ACM SIGGRAPH 2008 Class on

Transportation Visualization

Class Organizer & Instructor:

Theresa-Marie Rhyne
Director of the Center for Visualization & Analytics and
the Renaissance Computing Institute's Engagement Facility at North Carolina State
University
tmrhyne@ncsu.edu OR tmrhyne@renci.org

Instructors:

Michael Manore, P.E.
Chair of the Transportation Research Board's Committee on Visualization in
Transportation
& Independent Consultant - AEC Visualization
Michael.manore@gmail.com

Ronald G. Hughes, PhD.
Program Director for Visual Analytics, Modeling & Simulation,
Institute for Transportation Research and Education
North Carolina State University
rghughes@ncsu.edu

Abstract: This class will highlight how transportation planners, engineers and members of the Transportation Research Board's Committee on Visualization in Transportation are using computer graphics techniques and interactive visual displays in their system planning, project design, construction and public involvement activities. Practical examples include the depiction of how three-dimensional models of alternate roundabout treatments in roadway designs are currently being used in conjunction with microsimulation models of driver-vehicle interactions to evaluate alternative crossing solutions for visually impaired pedestrians at roundabouts and channelized turn lanes. We would like to share some of our observations with the SIGGRAPH community to gain additional insight and foster future cross disciplinary interaction.
Introduction

In this short class, we provide a brief overview of how computer graphics techniques and visualization methods are currently being applied to examine transportation planning and engineering design issues and solutions. Each instructor of this class is a member of the Transportation Research Board (TRB)'s Committee on Visualization in Transportation. We hope to cross boundaries and integrate the viewpoints of transportation engineering and computer graphics as well as illustrate parallels to the more recognized areas of scientific visualization and information visualization.

In its September/October 2007 issue of TR News, the Transportation Research Board focused on "Visualization in Transportation". Each instructor prepared an article for this special TR News issue that highlighted the use of computer graphics and visualization for transportation education, research, planning and construction. With the permission of the TR News publication and the Transportation Research Board, we provide these discussions as our notes for our SIGGRAPH 2008 class. We also include the slides from the “Defining Transportation Visualization” topic shown in the class outline below.

The TRB’s Committee on Visualization in Transportation’s web site is located at: (http://www.trbvis.org/MAIN/TRBVIS_HOME.html).

*Photo shown from a transportation visualization working session at the Renaissance Computing Institute's Engagement Facility at NC State University.
Transportation Visualization Class Outline:

Introductory Remarks (5 minutes) (Hughes, Manore, and Rhyne)

Defining Transportation Visualization (25 minutes + 5 minutes of questions) (Theresa-Marie Rhyne)

Visualizing the various elements of transportation systems: how they ‘look’, how they ‘work’ and different requirements for planners, engineers, and public stakeholders (25 minutes + 5 minutes of questions) (Ron Hughes)

Applying Computer Graphics Techniques in Transportation Design and Construction including How to Educate Transportation Engineers about Visualization (25 minutes + 5 minutes of questions) (Michael Manore)

Concluding Remarks - Where to Find Out More (10 minutes) (Hughes, Manore, and Rhyne)

*Photo shown from a transportation visualization working session at the Renaissance Computing Institute's Engagement Facility at NC State University.

Prerequisites: An interest in learning more about transportation visualization from transportation engineers and the Transportation Research Board community.
Instructors’ Short Biographies:

**Michael Manore** is a practicing engineer and chair of the Transportation Research Board's Committee on Visualization in Transportation. He has pioneered the application of visualization techniques to transportation in his work with Bentley Systems, Inc., the Minnesota Department of Transportation and other engineering efforts.

**Ron Hughes** has a Ph.D. in experimental psychology, and is responsible for the development, management, and execution of an extensive transportation visualization research program area for the Institute for Transportation Research and Education at NC State University. His transportation related research in this area draws upon years of prior experience with visual simulation and modeling in the military/defense environment and in the practical application of simulation in the aerospace area.

**Theresa-Marie Rhyne** is a long time contributor to the ACM SIGGRAPH and IEEE Visualization communities, having organized and taught previous courses in visualization and internetworked 3D graphics at both annual conferences, and is currently the Director of the Center for Visualization & Analytics and the Renaissance Computing Institute's Engagement Facility at NC State University.
Defining Transportation Visualization

One Way to think of Computer Generated Visualization:

Define it as

Computationally Intense

Visual Thinking.
So, maybe in a Roundabout way:

Visualization of Roundabouts created by Thomas Fischer of the New York State Department of Transportation in a collaboration with Ron Hughes of NC State ITRE. Shown on the RENCI@NC State Visualization Display Wall.

