the visualization?

- ❑ Is there anything about the nature of the facility and/or its operation that would benefit from an ability on the part of the user/client to 'walk thru,' 'drive thru,' or 'fly through/over' it an important adjunct to their making decisions about the design? Non real time walk/drive thrus can be accomplished through use of animation. Real time walk/drive thrus impose additional computational/image generation requirements and may sacrifice visual fidelity (realism) that may be important in public involvement environment.

- ❑ Is there a requirement for a 3D model of the 'built' environment (i.e., man-made structures, such as other buildings, etc.) in which the facility/feature will be placed?

- ❑ Will a 'standard section' (2D cross section view) of the proposed design provide adequate information for the user/client to judge (a) key physical dimensions, (b) impact of these dimensions on changes in volume and/or speed of traffic using the facility, (c) visual impact on area immediately surrounding the design are, or (d) effects of alignment deviations on specific property owners?

- ❑ Will there be a requirement for more than one individual to view the design (each from his/her own eye point) simultaneously (e.g, from the eye points of two different drivers; from the eye point of a driver and that of a pedestrian or bicyclist; from a driver's eye point as well as that of an observer positioned somewhere else in the environment?) Must these simultaneous viewing conditions be supported in real time, or can they simply be static views?)

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Special Viewing Conditions

- ❑ Will it be necessary to view the design under special viewing conditions, such as (a) different times of day, (b) different seasons of the year, or (c) under special conditions such as rain, fog, reduced visibility, etc?

- ❑ Will it be necessary to view proposed landscaping plans as they would appear after different periods of time? Will it be necessary to selectively add/delete different parts of the overall landscaping plan?

- ❑ Will it be necessary to view sub-surface details in ways not normally available for viewing (such as subterranean view of utilities or sub-surface view of marine conditions and structures)?

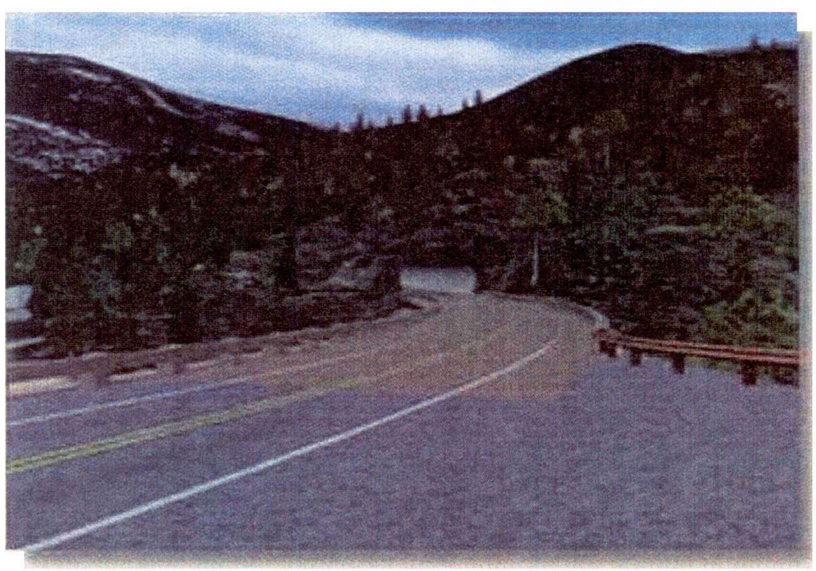

Figure 38. Tunnel Alternative From Guanella Pass Project as Displayed on Project Web Page.

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Will there be 'special' visualization requirements, such as the capability to visualize the project during different phases of construction?

❑ Will access during the construction phase(s) be an important issue in gaining public support?

❑ Will the construction process benefit from access to an accurate image of the finished product? Is it necessary to show encroachments, limitations to access, effects of reduced capacity, etc.?

❑ Would a 3D model of the final product that allowed the viewer to select specific viewpoints be helpful during construction? Who is to benefit from a detailed visualization of the construction process. . . the construction engineer, businesses and individuals affected by access limitations, those concerned with the maintenance of traffic and safety in construction work zones, etc.?

❑ Will there be requirements to view certain aspects of facility design and/or operation that are not normally 'visible' to the naked eye (e.g, will there be a requirement to view special aspects of the design and construction, such as framing, wire-runs, utilities, structural load factors, etc.?)

❑ Can access and traffic control issues during construction be defined with sufficient confidence during the concept definition and design alternative phases of the project?

❑ Will visualization aid the Department in the transition from design to construction?

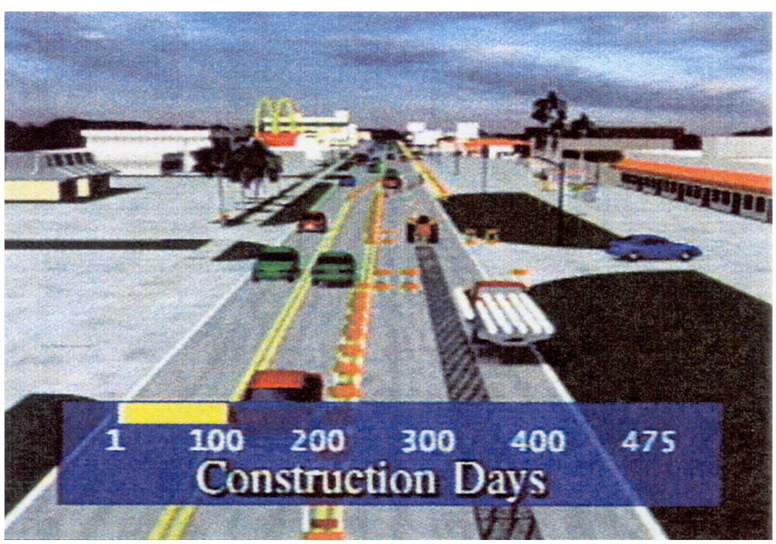

Figure 39. 3D Visualization Used to Display Phase of Construction (Courtesy of FDOT and MPI, Inc.).

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2D or 3D Requirement?

- ❑ Will traditional 2D engineering drawings (e.g, typical section/cross section) be sufficient for the public to effectively visualize the proposed design concept? 'Typical Section' views can provide understandable, accurate data on project dimensions, but are not suited to providing information on how the facility will impact the surrounding area or providing data on how the facility will improve operations.

- ❑ Will artist renderings contain sufficient realism and technical accuracy? Artist renderings are useful in providing an 'impression' of the final product, may or may not be drawn to scale, and may contain some degree of 'artistic license' on the part of the artist.

- ❑ How important are sight distances, fields of view, and other visual considerations for public support of this project? These aspects of the design can be accurately represented in 2D, but can more effectively conveyed to a non-engineering observer using formats that present more realistic 3D view.

- ❑ Will a 3D CAD model of the design feature, facility, etc. be required for the present stage of design? Will it be necessary to generate alternative views of the facility? Will it be necessary to drive thru or walk thru the facility/environment? Will it be necessary to modify/change some portion of the environment/facility design while leaving the remainder unchanged?

- ❑ Will it be important to view the feature/facility within a photorealistic (i.e, picture-like) setting? Photo composite views provide a high degree of visual fidelity or realism, but do so by sacrificing the ability to view the design from different perspectives or vantage points? Additional viewpoints will require additional composite images to be generated.

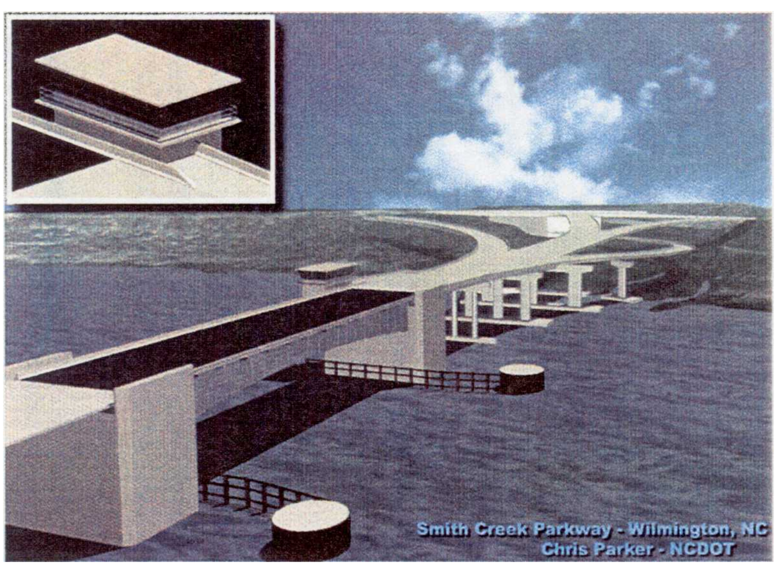

Figure 40. Preliminary 3D Model, NCDOT Smith Creek Parkway Project, Wilmington, NC.

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Is there a requirement for visualization to show how the facility will 'operate' as well as how it will 'look?'

- ❑ Will the new design alter traffic patterns in such a way that public consensus and acceptance will depend upon an ability to understand the nature of the changes? Will animation be beneficial in conveying the nature of these changes? Can the effect of these changes be effectively presented through 'snap shots' (non animated) views of facility operations?

- ❑ Will an ability to visualize actual traffic flows be required for design? If yes, will there be a parallel (or previous) effort to model/simulate traffic under existing and proposed conditions? Is traffic count data required for the modeling available? How old is the data? Will new data need to be collected?

- ❑ Will an ability to visualize actual traffic operations be an important factor in achieving public consensus and support for the proposed design? If so, what aspects of traffic operations will be important (e.g, parking, traffic densities, vehicle speeds, location of qeues, signal timing phases, etc.)?

- ❑ Will the type of 2D graphic output associated with some traffic models be sufficient to convey operational traffic performance to the general public? Will simple point/mass views of vehicles operating in a simplified 2D representation of roadway geometry be sufficient . . . for the design team . . . for the eventual end user (public)?

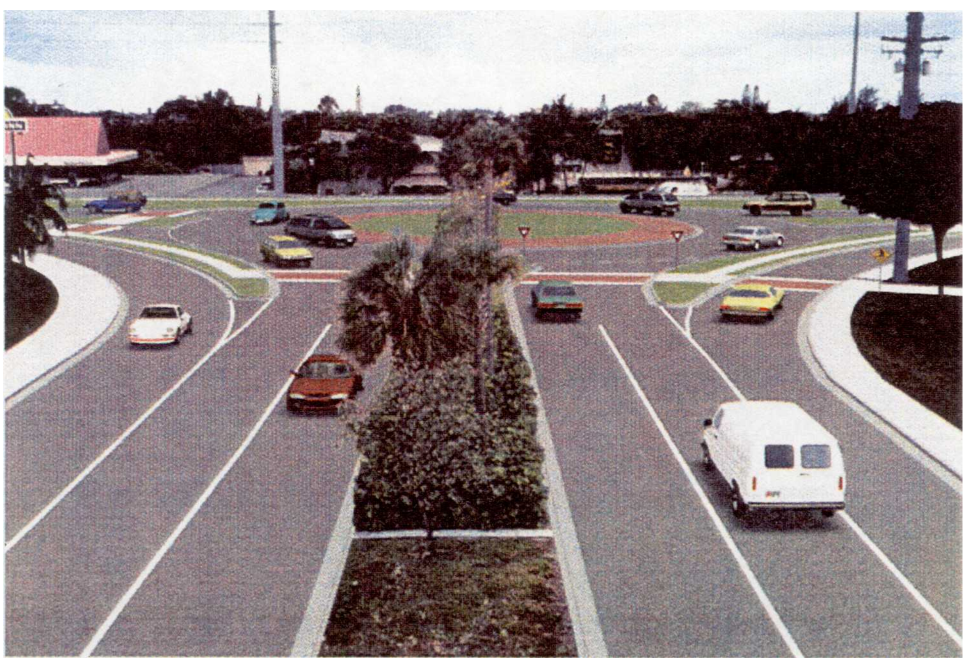

Figure 41. Animated Photo Simulation of Traffic Operations at Proposed Roundabout. (Courtesy, FDOT and MPI, Inc.)