Transportation Visualization is about...

Visualization of Crossing Solutions developed by Thomas Fischer of the New York State Department of Transportation in collaboration with Ron Hughes of NC State ITRE. Shown on the RENCI@NC State Visualization Display Wall.
Bridging Knowledge & Insight!

Visualization of an alternative for a Bridge Replacement. Image courtesy of and created by Chris Parker for the North Carolina Department of Transportation (NC DOT).

What about GeoVisualization?:

Defined as the Merger of Geographic Information Systems and Visualization
GeoVisualization Example

Working with faculty in NC State University’s College of Design on a Visualization of the Blue Ridge Parkway.


What about “visualization” in the planning & engineering communities:

- Geographic Information Systems:
- Computer Aided Design:
- Immersive Simulation:
- Other computer generated methods:

In the Computer Science arenas these methods would be categorized under the broad umbrella of Computer Graphics & Interactive Techniques - methods that are presented at the Association for Computing Machinery's Special Interest Group on Graphics (ACM SIGGRAPH)'s annual conference and exhibition.
Example: NC SU Virtual Campus Using GoogleEarth:

On August 2, 2007, RENCI@NC SU hosted a demonstration by the NC State Univ. Distance Education & Learning Technology Applications (DELTA) Unit & students from the College of Design of their NC State Univ. Virtual Campus application built in Google Earth.

Photo: Theresa Marie Rhyne

There are three Visualization Subfields:

- Scientific Visualization: defined by an NSF Report of 1987, first IEEE Visualization 1990 Conference focused on Scientific Visualization
  
  the visual display of spatial data associated with scientific processes such as the bonding of molecules in computational chemistry.

- Information Visualization: evolved in early 1990’s, first IEEE Information Visualization Symposium held in 1995 with IEEE Visualization Conference developed visual metaphors for non-inherently spatial data such as the exploration of text-based document databases.

  
  The science of analytical reasoning, facilitated by interactive visual interfaces.
Let’s consider Transportation Examples:

Scientific Visualization Example:
Visualization of Speed Profile Upstream of Freeway Bottleneck by Nagui M. Rouphail, ITRE, 2007.

Information Visualization Example:
from online GIS database of fatal crashes involving trucks in North Carolina, 2001-2005, ITRE.

Visual Analytics Example: display for collaboration and sharing of visual information by transportation researchers and users. Imagery is from a 3-D model of alternative roundabout treatments under consideration by National Cooperative Highway Research Program (NCHRP) Project 3-78, Crossing Solutions for Visually Impaired Pedestrians at Roundabouts and Channelized Turn Lanes. Imagery developed in collaboration with Thomas Fischer, New York State Department of Transportation (NY DOT).
For Further Reading:

Visualization and the Larger World of Computer Graphics
What’s Happening Out There?

By Theresa-Marie Rhyne

In TR News, September – October 2007 issue

See: http://research.csc.ncsu.edu/cva/TRN_RHYNE.pdf
Visualization in Transportation
Empowering Innovation
Visualization Education and Training
MICHAEL A. MANORE

The transportation industry is advancing on all fronts to apply visual technologies, reflecting increased awareness, understanding, and interest. Every month, trade and professional publications introduce new and innovative uses of visualization tools, as researchers and practitioners explore new ways to create and deliver infrastructure.

The transportation industry is tasked with planning, designing, building, and operating infrastructure to accommodate evolving transportation needs. Is visualization another of many tools—or is it a catalyst for a new way of thinking?

Throughout history, every profession has adopted the latest tools to improve the quality and efficiency of the work performed. But often the adoption of a new tool—typically in conjunction with professional and technological advances or some other major event—has engaged practitioners in rethinking how they deliver their product or service. Transportation has arrived at such a transition.

The presence of visualization has expanded so rapidly in the past 5 years that organizations have yet to fathom the implications for program delivery, and professionals have yet to sort out the implications for their practice and for the education of their successors.

Higher Levels
Visualization is more than automating traditional tasks such as word processing or drafting, and it is more than the sharing of overwhelming amounts of information faster. Visualization enables communication, learning, problem solving, collaboration, and decision making at a higher level of thought, and it will challenge current practices for delivering transportation programs.

Visualization training and education, therefore, require more than teaching how to create and animate three-dimensional (3-D) geometry. The goals should include

- Applying progressive visual methods to comprehend and communicate the magnitude of transportation data and needs, to enable more targeted capital investment strategies;
- Enabling organizations to incorporate project delivery practices that are visually and spatially enhanced;
- Complementing traditional learning methods with innovative visual learning environments to
  - Expand problem-solving skills,
  - Enhance comprehension, and
  - Extend engineering communication to include visual with written and oral skills.
The transportation community leverages a wealth of data and information intended to define and make sense of society’s evolving needs for transportation infrastructure. An even greater amount of data and information is leveraged to understand the state of the infrastructure and its performance. Transportation has become an extremely complex industry, and the ability of professionals to fund, plan, design, and deliver functionally appropriate infrastructure will require tools that enhance the ability to learn, think, and communicate.

**Advances Under Way**

Most engineering consulting firms today would recognize visualization as a necessity for winning big projects or as a line item to charge to a client. Transportation agencies may consider visualization a luxury that demands additional resources and is typically reserved for public involvement on large projects.

But related advances, evolving and under way, show that the industry is rethinking ways to improve the delivery of products and services through visually enhanced tools. These advances include:

- Machine control and digital staking, both of which require accurate 3-D subgrade models;
- Interactive 3-D and 4-D models linked to project scheduling software;
- Immersive driving simulators to assess human factors in design and in work zones;
- Immersive display systems for stakeholder involvement;
- Terrestrial, mobile, and airborne lidar survey systems;
- 3-D geographic information systems and technologies similar to Google Earth, applied in environmental impact statements and land use planning;
- Microsimulation visualization methods for complex traffic modeling and forecasting; and
- Temporal visualization of freight movement data, working with radio frequency identification technologies.

**Resulting Concerns**

New advances, however, introduce new interests and new concerns. Some of the leading concerns expressed by the transportation industry about visualization include the following:

- Defining the breadth of visualization, modeling, and simulation;
- Understanding which technology to apply at what point and for what purpose;
- The cost of upgrading information technology infrastructure to manage and share data;
- Developing the expertise to handle, capture, and create data;
- Training professionals to plan for and use visualization;
- Understanding the organizational and professional ethics related to visualization;
- Projecting expected returns on investment compared with the costs of not using visualization;
- Developing standards for the content, accuracy, and quality of contractor and consultant data submittals;
- Writing effective contract language for visualization services;
- Understanding implications for organizational work flows and opportunities to improve business practices;
- Integrating and relating the data to the kinds of data and information already in use;
- Rethinking position descriptions for hiring professionals and specialists;
- Promoting visual learning environments for engineering students to develop visual communication skills; and
- Rethinking the capture of, display of, and interaction with transportation data to enable more effective executive-level decision making.

**Addressing Challenges**

Many organizations are addressing some of these challenges by initiating small groups to master the basics. These organizations include the departments of transportation of Washington State, Minnesota, Utah, Alabama, and New York State; and such companies as Parsons Brinckerhoff, Freese and Nichols, and URS Corporation.

In response to the new public involvement and planning-level requirements for visualization in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the Federal Highway Administration (FHWA) has organized a task force to identify and learn about all visualization-related efforts, resources, and opportunities and to lead the organization in addressing many of the interests and concerns. With Parsons Brinckerhoff,
FHWA’s Federal Lands Division has created a website to inform their staff and the transportation community about certain aspects of design visualization. The Federal Transit Administration has initiated a research project, Evaluating the Effectiveness of Widely Available 3-D Visualization Tools in Support of Public Participation, under the Public Transportation Participation Program.¹

The Transportation Research Board recently established the Visualization in Transportation Committee to perform outreach and define areas for research. The committee convened the 5th International Visualization in Transportation Symposium and Workshop in October 2006 and made the proceedings available on the Internet.²

In the absence of a focused resource for training and education, progress at transportation organizations can be credited to

- One or two visionaries who balance vision with strategic action;
- Executive support and willingness to shoulder some trial and error;
- Technology provider training and consulting;
- Trade and research publications;
- Conferences; and
- Monetary returns, realized or anticipated.

The resources are sufficient for any transportation organization to get started in understanding the technology and in leveraging the benefits.

21st Century Engineers
In 2004 the National Academy of Engineering (NAE) published two timely books: The Engineer of 2020 (1) and Educating the Engineer of 2020 (2). The NAE efforts covered all fields of engineering, and discussed the demands that society and the profession will place on future engineers. Some of the major points include the following:

- The world’s population will reach 8 billion in 2020, with most of the growth in underdeveloped countries. The engineering profession will need to provide solutions to an increasingly diverse population.
- The numbers of foreign-born engineering students in the United States may decline, creating a need to increase and retain U.S. students.
- Globalized and virtual work teams will collaborate on electronic designs.
- More work will be done in multidisciplinary teams, requiring excellence in communication. The incorporation of social elements into the engineering process—such as context-sensitive solutions—will introduce complexity.
- Greater social interaction will be required between engineers and their customers.
- Engineers will engage in public policy, because of the implications that advances in technology and engineering practice will have for society.