Visualizing ‘Operations’ in Addition to ‘Appearance (Continued)

- ❑ Do you have the ability to link virtual traffic performance to analytic models of traffic performance? Can you accomplish this link in real time? What will be the basis for your claim of technical accuracy in your visualization of traffic performance?

- ❑ Do I need to accurately represent the non-motorized elements (e.g, ped/bike elements)?

- ❑ In representing non-motorized (ped/bike) elements, will it be sufficient to simply represent their presence and densities (peak and non peak periods) or will it be necessary to display them in motion as well?

- ❑ Is it necessary that motorized and non-motorized elements behave interactively (e.g, that motor vehicles respond to presence of pedestrians and bicycles in/near the travel lane?)

- ❑ Are there data available to define non-motorized (ped/bike, etc.) characteristics (e.g, in the case of a roadway design, the volume and speed characteristics of non-motorized elements)?

Note:

There currently are no capabilities for directly linking the output of traffic models to visualizations of the types being considered here. Currently available traffic models such as NETSIM, INTEGRATION, CORSIM, etc. do not have photorealistic display outputs. To the contrary, their visual display outputs are limited to simple 2D displays showing stylized representations of vehicles, their lane position, turning movements, etc.. To develop a realistic, accurate representation (i.e., animation) of traffic, it is necessary to first ‘model’ that performance, and then to use the outputs of the model as the basis for a frame-by-frame positioning of vehicles to be displayed in the animation (see examples on next page). There is presently no higher-order language, or object oriented code that will allow the visualization developer to simply ‘select’ a desired vehicle speed or traffic volume. The visualization of vehicle speeds and volumes must still be developed on a frame-by-frame basis. Once completed there is no variation in the behavior of the traffic; there is no ability to do any ‘what-ifs,’ and there is no ability to vary the observer’s eye point or point of gaze. To do so requires the development of a different animation sequence.

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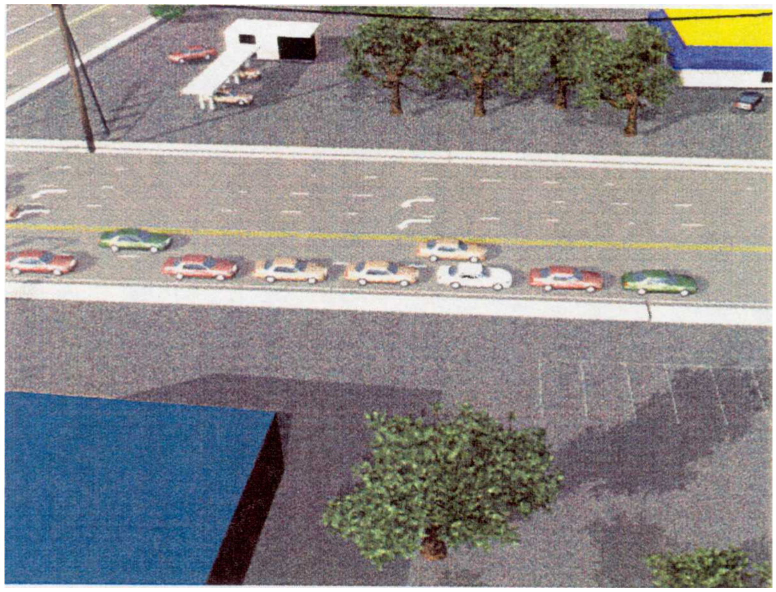

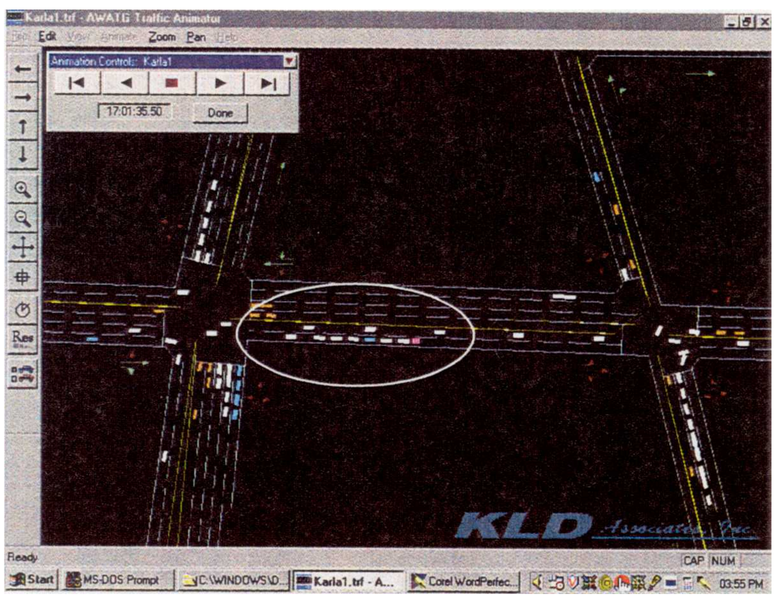

Figure 42. Frame from 2D Graphic Output of Traffic Model (bottom) and Same Output (see ellipse in bottom figure) as Shown in Frame from 3D Animated Display (top). Courtesy of KLD Associates, Inc.

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Animation and/or Walk/Drive Thru Requirements

- ❏ Is there a requirement to be able to dynamically 'walk thru' or 'drive thru' the environment?

    Walk thrus, drive thrus, etc. require a 3D model that can either be run in real time or used to generate an animation. Animations can require significant machine time to render and will be limited to predefined paths and points of gaze.

- ❏ How many different walk-thrus or drive-thrus will be required? What is the duration (in seconds) of each, remembering that for each second of animation there will be a requirement to generate 30 frames of imagery to achieve the perception of continuous motion. Remember too that rendering time will I increase as a function of scene content and detail. It can literally take 'days' to render a very short duration animation.

- ❏ Can specific 'paths' through the environment be defined in advance, or will there be a requirement for the user/client to freely (that is, in real time) determine his/her path as well as to control his/her rate of movement along that path?

- ❏ Will walk-thrus and drive-thrus require the simulation of continuous motion or will it be sufficient for the user/client to 'move' along a path by simply making observations from successive (discrete) locations?

Figure 43. Simulated View of Pedestrian from FDOT Roosevelt Blvd PD&E Study (Courtesy of FDOT and MPI, Inc.).

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Are there environmental issues/concerns that visualization could be used to effectively address early in the project?

- ❏ What environmental issues and concerns must be addressed by the design? (for example, screens/shelters/barriers, etc. for visual and noise control, air quality impacts, marine impacts, etc.)? Which of these can be more easily clarified through the use of visualization as opposed to conventional numerical and graphical analysis techniques?

- ❏ Think of 'visualization' as not being limited to the visual modality. Think in terms of a multi-media capability (to include the accurate representation of noise (aversive as well as pleasant effects).

- ❏ Are there aspects of the Section 404 permitting process where visualization might be used to facilitate project approval?

- ❏ Where do visualization applications need to be integrated with the use of GIS and computer models/simulations?

- ❏ Where historical preservation issues are essentially 'visual' in nature, can visualization be used to achieve consensus on the visual requirements of the design?

- ❏ If landscaping is a major design or mitigation issue, can visualization be used to achieve a more rapid consensus on design requirements? Will there be a requirement or benefit associated with the display of landscaping at different stages of growth/maturity?

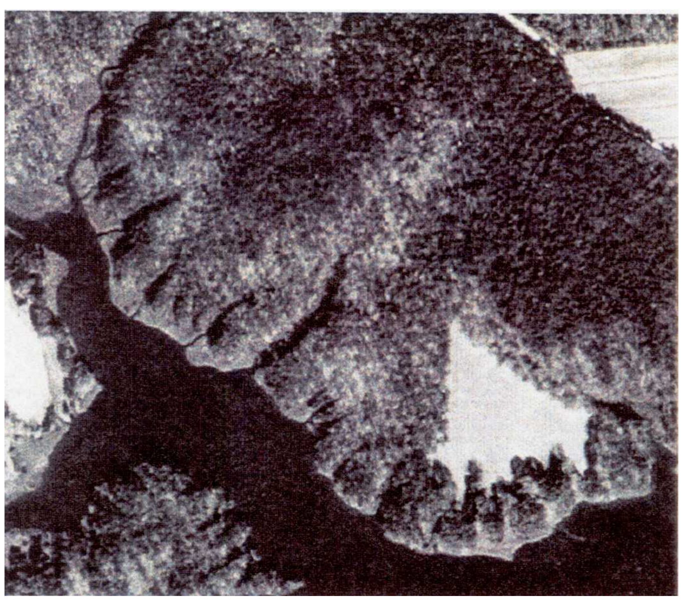

Figure 44. 2-Meter Satellite Imagery of Pamlico Sound, NC (from Aerial Imagery, Inc. web page)

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How will I display the products of visualization to the user/client?

- ❑ What format will be used to 'display' the products of the visualization effort (e.g, 'boards,' videotape, CD-ROM, laptop and projector)?

  Boards (large prints) are easy and relatively inexpensive to generate and easy to transport for use in a public setting. Videotape represents a convenient format for exercising control over the presentation as well as a good means of presenting animation. Local facility support (projection equipment) is usually no problem where a normal TV monitor can serve as display. For larger audiences, multiple monitors or a large screen monitor will be required. Videotapes can also be copied and made available to the media and key individuals. Use of laptop computer and presentation graphics (e.g, PowerPoint, etc.) is an easy format for most to work in, but requires user to provide projector. Generally PowerPoint presentation can be adapted for Internet presentation. Ineffective presentation methods can greatly reduce the overall effectiveness or benefit of visualization.

- ❑ Will members of the design team at different geographical locations be required to interact with the design?

- ❑ Is there a requirement for communicating with the public using means other than the typical public hearing? (e.g., Internet web page, project newsletter, etc.)?

- ❑ Is Internet or Web access intended to permit the public or other user to simply 'view' material or is it also intended to allow the public to provide feedback and comment?

- ❑ Is there a requirement that quantitative feedback be provided in a format that can be collected and analyzed by the DOT?

- ❑ How interactive does the visualization need to be in terms of allowing observers to actually manipulate design details (e.g, move/modify/delete objects, etc.)?

- ❑ How will 'configuration control' be maintained with visualization materials? When it is easy to make changes, it is easy to loose track of what 'version' of the design one is dealing with.

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Impacts on Cost, Time-to-Develop, and Flexibility of Use

- ❑ How critical to the overall project budget is the cost of visualization?

- ❑ How critical is the time required to produce the visualization? The progression in terms of development time (and related cost) generally goes from simple 2D drawings, to 3D models, to virtual 3D environments, to animation, to real time performance.

- ❑ How much flexibility is desired in terms of the ability to modify and revise the product of the visualization? Will visualization be limited to a finite number of preliminary designs or design alternatives; to what extent will must the visualization need to accommodate new 'alternatives'; how will you distinguish between what would be 'desirable,' 'reasonable' and 'essential' in terms of reflecting proposed changes in the visualization?

- ❑ Will visualization largely be a 'byproduct' of a 3D design process, or will the work involved in using visualization be almost entirely the product of a unique process?

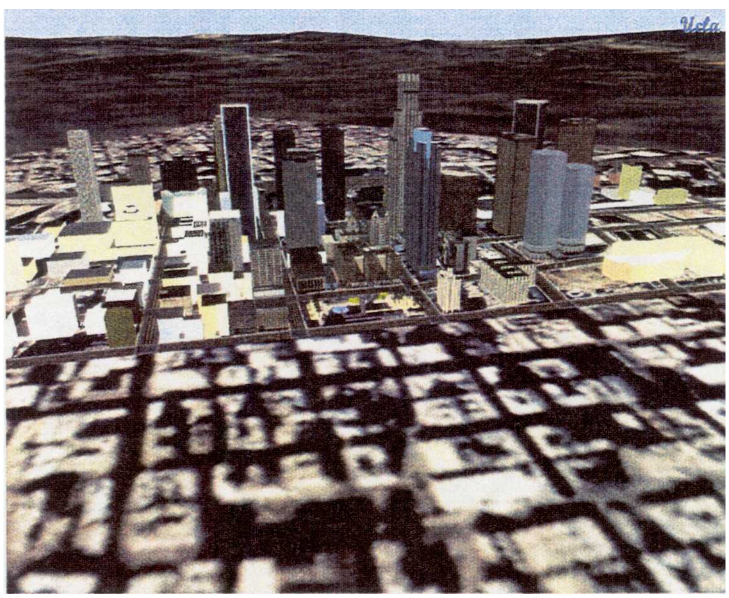

Figure 45. Example of 'Virtual' Imagery Embedded in High Altitude Aerial Photograph (from NSF Virtual LA Project, UCLA School of Architecture and Urban Design).

Section V

Cost, Fidelity, Development Time, and Effectiveness Tradeoffs(1)

This section of the report addresses the factors that contribute to the operational *effectiveness* of visualization; in particular, the relationships that exist between cost, development time, visual and operational fidelity. These issues are addressed in terms of comparisons and contrasts between the most commonly used visualization methods and techniques. The goal is to develop for the potential user of visualization a sort of 'mental picture,' if you will, of how these factors relate to one another and how a better understanding of these relationships might be used as 'guidelines' in selecting alternative visualization methods and techniques.

Expressing these relationships in graphic form presumes that we know more than we do about how these factors are related. The reader should feel free to argue the precise placement of these factors on the graphs that have been developed. The important point is not whether or not we have it exactly 'right' but rather that the attempt to do so may create a dialogue among visualization developers and project managers as to how various methods, techniques, and approaches to visualization affect, and are affected by, such factors.

In trying to understand 'effectiveness' it is important to recognize that visualization efforts are not undertaken solely for public presentation purposes. While public presentation clearly remains the primary motivation for most current applications, there was clear recognition among members of the Roosevelt Blvd PD&E team that visualization could be a useful design tool.

(1)This material in this section was developed, in part, through HSRC work on FDOT-sponsored application of visualization to the North/South Roosevelt Boulevard PD&E study in Key West, FL. This same material can also be found on the CD-ROM final report for that project (FHWA-RD-98-173).

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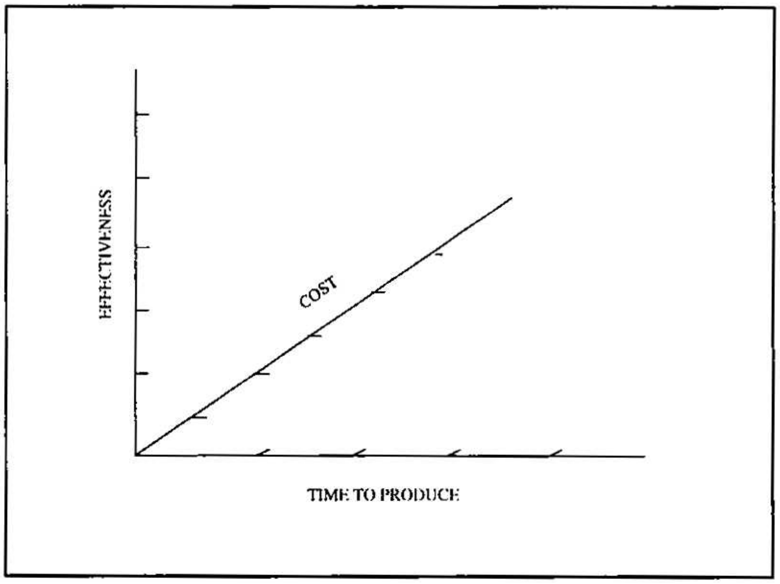

Figure 46. Effectiveness as a Function of Cost and Time to Produce

Cost and time to produce are key factors in evaluating the utility or effectiveness of visualization. It is also important to consider effectiveness from both the designer's perspective as well as the public's. It is probably safe to say that a designer does not require the same level of photo-realism as a non-technical individual attending a public presentation of design alternatives. The public on the other hand does not need to physically manipulate difference elements of the design but rather to only choose between alternatives that are presented. Photo composites represent a convenient form of presentation so far as the public's requirement for 'realism' is concerned. The 2D nature of photo composites and artists renderings lack the flexibility contained in 3D virtual environments.' The virtual environment perhaps comes closest to a designer's use of scaled 3D mockups, with the difference being that changes to the 'mockup' are accomplished through software rather than actual construction. To the extent that 3D CAD data are available, the time and effort associated with developing the 3D virtual model can be minimized. The 'realism' with which the 3D world can be viewed is largely dependent upon the image generation/processing capability of ones hardware. The 'rendering' requirements associated with non-real time systems, while capable of generating photo-realistic displays, suffer severe penalties in terms of development time, especially where there are major animation requirements. Higher cost real time systems, while providing greater drive-thru and walk-thru capabilities cannot presently match the photorealism of non-real time systems or photo composites. In any event, the availability of the 3D model(s) provides the necessary design data to create images that are easily inserted into photo composites (for public presentation) or manipulated by the engineer in evaluating alternative design treatments. The effectiveness of both types of systems for displaying 'operational' performance (e.g, traffic) is limited, and therefore requires the joint use of other media (e.g, the 2D display outputs of traditional traffic models/simulations).

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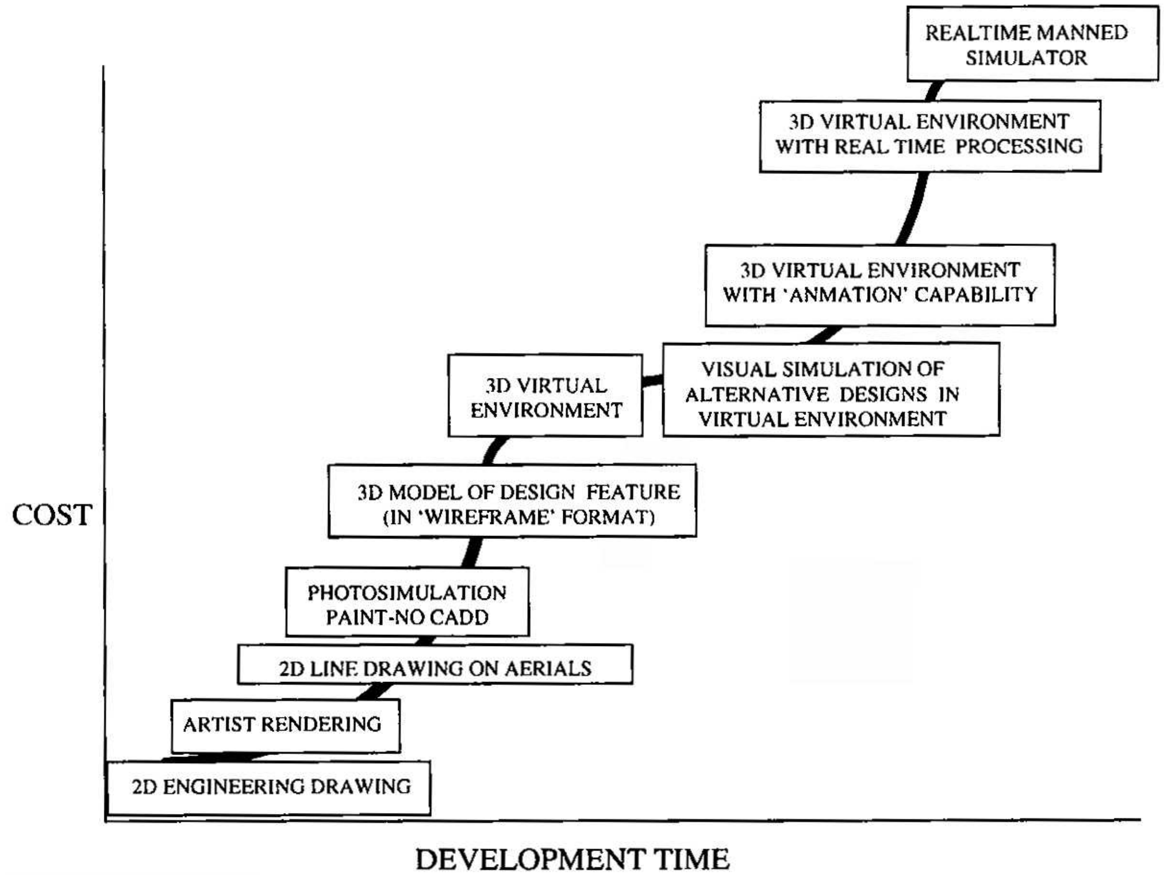

Figure 47. Cost as a Function of Development Time for Typical 2D and 3D Visualization Methods and Treatments

This figure shows the hypothetical relationship between cost and development time associated with visualization 'options' most commonly available to the potential user. The function relating cost and development time is purely 'notional' at this point. The use of 2D engineering drawings is assumed to represent the point of lowest cost and shortest development time. The critical points on the cost side of the curve occur (a) where one goes from 2D to 3D methods, and (b) where one goes from non real time computational and display capabilities to 'real time' processing capabilities. Major impacts on development time occur first when moving from engineering drawings and artist renderings to the use of photo simulation, and again when moving from 3D 'models' to 3D 'environments.' The highest levels of cost and development time are associated with the use of high fidelity, real time, man-in-the-loop simulation. High cost and extended development times may or may not be correlated with increased effectiveness.