The most prominent influence identified by NAE is technology, which not only defines new subdisciplines of engineering but also responds to demands from society, influencing how engineers develop the expertise to accommodate those demands. Society already is influencing transportation visualization technologies. For example, the prevalence of computer graphics in movies, commercials, video games, educational programs, and learning software has prompted stakeholders to have little patience for a project team that shows up at a public meeting with 2-D computer-aided drawings.

Integrated Visualization
With the complexity of today’s transportation projects, and the influence of innovative methods and practices such as machine control, context-sensitive solutions, and design–build, more and more engineering firms are teaming together, and project colleagues are often distributed globally. In these environments, clear and comprehensible communication is vital.

Sending and finding volumes of project information quickly is not enough—the information must be comprehended almost as fast and must improve the project team’s ability to interact. Effectively integrated visualization can address this need directly.

Visual Learning Environments
The 2003 edition of the American Society of Civil Engineers’ (ASCE’s) report card, America’s Aging Infrastructure, awarded the nation’s infrastructure a grade of D+, recently downgraded to D. The report card is not intended to cast blame but to summarize the state of affairs and its implications. At the same time, the United States has a shortage of engineering professionals to address this issue efficiently and creatively.

Influences on the enrollment of engineering freshmen include salary potential, career advancement opportunities, and the complexity, expense, and duration of the program. Retention is an even greater concern. According to NAE, if universities could retain their engineering freshmen to gradua-
tion, the number of engineers would increase by almost 40 percent. The Engineer of 2020 starts out:

Engineering is a profoundly creative process. A most elegant description is that engineering is about design under constraint. The engineer designs devices, components, subsystems, and systems and, to create a successful design, in the sense that it leads to an improvement in our quality of life, must work within constraints provided by technical, economic, business, political, social, and ethical issues. (1)

Visual learning environments that foster the development of this creative process may provide incentives for today's engineering freshmen. Most of today's engineering freshmen have grown up with PlayStation, Xbox, Microsoft Flight Simulator, SimCity, Toy Story, Lord of the Rings, cell phones, and instant messaging. In short, they are wired differently from the generation of engineers now practicing—accordingly, some of the drivers and needs that sustain interest in an engineering career are different for today's freshmen.

One approach attracting attention is the creation of visual learning environments to teach everything from basic courses in statics and dynamics to advanced topics such as constructability reviews and critical path project scheduling. Some engineering educators and universities already are employing visual learning environments for their students.

Virtual Construction
The Computer-Integrated Construction (CIC) Research Program at Pennsylvania State University has gained considerable success in teaching an inherently complex task of engineering—how to perform design reviews and optimize scheduling for construction. CIC Director John Messner developed the program and has noted improvement in students' abilities not only to learn the subject matter, but to communicate individually and in teams (3). These skills have direct applications to project team dynamics in the real world.

Traditionally, writing and speaking have been the communication skills emphasized for engineering students, but changes in technology and the evolving demands of the workplace merit the development of a student's visual communication skills beyond PowerPoint and 2-D plans. Visual communication skills can complement and enhance the quality and effectiveness of writing and speaking.

Construction projects bring all these skills together. The best planning, the best design, the best engineering analysis mean little unless the project team can figure out how to stage, schedule, and build the project effectively. Communication, collective understanding, and timing are key for turning a design into a usable piece of infrastructure, and visualization has a role in this.

Video Game Realities
The annual conference of the American Society of Engineering Education is experiencing an increase in papers on visualization applications for the classroom. A 2007 paper, Implementing a Video Game to Teach Principles of Mechanical Engineering, not only reported on the use of visual technologies but noted an increased depth of learning among the students (4). The author, Brianno Coller of Northern Illinois University, experimented with a new way of teaching a course in numerical methods to undergraduate mechanical engineering students.

Coller cites findings from a March 2005 study of media in the lives of children ages 8 to 18:
- 83 percent of 8- to 18-year-olds have at least one video game console at home;
- 31 percent have three or more; and
- All children in the study, regardless of race, gender, or economic status, spend an average of 68 minutes per day playing video games (5).

Coller discusses the relationships between video games, motivation, problem solving, and improved learning. He organized two groups of students who were taught the same subject material—one group with traditional methods only, and the other group with traditional methods complemented by a video game, NIU-Torcs, codeveloped by Coller's team.