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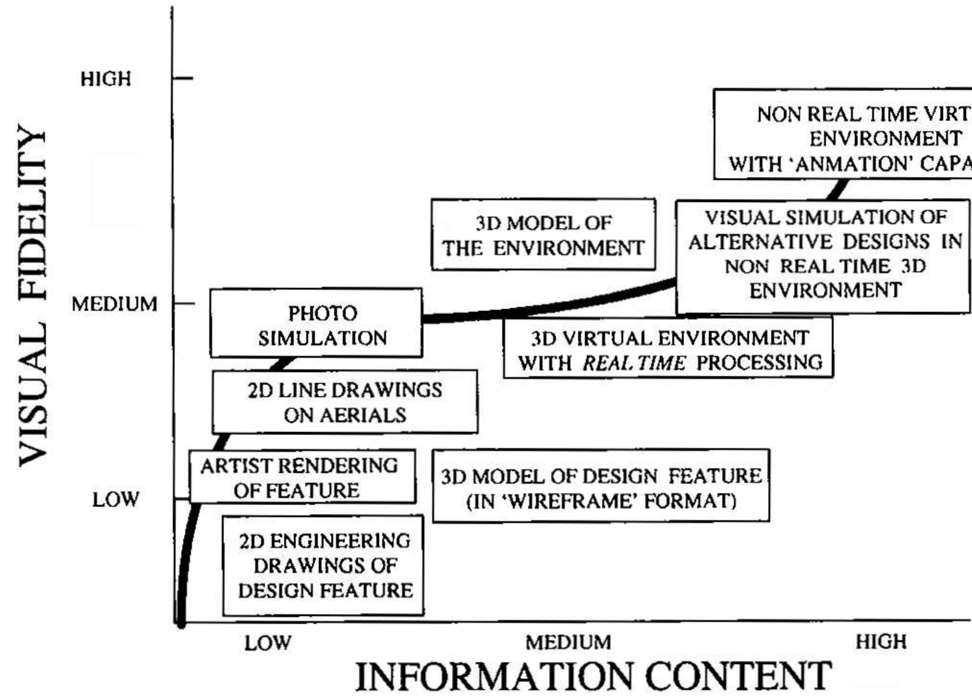

Figure 48. Visual Fidelity as a Function of the Information Contained in the Display

This figure shows the complex relationship between how realistic a display appears to the non-engineering viewer and the engineering detail or technical accuracy inherent in the display. A photograph is a two dimensional display. It is not generated from 'data.' Because a photograph contains no data about the spatial and temporal characteristics of objects, it is not possible to generate alternative views other than those created by zooming in or out. Photographs nevertheless provide a high degree of perceived 'realism' or visual fidelity from the viewers standpoint. By inserting computer generated views of design changes into a photographic background, the measured detail of a proposed design can be viewed in a highly realistic context. While it may be possible to rotate the part of the display which has been computer generated, it is not possible to 'rotate' the photographic background to generate alternative viewpoints. And since there is no 3D data contained in photograph, it is not possible to 'navigate' or 'move through' a photo composite. A major shift in capability occurs when the 'environment' is computer generated and represented as a 3D virtual world. While increasing ones flexibility to move through the design and to view objects within the design from different viewpoints, virtual environments force one to sacrifice visual fidelity (realism) for real time capability. Since the designer may not require a high degree of 'realism' he/she may find that real time system performance is more valuable than a high degree of visual fidelity. The public on the other hand, who may be satisfied with a limited number of viewpoints, may benefit more from a sense of 'realism' than from the unconstrained opportunity to drive or walk through the design. The drive thrus or walk thrus desired for public presentation can be generated in real time or in non-real time (animation). Time and cost considerations associated with the use of animation are important factors to consider.

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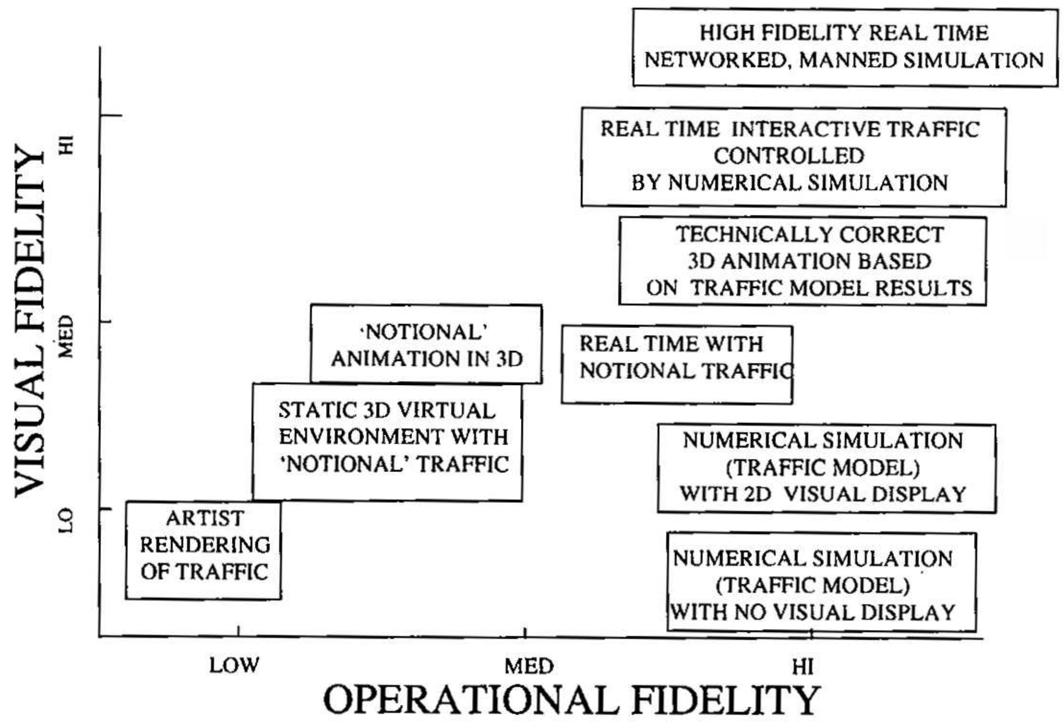

Figure 49. The Relationship Between Visual Fidelity and Operational Fidelity

This figure distinguishes between methods that are good at showing what something will 'look like' and those that are good at showing how something is proposed 'to work.' From the standpoint of the latter, our concern is with effective ways to visualize 'traffic.' A comparison of the different visualization methods shows that high degrees of operational fidelity may range from (a) applications having low degrees of photorealism (e.g, the 2D graphic output of a traffic model) to (b) those with moderate levels of realism such as what might be associated with an animation of nominal traffic flow in a photo composite environment, to (c) a real time display environment where the behavior of individual traffic elements is governed by a numerical simulation (model) running in parallel, and in real time. At the low end of realism and operational fidelity is the artist's rendering of proposed operational conditions. Operational fidelity should not be sacrificed for visual fidelity where operations is a key concern (e.g, in the operation of a proposed roundabout). Neither should visual fidelity be sacrificed for real time performance when the photo realistic quality of the display is judged critical to public understanding and approval of design concepts. There are no clear cut rules for deciding how much visual fidelity is enough or how accurately operations need to be represented in a visualization for public use. Where photorealism and operational fidelity are both required, one should consider the complimentary use of photorealistic methods to convey appearance and the numerical output of traditional traffic models to convey operations.

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Appendix A

Appendix A provides the results of a survey developed jointly by the UNC Highway Safety Research Center (HSRQ and the North Carolina Department of Transportation. State DOT points of contact to whom the survey was sent are provided, as is the survey form itself.

The purpose of the survey was to provide a quick assessment of the state-of-practice in visualization, as currently used within the transportation field at the state DOT level. The results are useful in providing a point of reference to which current NCDOT capabilities and practices can be compared. The sample of states (including the District of Columbia) is not complete, and should therefore not be used to infer the 'true' or even 'representative' level of visualization capabilities and utilization nationwide. This is a survey of state DOT visualization capabilities and, as such, does not provide an accurate impression of the extent to which these new technologies are being applied throughout the transportation community (e.g, by individual contractors independent of any formal state or federal requirement to do so). The results do, however, confirm current perceptions (measured or otherwise) of the effectiveness of visualization within the public involvement process.

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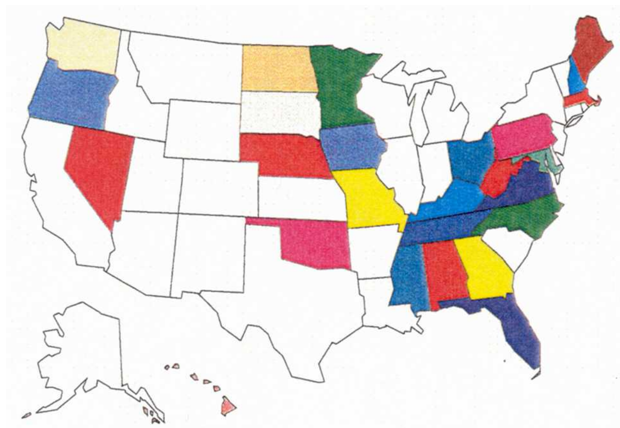
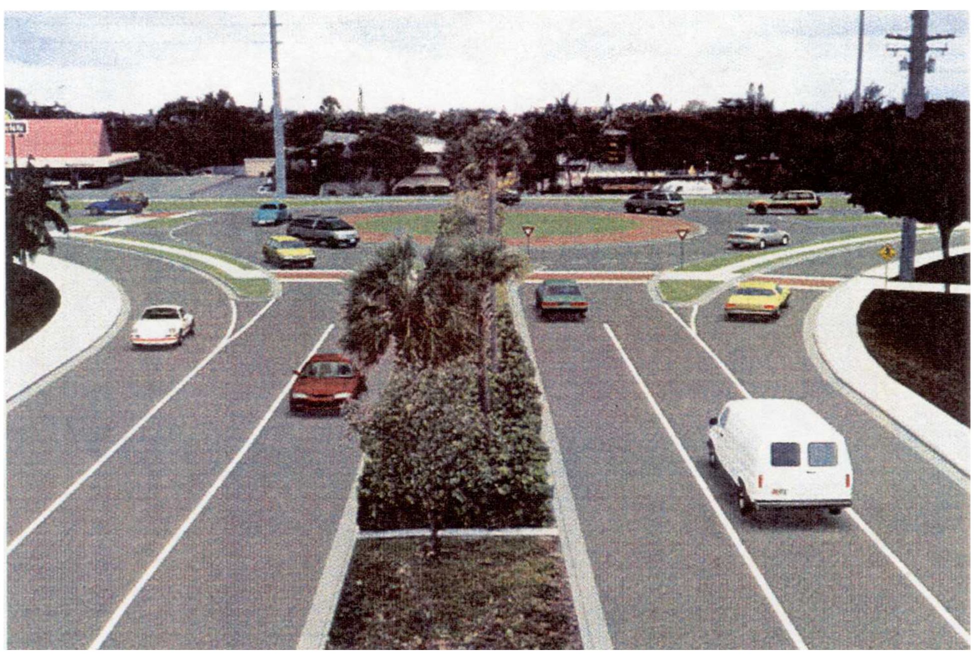
VISUALIZATION
AT THE STATE DOT LEVEL



A Survey of 27 States
Including the District of Columbia



University of North Carolina at Chapel Hill
Highway Safety Research Center

December I998

VISUALIZATION AT THE STATE DOT LEVEL:

A Survey of 27 States Including the District of Columbia[1]

ABSTRACT

Twenty-seven states including the District of Columbia repsonded to a survey designed by the UNC Highway Safety Research Center (HSRQ and the North Carolina Department of Transportation for the purpose of soliciting information on the use of visualization at the state DOT level across the US. The survey addressed issues ranging from manpower and personnel, to hardware and software capabilities, to the use of current techniques and applications (including animation and real time), to perceived effectiveness. Given the incomplete response to the survey, it should not be assumed that the information obtained is representative. The results, nevertheless, provide an indication of the current level of support for visualization, the types of typical products and formats being used (primarily for public involvement versus design), the conditions most likely to prompt the use of visualization, attitudes toward the use of animation (4D), as well as attitudes on the part of these particular state DOTs to the level of 'collaboration' desired in the public involvement process.

*[1] This effort was originally begun as part of a Florida DOT R&D project dealing with simulation which, as defined for that particular effort, involved the development and application of visualization as well as real-time, manned simulation. A report on that effort, entitled, "**The Development and Application of Simulation-Based Tools Within the Florida Department of Transportation,**" is available from the FDOT Transportation Research Center in Tallahassee, FL.*

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INTRODUCTION

While two national level TRB conferences on the topic of 3D/4D visualization in transportation (Houston, 1995; Minneapolis, 1997), a national level teleconference on visualization in transportation (CTE, 1996), and an NCHRP synthesis report on the topic (NCHRP Report No. 229, dated 1996) suggest widespread use of visualization in the public involvement process, there is little information available on a state-by-state basis as to the ′real′ state-of-practice in terms of day-to-day operations. As part of an NCDOT research and development effort to establish general ′guidelines′ for the use of visualization at the project level, a survey was developed jointly by the NCDOT and the UNC Highway Safety Research Center (HSRC) to determine

- ☐ the extent to which state DOTs within this country are currently utilizing visualization
- ☐ the conditions most often prompting a decision to use visualization
- ☐ the extent to which such efforts are being support in-house or through outside contractor support
- ☐ the types of hardware and software being used
- ☐ the most typically used visualization ′products′ and ′formats′
- ☐ attitudes toward the present and future use of ′animation′ (4D)
- ☐ the level of perceived effectiveness, and
- ☐ the extent to which establishing a more ‘collaborative’ environment between the public and the DOT is considered a goal.

We were also interested in the extent to which individual state DOTs have a ‘vision,’ if your will, of what they are ultimately trying achieve in the area of visualization, and whether or not there is a perception of the larger issue dealing with the integrated use of spatially-referenced data (e.g, CAD, virtual 3D/4D, imaged based (photogram metric) data, and GIS).

METHOD

The Survey

A paper and pencil survey was developed jointly by the UNC Highway Safety Research Center and members of a Technical Advisory Committee (TAC) appointed to work with the HSRC on an NCDOT-funded R&D effort oriented to the development of initial ‘guidelines’ for the use of visualization in project design and public review. The TAC consisted of members from Roadway Design, Traffic Engineering, Planning and Environmental (P&E), Engineering Automation, and Public Affairs. The goal of the survey was to use information

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gathered through state DOT responses to the survey as one source of input to the 'guidelines' being developed for use by prospective project engineers. The survey was mailed to state DOT representatives identified by the NCDOT Research and Development Unit as points of contact in their respective state on current visualization efforts, or in the case where states possessed no capabilities in this area, to comment on that state's decision not to use visualization. Those points of contact are provided as a part of this section.

The survey itself consisted of 28 'items,' some consisting of multiple response opportunities, some with an open-ended format to allow for narrative responses, and others calling for the respondent to use rating scales that were provided to solicit input on the extent to which certain factors were judged to be involved.

RESULTS

The following states (including the District of Columbia) responded to the survey: Florida, Ohio, Maryland, Nevada, West Virginia, Georgia, North Dakota, Pennsylvania, Tennessee, Maine, New Hampshire, Mississippi, Kentucky, Oregon, Washington, Minnesota, South Dakota, Nebraska, Massachusetts, the District of Columbia, Hawaii, Alabama, Iowa, Missouri, North Carolina, Virginia, and Oklahoma. The following provides a collective summary of their individual responses.

To what extent is visualization being used at the state DOT level?

> Of the 27 states (including the District of Columbia) who responded to the survey, only three (New Hampshire, South Dakota, and the District of Columbia) reported that they did not use visualization in communicating design concepts and design alternatives to the general public. Each of the three indicated a lack of in-house expertise in visualization. South Dakota and the District of Columbia indicated they did not feel the results justified the costs and that traditional presentation methods were fully adequate.

For those states who reported having visualization capabilities, are those capabilities being provided through in-house resources or via outside contractors and or consultants?

> Slightly over half the states (52 percent) reported having in-house visualization capabilities; 39 percent reported relying upon consultants and outside contractors for visualization support; while 2 of the 23 states utilizing visualization reported using a mix of in-house and contractor resources.

From a manpower and personnel standpoint, what is the approximate size of current in-house visualization support staffs?

> About half (46 percent) of those who reported having in-house capabilities indicated that the size of their visualization support group was in the range of 1-3 individuals. An equal percentage indicated having 3-5 individuals responsible for visualization support while only one of the states with in-house expertise reported having 5 to 10 individuals in this area.

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Where state DOTs report having in-house visualization support capabilities, how skilled are these individuals?

Of the 13 states having in-house visualization resources, two reported that the highest level of technical skill present in the group was that of the graphic artist/illustrator. Two other states indicated CADD level expertise as being the highest skill present. Six states reported capabilities for 3D data base modeling while only one three states (Oregon, Washington, and Minnesota) reported having staff with expertise in real time image generation systems.

From where have these individuals been recruited?

Of the 13 states with in-house visualization support capabilities, eleven indicated that these capabilities had been recruited from within the state DOT organization itself. Two states indicated that visualization capabilities had been recruited from outside the DOT, while one state indicated its staff had been recruited both from the inside as well as outside the DOT.

Can state DOTs afford to retain individuals with these special skills?

Fifty-seven percent believed that current salary scales within their DOT were sufficient to retain these individuals, while the other 43 percent believed that current DOT salary scales were not sufficient to retain qualified individuals.

Where are visualization support capabilities located 'organizationally' within those states reporting to have such resources? Where such capabilities exist, do they tend to be centralized or decentralized?

Responses revealed no clear answer to these questions. Most, but not all states, report that visualization is generally found somewhere within the design part of the organization, most often within a CADD support or roadway/highway design unit. Organizationally, the lack of a consistent 'home' for visualization appears to be more a reflection of its 'roots' than it is its potential for becoming an integrated part of the overall design process. Only the Pennsylvania DOT in its *Vision for Design 2020* puts forth a 'vision,' if you will, of how visualization might eventually become an integral part of the overall engineering design and product development process. In most cases, those who are involved in visualization continue to characterize their mission as providing a 'support' function. Characterizing the locus of this support as either 'centralized' or 'decentralized' may imply more conscious control over its application than actually is the case. Centralization does not necessarily mean that visualization requirements from throughout the organization are being systematically channeled through some central point, but rather that the application of visualization does not yet extend beyond the small group from which it originally evolved.

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Is it possible to characterize the hardware and software resources currently being used by state DOTs to provide visualization support?

Because visualization capabilities have evolved as a part of the standard hardware and software capabilities used for computer aided design, it is not surprising to find that most DOTs report visualization capabilities closely linked to MicroStation and Integraph hardware and related software. Most DOTs report a reliance upon PC (Pentium level) platform capabilities operating in a Windows NT environment. Large (e.g, 128 meg or greater) RAM requirements are commonplace. Only one of the state DOTs reported real time image processing capabilities (e.g, using Silicon Graphics hardware). In general there are little or no real time applications at this time with almost all requirements for 'dynamic' displays being satisfied through the use of animation. The machine intensiveness associated with animation (in particular, the rendering part of the process) at the PC level continues to be a major factor in the lack of support for animation at the DOT level, even though most DOTs recognize the need for the increased application of animation in the future. Geopak represents a core capability for many of these states. Adobe Photoshop software is found in the inventory of most state visualization groups and continues to be used extensively in the development of the photo-simulation products that still represent the bulk of visualization products that are generated. Capabilities for generating 'video' products generally separate the men from the boys in terms of the perceived level of sophistication of the the visualization products that are produced. Inventories of equipment used by the Washington DOT and the Minnesota DOT are included in Appendix B.

Are visualization support capabilities being used by state DOTs mostly for public involvement or for design?

Fifteen of the twenty-four state DOTs who report using visualization, indicated that 90 percent or more of such applications are for the purpose of public involvement. Oregon reported an equal emphasis on visualization applications for design and public involvement whereas only three states (Nevada, Missouri, and Minnesota) reported that 'design' and not public support constituted the larger portion of visualization applications.

What are perceived to be the reasons for using visualization?

In terms of the factors reported by the state DOTs as 'often' or 'always' influencing their decision to use visualization, the most important was "the department's desire to communicate more effectively with the public." Next in importance was the 'complexity of the design project' followed by the "controversial nature of the project" and "the belief that visualization will increase the likelihood of public consensus." The latter two were rated as being of equal importance. Of intermediate importance was the perceived role of visualization in presenting new, complex, or innovative design concepts. Factors reported as 'almost never' being a factor were (a) the belief that project costs would somehow be lower in the long run if visualization were to be used, and (b) public expectation for the use of visualization.

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What is the perceived ability of state DOTs currently using visualization o deal with scope of services, the particular methods and treatments available, and cost?

On a scale from 1 to 10 where a '1' was a response of "No Confidence" and a 10 was a response of "Extremely Confident," those states currently using visualization reported what would, at best, be described as an intermediate level of confidence in these areas. There were, of course, differences across states, with Minnesota and North Carolina DOTs both expressing a high degree of confidence in their ability to address scope of services, approach, and cost.

Is it possible to characterize what types of visualization applications are the most frequent and likewise those which tend to be used the least?

Over half (14 of 24) the state DOTs reported that their applications of visualization, regardless of whether done in-house or by outside consultant, were for the most part limited to photo composites. With respect to the use of animation, only two state DOTs (Florida and Kentucky) that they made regular use of animation in their public presentations. Regarding animation, 15 of the 23 state DOTs reported that they had no 'official position' on the use of animation, even though an approximately equal percentage (13 of 23) reported that they anticipated an increased use of animation in future projects. Four of the 23 questioned whether the benefits of animation outweighed the time and labor involved in its generation, even though a similar (but different set of state DOTs) believed animation could be useful in conveying operational concepts. Only a small group of state DOTs (2 of 23) believed that animation held a value for design similar to that held for use as part of the public involvement process.

In what form are the products of visualization most often used?

Large, usually wall-mounted display 'boards' continue to be the most frequently used format for presenting visualization products to the client. Florida, North Dakota, Oregon, Nebraska, Massachusetts, and North Carolina each reported the use of video tape presentation methods 25 percent or more of the time. Only Georgia, Pennsylvania, and Oregon reported the presentation of visualization materials via CD-ROM. Thus far, only Oregon, Washington, and Missouri reported use of the Internet in conjunction with visualization.

Were there differences between state DOTs in terms of how they perceived visualization to support 'collaboration' between the DOT and the general public?

Only Oregon and Minnesota believed that the purpose of presentations was to permit the public to see the effects of their (the public's) suggested changes/inputs 'on-line.' Eleven of the 24 states currently reporting the use of visualization indicated that presentations were an effort to reflect public needs and system requirements, but that their purpose was not to permit on-line modifications to the material being presented. A smaller percentage (9 of 24) state DOTs indicated that presentations, in their mind, were intended to clearly present DOT design alternatives and not to generate additional discussions/inputs. The

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rather wide range of responses suggests that state DOTs differ significantly in terms of their notion of what constitutes necessary and sufficient interaction with the eventual users of its products.

What expertise did these particular state DOTs, currently using visualization, say they had in terms of effectively integrating GIS, CAD, virtual, and photogrametric sources of data?

Six of the 22 states responding to this question indicated they were either not to do so at all or could do so only with 'great difficulty.' Twelve (12) reported being able to achieve the effective integration of different sources of spatially referenced data with 'some difficulty,' while only 4 for the 22 reported being able to do so with only moderate to little difficulty. The ability to effectively integrate these sources of data across the overall engineering design process represents a key technical challenge for DOTs as they move from worlds defined by 3D versus linear concepts. Being able to do so effectively is important to exploiting the potential for visualization. Only two (2) of the states in the survey reported that being able to do was a well defined, primary goal within their DOT. Over half (14 of the 23) indicated that the integrated use of spatially referenced data was recognized by their DOT as important, but not as a real factor in terms of day-to-day activities. Four (4) of the 23 admitted that this was not even recognized by their DOT as an important goal.

To what extent is visualization (broadly defined to include 2D GIS methods) used in the evaluation of environmental impacts?

Responses suggest that GIS continues to be used primarily as a data base tool for relating different sources of information that are spatially referenced. This was little or nothing in the survey responses to indicate that efforts are underway to achieve a more effective integration of 2D GIS and 3D 'virtual' types of environments or to explore ways in which the type of information typically coded in GIS can more effectively be visualized by the user (engineer or member of general public).

Do any of the state DOTs currently using visualization have a 'vision,' if you will, of where visualization fits into the overall process of requirements definition, engineering design, public involvement, product development/construction, and operations?

Only about 1/4 of the state DOTs who responded to the survey gave any indication of a 'plan' or 'vision' for how the area of visualization might fit into the overall DOT process, except from the standpoint of its present use for public involvement. When any evidence was given for a 'plan' or 'vision' it was usually related to the efforts of a small internal group to extend the application of visualization to areas beyond roadway design (e.g, to planning and environmental). The focus was generally on responsiveness and quality products. Only PennDOT in its *Vision for Design 2020* attempted to place visualization within the mainstream of DOT engineering activities. The existence of a 'vision' does not mean that PennDOT is any farther along than other state DOTs with respect to its application of visualization technology. It is clear from a look at where visualization capabilities presently reside within these DOTs that little thought has been given to its more strategic importance to the DOT.

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SUMMARY

Feedback from twenty-four state level departments of transportation, roughly half currently having in-house visualization capabilities, does not provide a comprehensive assessment of the current state of practice in visualization within the US. One should not attempt to over generalize from these results to the state- of-practice nationwide. Nevertheless, the responses do provide insight into where the current emphasis lies in terms of the application of visualization to surface transportation system projects. With respect to the manpower and personnel resources at the state DOT level committed to visualization, it appears that most state-level capabilities remain small (1-5 persons) and centralized. With respect to the effectiveness of the visualization support provided by these resources, there seems to be general agreement that the benefits of visualization outweigh the cost, even though the actual cost of visualization remains an area of uncertainty in most of the states who responded to the survey.

One concludes from this small sample that, for many, visualization support of the public involvement process remains limited to the use of photo composites presented in the traditional large format, wall-mounted 'board' type displays. Those states who expressed a 'vision' of what they wanted to accomplish through visualization indicated a desire to move beyond photo composites and to work toward the use of visualization throughout the entire design process, to include its use in operations, maintenance, and construction. The best articulated 'vision' of where these technologies fit into the overall process came from PennDOT's Vision for Design 2020 document which placed visualization and other related technologies within the broader context of long range department goals for improvements in the overall design process, in communication, and in the incorporation of new technologies.

Animation, while foreseen by the majority of these states as being increasingly important in the future, is not widely used. It is clear that a number of questions remain as to the effectiveness of animation, even for the representation of dynamic operational issues (such as 'traffic') and effects, The perceived effectiveness of animation is likely to be confounded by the current difficulty of its production. The use of video as a means of presenting the products of visualization is reported to be the second most often used format with some suggestion that the Internet and World Wide Web may also become popular means for making the products of visualization more accessible to the general public.

With respect to the use of visualization for public involvement and for design, the present data suggest that most state DOTs perceive visualization as more of a tool for facilitating communication in the public involvement process. Only three states reported the predominant emphasis of visualization being for design. The data suggest that this is not an 'either-or' (i.e., public involvement or design) issue, but rather one that involves some 'balance' between the two.

Lastly, with respect to the larger issue of integrating for more effective use the different sources of spatially-referenced data found within the DOT (i.e, CAD, virtual 3D/4D, GIS, and photographic imagery), the data suggest (a) that states recognize the importance of doing so, (b) that while the need to do is recognized, it is not a high priority or goal within

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the DOT, and (c) that where there have been efforts to do so, such integration is achieved (in most states) only with great difficulty. Where examples of this type of integration were cited, they were most often related to using spatially defined data (e.g, GIS definition of right-of-way, locations of wetlands, forest, historical sites, etc.) in conjunction with digital terrain data, ground, and aerial photography.

DISCUSSION

The NCDOT is on a par with, or ahead of, most of the states who responded to the survey with respect to its in-house capabilities for utilizing visualization for design and public involvement. Manpower/personnel resources within the NCDOT that are available for visualization support are presently extremely limited. As visualization support requirements expand from roadway design applications to applications in other areas (e.g, Planning and Environmental, Traffic Engineering, etc.), the 'core' visualization group now within the Roadway Design Branch will need to be expanded. Whether that expansion of capabilities is best achieved through the establishment and operation of a centralized visualization 'unit' or disseminated throughout the different functional parts of the organization is an issue that must be addressed.

With respect to the application of more sophisticated visualization capabilities (such as the use of video and animation), the NCDOT reflects the majority position of those states sampled by the survey. . . that is, that the benefits of animation may or may not outweigh the current costs of generating animation and that animation may or may not be the most effective way of communicating the operational (dynamic) aspects of a proposed design or design change. Regardless of the 'true' answer, it is important to separate ones perception of the value of, or need for, a capability such as animation, from the current difficulty or cost associated with its development and application. . . especially when technology is moving in a direction that will make such capabilities more cost effective in the near term (3-5 years).

An interesting finding of the present study was the number of states using visualization (principally in support of public involvement) who expressed the view that the purpose of these tools was to more clearly present the preferred DOT design while minimizing public discussion and input. The common view seems to be that if you can make the 'picture' real enough, you can somehow guarantee public acceptance of the proposed design. . . with little or no need for discussion or public input. It must be understood that the public's ability to more clearly understand the DOT's position is no guarantee that the public will accept that position. The public makes decisions about proposed improvements based upon its perception of benefits, not necessarily the 'factual' aspects of the proposed design. What may be a 'benefit' from the standpoint of the DOT may or may not be a 'benefit' from the standpoint of the public.

Visualization, to be maximally effective from a DOT's standpoint, needs to convey benefits, not just highly realistic views of completed facilities.

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Visualization is not intended to eliminate communication and public interaction, but rather to facilitate it. Likewise, there is evidence that the public expects to see the DOT provide more information still by other means, such as the Internet and World Wide Web. We have succeeded in making the picture realistic enough to be able to communicate complex design alternatives to the public. We have moved beyond simple artist renderings and static 2D engineering drawings. Now we must work on how to listen to and respond to the public's desire to provide feedback on what it sees and to create opportunities to allow the public more on-line involvement in the definition and evaluation of proposed improvements. This increased level of interaction and public participation in the design process will be difficult for many DOTs to achieve. In the age of 'information, however, doing so will become part of how one is required to do business.

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Attachment to NCDOT Visualization Survey Results

Excerpts from

Vision for Design 2020

Pennsylvania Department of Transportation

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*Note: **BOLDFACE** added to highlight information pertinent to use of visualization and related technologies*

From section on **THE DESIGN PROCESS**

. . . The designer uses **computer animation technologies** to quickly prototype different designs. The designer develops **virtual models** of the project and surrounding environment to assess the design from the user's perspective. The designer, **using a virtual environment, quickly prototypes various design options** and evaluates their impact upon the overall design. Project teams also use the same technologies to help the public and resource agencies participate in the design and understand the advantages of the different alternatives. All of this **allows project teams to work interactively** to develop, analyze and refine project alternatives. PennDOT's ultimate customer, the **transportation facility user, has new opportunities to participate** in all phases of the design. The public an view the impacts of new development and even **take a virtual trip on the new facility** to provide feedback about the design. All of this allows project teams to work interactively to develop, analyze and refine project alternatives. **Once the final design is completed, the design is presented as a computer animation** that allows the public to visualize the completed transportation facility through computer simulation.

Information is at the fingertips of project teams as they access information and communicate with their project team and partners. All design products are created electronically from preliminary scoping to the notice to proceed to the plans package delivered to the construction contractor. Paper can still be used, but designers and reviewers prefer to review **multi-media documents** in a hypertext format that enables dynamic linking of information. The format also provides for the **use of images, video, and sound within a document.**

. . . All these changes result in real bottom line performance - **75% of projects delivered from PMC approval to PS&E approval within 2 months.** This is done without losing sight of the human element, the need to treat property owners and the public with respect and care.

From section on **COMMUNICATION**

PennDOT uses a variety of media for storing, retrieving, and disseminating information. Al information is stored electronically. Depending upon the need, a variety of methods are used to disseminate information. The more popular methods of disseminating information include **video conferencing over the Internet, satellite broadcasts, World Wide Web sites, kiosks, electronic mail, and multi-media presentations using CD-ROMs. Public input is sought** through televised, mutli-directional conferences as well as traditional public meetings. PennDOT uses alal 6f these technologies to bring PennDOT closer to its customer. . . .

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Project teams communicate with other teams, team members, and with external partners electronically. Documents, images, CADD drawings, and video are among the items that can be shared. To access information, external **partners are not required to have specialized software,** as information can be accessed through low cost commercial software such as Web browsers. Live links to remote locations in the field are used for scoping field views when all participants are unable to physically attend. . . .

From section on **SPECIALIZED TECHNOLOGY**

A variety of specialized technologies are used to solve specific business problems. Two examples are satellite imagery, used to delineate wetlands or to perform land use determination and a video logged inventory of the transportation network. **Visualization technology, virtual reality, and video conferencing are used to help decision makers identify issues and evaluate alternatives in real time.**

From section on **EXPERT SYSTEMS**

. . . The combination of **CADD and GIS allows designers to develop 4D designs in the actual environment** while including **smart objects** that understand their relationship to other objects and the associated design standards.

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STATE DOT VISUALIZATION SURVEY FORM

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STATE DOT VISUALIZATION SURVEY

Sponsored by Research Unit
North Carolina Department of Transportation

1. Does your state DOT (to include consultants and subcontractors working for the state) use computer-aided visualization methods in communicating design concepts and design alternatives to the general public

   YES (proceed to No. 3) ***NO*** (proceed to No. 2 and stop there)

2. If your answer to Question Number 1 is "NO," is it because (circle one or more)

   A. Your state DOT does not feel the results justify the costs
   B. Your state DOT feels that traditional presentation methods are fully adequate
   C. Your state DOT lacks in-house expertise in visualization
   D. There is no management support for visualization
   E. Other____

STAFFING AND ORGANIZATION ISSUES

3. To date, has your use of visualization been primarily via the use of *in-house* resources or via *outside* consultants and contractors?

   IN-HOUSE (go to 4) ***CONSULTANT / CONTRACTOR*** (skip to 11)

If your visualization work is being conducted 'in-house,'

4. How many personnel are directly involved with visualization support? (Circle your choice)

   1-3 3-5 5-10 more than 10

5. Which represents the highest level of visualization skill currently within your state DOT organization? (Select one)

   ______ Graphic Artist/Illustrator (e.g., PhotoShop, Corel Draw, etc.)
   ______ CAD Draftsman (e.g., AutoCAD, etc.)
   ______ 3D Data Base Modelers (3D AutoCAD, GeniGraphics, etc.)
   ______ Multi-Media/Interactive Programming
   ______ Real Time Simulation

6. From where were your current visualization personnel recruited?

   _______ From within the DOT ______ From outside the DOT

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7. Does the current DOT salary scale permit you to effectively retain these individuals?

YES ***NO***

8. Where is the visualization unit located *organizationally* within the DOT?

9. If your visualization capabilities are primarily in-house are they *centralized* at the state DOT level or are they *decentralized* within your districts, regions divisions, etc.? (please circle your choice)

CENTRALIZED **DE-CENTRALIZED**

NOTE: If visualization capabilities are DECENTRALIZED, please forward this form to the appropriate point(s)-of-contact where the actual work is being conducted.

HARDWARE AND SOFTWARE CAPABILITIES

10. Would you please provide a brief description of your state's in-house visualization operating systems and applications software:

Hardware:

(Please Use additional sheets)

Software:

DECIDING WHEN TO USE VISUALIZATION

11. In general, what percentage of your state DOT's visualization work is performed in direct support of the public involvement process? What percentage is performed in direct support of design? (Assume the two total 100 percent)

Public Involvement:______% **Design:______%**

12. ***How often*** is each of the following a factor in your decision to use visualization? Use the scale below to indicate the importance of each factor

Never a Factor *Almost Never* *Sometimes a Factor* *Often a Factor* *Always a Factor*

1-------------2--------------------3---------------------4------------------------5

______ controversial nature of the project
______ complexity of the design concept or design alternatives
______ overall dollar value of the project
______ the department's desire to communicate more effectively with public
______ the belief that visualization will increase the likelihood of public consensus
______ the belief that visualization benefits outweigh the costs

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______ the belief that in the long run project costs will be less if visualization is used
______ the belief that in the long run visualization improves the 'quality' of the final product
______ the belief that visualization improves the overall 'process'
______ the belief that the public 'expects' the DOT to use visualization
______ presentation of new or innovative design features

13. In your opinion, how confident (on a 1-10 scale) is your state DOT in terms of developing a detailed ***scope of services*** for visualization support, regardless of whether that support comes from in-house resources or is contracted out?

1 2 3 4 5 6 7 8 9 10
No Confidence *Extremely Confident*

14. In your opinion, how confident (on a 1-10 scale) is your state DOT in terms of estimating the ***cost*** of visualization support services?

1 2 3 4 5 6 7 8 9 10
No Confidence *Extremely Confident*

15. In your opinion, how confident (on a 1-10 scale) is your state DOT in terms of selecting different visualization ***methods and treatments*** (e.g, 2D versus 3D, photo composite, when to use animation, when to use real time, etc.) based upon their effectiveness?

1 2 3 4 5 6 7 8 9 10
No Confidence *Extremely Confident*

METHODS

16. Are your applications of visualization (whether done in-house or by outside contractor) limited, for the most part, to **photo composites**?

YES ***NO***

17. Do you regularly make use of **animation** as part of your public presentations?

YES ***NO***

18. What is your DOT's position on the use of animation in the presentation of design concepts? (*Select one or more response*)

______ question whether its benefit is worth the time and labor involved to do it
______ can be effective in conveying operational concepts
______ anticipate increased use of animation in future efforts
______ can be useful in public presentations, but doubt its value for 'design'
______ there is no 'official' position

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19. In your opinion, do the benefits of visualization generally outweigh the cost?

Never	*Almost Never*	*Sometimes*	*Most of the Time*	*Always*

1 --------------2-----------------3------------------------4-------------------------5

20. What percentage of the time are each of the following display formats used to convey the products of your 3D efforts?

_______ Large, wall-mounted display 'boards'
_______ Videotape
_______ CD-ROM
_______ User access via Internet web page
_______ Projection using laptop and LCD-type projector
_______ other (explain) ____

Total: *100%* ____
____

21. Which statement best defines how well your current visualization methods support '**collaboration**' between the DOT and the general public?

_____ Presentations permit the public to see the effects of their suggested changes/inputs on-line

_____ Presentations am an effort to reflect public needs and system requirements, but do not permit on-line modifications to the material being presented

_____ Presentations are intended to clearly present DOT design alternatives and not to generate additional discussions/inputs

22. To what extent are you able to integrate (that is, to combine, manipulate, etc.) CAD, 3D/4D models and methods, GIS, and photogrammetric data in producing visualization products?

1	2	3	4	5	6
Not at all	*Only with Great Difficulty*	*With Some Difficulty*	*Some Difficulty*	*Moderate Difficulty*	*With Little or Difficulty*

23. To what extent is such an integrated approach a goal within your DOT? (Select one)

______ a well defined, primary goal
______ recognized as important, but not a real factor in terms of day-to-day activities
______ not recognized as an important goal

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24. If this type of cross-department, cross-discipline integration is a goal, who is the main point of contact for this work within your state DOT?

Name:______________________________ DOT Address:_____________________________
Phone___________________FAX____________________Email________________________

25. Does your state DOT (either in-house or via outside consultants) utilize any ***real-time*** image generation system capabilities as part of either its public involvement and/or design work?

YES (please explain) ***NO***

____
____
____
____

26. Does your state DOT utilize visualization (broadly defined) in the evaluation of *environmental impacts*? (for example: GIS mapping of environmental features such as wetlands or historic preservation sites; overlaying GIS data on 3D digital terrain models, 3D representation of air quality or noise impacts, etc.)?

YES (please explain) ***NO***

____
____
____
____
____
____
____
____

FUTURE DIRECTIONS

27. Does your state DOT have a ***'vision'*** statement for what it is trying to ultimately achieve in the area of visualization (however broadly defined)?

YES (please explain) ***NO***

____
____
____
____
____
____
____
____
____
____

'SUCCESS' STORIES

28. Does your state DOT have any visualization ***'success stories'*** that it would be willing to share with others involved in the application of visualization to transportation system issues?

____

____ ***please attach additional sheets as necessary***

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VISUALIZATION POINTS OF CONTACT

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Roadway Design Bureau
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Frank Busch
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Reeves Center
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Washington, DC 20009

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Road and Airport Design
271 Capitol Avenue
Atlanta, GA 30334
(also: James Kennerly, State Road and Airport
Design Engineer)

Larry Leopardi
Assistant Chief, Engineering
Hawaii Department of Transportation
Highways Division
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Honolulu, HI 96813-5097

Ray Oldham
CADD Users Manager
Roadway Design Section
Idaho Transportation Department
P. O. Box 7129
Boise, ID 83707-1129

Dohn Beard
Bureau Chief
Bureau of Information Processing
Illinois D. O. T.
2300 South Dirksen Parkway
Springfield, IL 62764

Mary-Jo Hamman
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100 North Senate Avenue
Room N642
Indianapolis, IN 46204-2216

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Cheyenne, Wyoming 82003-1708

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APPENDIX B

Hardware and Software Resources

for

Washington State DOT

Jim Michal, Manager
Computer Aided Engineering
Transportation Building
PO Box 47300
Olympia, WA 98504-7300
360-705-7116
Michal@wsdot.wa.gov

and

Minnesota DOT

Dennis Moline
Minnesota Department of Transportation
Visualization Unit, Mail Stop 688
395 John Ireland Blvd.
St. Paul, Minnesota 55155-1899
612-282-2882

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Minnesota Department of Transportation Visualization Unit Resources

As of June 30, 1998

Point of Contact:

Dennis Moline
Visualization Program Sup.
Visualization Unit, MS 688
395 John Ireland Blvd
St Paul, MN 55155-1899

The Visualization Unit stations are on a 100 Base T line.
The building is on a 10 Base T line.

The Visualization Unit has:

Color Printers
- Tektronix Phaser 440
- Tektronix Phaser 350
- Hewlett-Packard DesignJet HP 2500CP

Workstation #1
- 200 mHz
- 264 mb memory
- 10 gb storage
- Zip Drive

- MicroStation SE
- ModelView
- PhotoShop
- Photo Vista - Live Picture
- Smart Terrain Analyst - Integraph

Video Station #2
- 200 mHz
- 132 mb memory
- 14gb storate
- Sony UVW 1800 Video Cassette Recorder
- Sony PVM 13510 Monitor
- Ensemble Serial Box IV

- MicroStation SE
- ModelView
- PhotoShop
- Premier
- Sound Forge xp

Workstation #3
- 200 mHz
- 132 mb memory
- 4 gb storage
- Zip Drive

- MicroStation SE
- ModelView
- PhotoShop

Copy Station #5
- 133 mHz
- 64 mb memory
- 2 gb storage
- Zip Drive
- Jaz Drive
- Nikon LS-4500K Scanner

Lap Top Workstation #6
- 266 mHz
- 264 mb memory
- 4 gb storage

- MicroStation SE
- ModelView
- Photoshop

Portable Light Table - Satin Glow
Slide Projector - Kodak Ektagraph
Dry Mounting Pres -Seal Commercial 210M-X

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Nikon Camera - N90S
Nikon Lens -24- 120 mm
Panoramic Camera Mount -3Sixty -Peace River
Studios

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Visualization Resources in Washington DOT

Point of Contact:

Jim Michal, Manager
Computer Aided Engineering
Transportation Bldg
PO Box 47300
Olympia, WA 98505-7300

1 Gateway Computer, Model G6-200
3 Intergraph Dual Pentium 200 Computers (TDZ-410)
1 Gateway Computer, Model P5-90
3 Intergraph 21" Monitors (sd 197)
1 21" computer monitor
1 Sony 17" Computer Monitor (Multiscan 17sf)
1 HP ScanJet IIc
1 HP ScanJet Iicx
1 HP DeskJet 1200C/PS Printer
1 QMS System 860 Laser Printer
1 EnCad NovaJet Pro 50" Plotter
1 EnCad NovaJet Pro 36" Plotter
1 Syquest EZ Flyer 230 External Zip Drive
1 Iomega 100 MB External Zip Drive
1 Intergraph 9GB External Hard Drive
1 Intergraph 4GB External Hard Drive
1 Intergraph 2GB External Hard Drive
1 Intergraph 1GB External Hard Drive
2 External Exabyte 8505 Tape Drives
1 Sony Hi8 HandyCam Pro 3CCD Video Cam
1 Sony Digital HandyCam, DCR VX1000
1 Canon 35mm EOS Rebel G Camera
1 Canon 35mm EOS Rebel X Camera
1 Kodak Digital Camera, Model 120
1 Tamron Lens 24-70mm
1 Polaroid Spectra 2 Camera
1 Tekskil Companion TelePrompter
5 Sony SLV 1000 SVHS VCRs
1 Sony TC WE 605S Dual Cassette Tape Deck
1 JVC TD-W317 Dual Cassette Tape Deck
3 21" Sony PVM-2030 Video Monitors
1 13" Sony PVM- 1350 Video Monitor
2 Smith Victor KT 1500 Lighting Kits
2 PhotoFlex Light Disks w/stands
2 Bogen Tripods
1 Mackie 1202-VLZ Mixer Board
2 EV D257 Earphones
3 Realistic P2M Microphones
2 Pioneer DM21A Microphones
1 Audio Technia ATW-1127 Wireless Micro-Phone System
1 NAD& 151 VR Wireless Microphone System
1 Realistic FM Video Camera Wireless Micro-Phone System
1 NADY 151 VRHT Wireless Microphone System
Various containers for storage and transporting of all camera equipment
1 1996 Ford 150 Super Duty Truck with Versalift Manlift Option

Business Plan Software:

CaiCE 6.1.7 (AGA) for design, DTMS, and modeling

CorelDraw6 for drawing and text handling, photo retouching and presentation prior to plotting

Elastic Reality for special effects, warping, morphing, etc.

FreeHand (Macromedia)

FrontPage 98 (Mircosoft) for creation and management of CAE Support Team's Web site

Microsoft Office 95, primarily *Power Point* used as the presentation assembly tool prior to plotting

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MicroStation95 (Bentley) for design, drafting, and modeling

ModelView 3.5 (Intergraph) for providing three dimenssionalrendering and animation. Assists in providing photorealistic images

PaintShop Pro (JASC), photo editing software

PhotoShop 5.0 (Adobe) image editing program allowing creation and production of high quality digital images

Premiere 5.0 (Adobe) for on linear video editing.

ReelTime for video editing in real time

SoundForce XP (Sonic Foundry) for digital audio, sound recording, and editing

Studio Z

SuperPrint 5.0 (Zenographics) improves plotting speeds, and allows for enhancing the appearance of printed material on all types of printing media

Truespace2 (Caligari), for 3D modeling, animation, and textures in real time.

Typestry (Pixar) text and object manipulation and animation

XRes2 (Macromedia)

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Appendix C

GLOSSARY OF COMMONLY USED TERMS

This section provides a glossary of commonly used terms. Become familiar with the terms. As a project manager you need to become comfortable with these terms in order to communicate effectively with those who will be providing you with visualization support. This is true regardless of whether your support comes from in-house or from an outside provider.

> **Note:** As a project manager, you will obviously want to know about the cost associated with the use of visualization. Cost is the one area that is not dealt with extensively in these preliminary guidelines. Your best protection against unnecessary cost is 'competition.' To the extent that you can define in clear terms what you are asking for in terms of visualization support, you can solicit competitive bids for the same type of service and product. To the extent that you simply say that you want 'visualization' on your project, you are at the mercy of the visualization support contractor. The information in these guidelines should enable you to become an informed user of visualization support services.

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GLOSSARY OF COMMONLY USED TERMS

2D versus 3D displays

The terms *'2D'* and *'D',* when used in the context of visualization, apply to the properties of the *displays* used to convey visual representations of the 3D world and to the information upon which those displays are based. While we can *infer* the three dimensional characteristics of an object from a two dimensional display (such as a photograph or photo simulation), a two dimensional display provides the viewer with no information other than that directly available in the display which he/she is viewing. Even when we enhance the 3D aspect of the display (such as with binocular or stereoscopic displays), the only information about the image is that contained in the two dimensional nature of the individual displays. Just as real world 3D objects can be rotated, a 3D display can be electronically rotated to provide all possible views.

3D Model

A computer generated object (e.g, via CADD or other data base modeling tool) where individual surfaces have been rendered to be non-transparent resulting in the perception of a solid object. A 3D model may or may not be textured and depending upon the use and placement of a simulated light source, may or may not exhibit lighting effects (e.g., shadows, reflectance, etc.).

4D Display

The term '4D' refers to the temporal dimension of a display (that is, to its ability to display a change in conditions over time). 4D means more than simply a static display (snapshot) of a moving object. In some sense, a time lapse display would be considered to bean example of a 4D display. It is possible to have 4D displays that are *not* 3D in nature (e.g, a display showing a static object that is embedded within a video background). The perception of movement can either be real time or non-real time. A display showing traffic in motion of a freeway would be an example of a 4D display, irrespective of whether the perception of traffic is generated in real time (e.g, at 30 or more frames per second), or assembled as a result of an animation process.

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Aerial Photo

An image taken from an airborne platform from an altitude necessary to resolve important details in the view.

Animation

The perception of motion that is achieved by the rapid presentation (usually 30 frames or more per second) of successive stationary views. When using animation, the user is required to define a path, or spline, through the data base as well as the eyepoint and point of gaze. There is no flexibility to alter the view that results without creating a new animated sequence. Animation, while effective in conveying the operational characteristics of a design, is extremely time consuming when developed on systems that do not have a real time image generation capability.

Artist Rendering

A free-hand, drawing or painting of a proposed design or facility. Useful early in the conceptual phase of design. An artist rendering is not derived from CAD data. As a 2D representation, it contains only that information contained in the drawing. Other viewpoints or perspectives require additional renderings.

Computer Generated Model or Image

In contrast to 2D images (e.g, photographs) which have been digitized and stored in an electronic format, a computer generated image is an image which is derived from mathematical descriptions (model) of its physical dimensions and surface attributes. As such, different visual perspectives can be generated. Computer generated can vary from simple wireframe models with no surface texture to highly realistic, solid models with photo digitized texture maps applied.

Field of View

The physical size of a display defined in terms of azimuth and elevation. In real time systems, field of view (FOV) generally varies inversely with display resolution (that is, the larger the field of view, the poorer the display resolution). An example of where display resolution is important is where one is attempting to read and respond to simulated highway signing at the equivalent of real world distances.

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Frame

A single view as determined by observer location, eyepoint, and point of gaze. A system with real time image generation capability can generate upwards of 30 frames per second (considered to be the minimum requirement for the perception of smooth motion). Non real time systems, to create the same perception must rely upon animation for the same effect.

Geographic information Systems (GIS)

In essence, a data base management system for geo-referenced data. GIS data bases are typically arranged in 'levels' where each level deals with a different type of information (e.g, demographic; socio-economic, land use, etc.). All levels have in common the same set of coordinates. In some instances, it may be possible to 'drape' GIS 'data' over digital terrain elevation data.

Operational Fidelity

How well a model or simulation represents (in real time or not) the essential dynamic/temporal aspects of system performance.

Photo Digitized Texture

A process whereby a photograph of a surface is digitized then applied (mapped) to the face of a surface. The use of photo-digitized texture patterns allows one to create a level of visual realism that could not be modeled directly.

Photogrammetery

The derivation and use of various forms of spatially defined or geo-referenced data generally derived from aerial photographs.

Photo Simulation or Photo Composite

A photo-like image that has been created by inserting a view of the proposed facility or treatment (may or not be computer generated or CAD-based) into a photographic background. The product is a 2D view of the facility or treatment from a single eyepoint. It is not possible to generate alternative views and visual perspectives from a photo simulation or photo composite. The background imagery may be provided either from static photographs or from video.

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Quick Time VR™

A commercially available software capability that permits one to 'stitch together' individual images which collectively define a panoramic scene. The viewer is able to basically 'rotate' himself or herself 360 degrees about a point. Some capability is provided for the viewer to 'zoom' in or out simulating movement in/out along ones point of gaze.

Real Time

'Real time' refers to the capability of an image generation system to compute/update the visual display at a rate where an observer perceives smooth, continuous motion. 30 Hz is generally the minimum update rate for the effective perception of smooth motion. 60 Hz is generally required if the observer is required to effectively execute a visually mediated motor task (e.g, operating a vehicle).

Rendering

The process by which computer image generation software actually 'draws' an image based upon available information about the object's physical characteristics, the relationship of the object to the observer, and the effect of lighting on the objects' appearance.

Resolution

In display terms, the smallest pixel (picture element) that a viewer can detect. Sometimes expressed as resolution per line pair, where the measure is the smallest separation between pixels (on adjacent raster lines). All other things being equal, large field of view displays have lower resolution than small field of view displays. The ability of an observer to resolve the detail in an image is also influenced by contrast and brightness.

Satellite Imagery

Imagery taken from a satellite, usually in low earth orbit. Imagery may be panchromatic, spectral, or multi-spectral.

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Spatially-Referenced Data

Data that are defined in part by their spatial location/position. Spatial location or position becomes the basis for the management and manipulation of different data sources (e.g., information from CIS, CAD, a synthetic environment, photogrammetry, etc.)

Synthetic, or Virtual, Environment

A simulated 3D environment defined in terms of the information contained in a visual data base. Depending upon the image generation equipment being used, it may or may not be possible to 'navigate' (that is, drive thru or walk thru) a synthetic environment in real time.

Texture

The visual attribute(s) of a surface's physical characteristics (i.e, those attributes by which one infers such things as smoothness/rough ness, material type and composition, color, etc.

Typical Section View

A 2D engineering drawing (may be elaborated by artist rendering) generally showing a 'cross section' of a facility/roadway and which provides numerical measurement information about such characteristics as lane width, curb and gutter dimensions, presence or absence of sidewalk, presence or absence of median, side slope, etc. It is 'typical' in that the dimensions shown are constant for the entire 'section.'

Virtual Reality

A popular term generally used to refer to real time visual simulation system capabilities providing the viewer with a high degree of interaction. More recently, interaction has come to mean tactile as well as visual. Virtual reality applications often may employ a helmet mounted display system which provides the viewer an unlimited overall field of view, but usually at the expense of a rather small instantaneous field of view. The effectiveness of VR is often defined in terms of how effectively the viewer can be 'immersed' within the virtual environment.

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Visual Data Base

A special type of data base containing spatially defined information from which visual displays of objects and their surrounding environment can be generated.

Visual Fidelity

Generally taken as an index of visual 'realism,' where realism is a joint function of scene content and overall picture quality (resolution, brightness, and contrast).

Walk-Thru or Drive-Thru

An ability to move thru a virtual 3D environment and to observe the content of that environment from a given eyepoint or height above the ground. The ability to do so may be the result of an animation sequence where the path, eyepoint, and direction of gaze have all been pre-defined, or may be the result of the viewer's real time control over those parameters.

Wire Frame Model

A model of an object where each surface or face is defined visually by its boundaries (e.g., a typical CAD view). For the non-engineering observer, a wire frame model can be difficult to orient to inasmuch as the individual 'lines' which define the object's surfaces are all visible at once, making the perception of depth difficult.

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For more information on the CTE/NCDOT Joint Environmental Research Program:

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