The results showed minimal differences between the two groups in recalling the major topics and techniques in numerical methods. The students who learned the subject using the video game technology, however, were significantly more able to demonstrate...
Showing Students the Concepts

“...As an engineering educator, I have seen a constant evolution of visualization technology in the classroom,” notes Steven Barrett, Associate Professor of Electrical and Computer Engineering at the University of Wyoming. “Educators still use ‘chalk talk’ lectures, but a PC equipped with a video projection system has become standard classroom equipment. Instead of telling students about engineering concepts, we now can show them the concepts. This is a great first step to understanding the often complex details.”

Barrett served as Program Chair for the Computers in Education Division (CoED) of the American Society for Engineering Education (ASEE) annual conference in Honolulu, Hawaii, in June 2007. ASEE works for the advancement of education in engineering and in allied branches of science and technology, including teaching and learning, counseling, research, extension services, and public relations.

“In the CoED programs at the 2007 ASEE conference, we saw a plethora of new ideas on how to use tablet PCs with visualization software to capture and engage students’ attention in the classroom,” Barrett reports. “I also have witnessed an explosion of the use of modeling and visualization tools—such as the Mathworks MATLAB—which allow the educator and researcher the capability to model and visualize complex engineering systems.”

Involved in engineering education for the past two decades, Barrett previously was an active-duty faculty member at the U.S. Air Force Academy, Colorado Springs, Colorado, and was named the 2004 Wyoming Professor of the Year by the Carnegie Foundation for the Advancement of Teaching.

◆ How the various numerical methods worked;
◆ The appropriate uses and limitations of each method; and
◆ How the methods depended on one another.

The motivational effects of engaging visual technologies, such as a video game, therefore, may deepen the level of learning and understanding in engineering students beyond mere recall, and may enhance their ability to apply their knowledge more effectively and creatively in the real world. Coller’s work, together with Messner’s, strongly suggests that more engaging, visual learning environments may help to produce the caliper of thinkers, problem-solvers, and communicators needed to address society’s infrastructure needs.

Influencing Changes

On August 1, the I-35W Bridge in Minneapolis collapsed, making the national headline news for several weeks. The ASCE report card, which had highlighted the fragility of the nation’s aging infrastructure, also attracted media attention. As a result, considerable activity is under way at all levels to rethink the U.S. approach to addressing transportation infrastructure.

Combined with professional and technological advances or a major event, the use of new tools can engage practitioners in rethinking how they deliver a product or service. Visualization, in all its forms, can complement and influence the changes pending in the transportation profession. Visualization has far-reaching potential for

◆ Communicating infrastructure needs to leaders who must prioritize budgets,
◆ Enhancing the ability of transportation organizations to deliver timely and ever more complex programs within those budgets, and
◆ Educating the engineers who will make it all happen.

References


Additional Resources

The capabilities of computational systems have grown rapidly, fueled by continuous development in the microprocessor and computer graphics industries. These advances have enabled levels of computer image generation that were unimaginable by those involved in the defense applications of visual simulation in the 1980s.

Although early monochrome, mainframe-based systems lacked the resolution and scene content of today’s microprocessor-based systems, they generated imagery in real time, usually for training simulator applications—a true computational achievement. Today the computer graphics industry has achieved an abundance of visual fidelity, vivid color, and realistic scene content, and yet—at least in the area of transportation visualization—only seems to be discovering real-time image generation, as distinct from animation.

A key issue for transportation visualizations is the value of real-time images. Does the ability to move freely within an environment have more value than experiencing the constrained path of an animation? Is it more important to permit unconstrained, real-time movement through a database or to be able to make changes to that database extemporaneously or “on the fly,” to enable a stakeholder and a designer to investigate alternative designs collaboratively in real time?

Heritage and Distinctions
Computer-aided design (CAD) has a history that is equally long. Early computer image-generation database systems were, in large part, extensions of two-

1 http://mbinfo.mbdesign.net/CAD-History.htm.
dimensional (2-D) design capabilities inherent in CAD systems. Current visualization capabilities owe much to CAD but are distinguished more by image processing than by constructing objects in a database.

The task of visualization often is less about the polygonal structure of the objects and more about the ability to render the faces or surfaces defined by the underlying polygonal network of lines. The realism associated with modern visualization is more closely linked to what we see than to how the underlying model was created.

Color and texture are taken for granted today, but as recently as 30 years ago, every engineering design drawing was generated manually with pen and ink. Real time was the time required to produce an image manually—that is, to draw it. Today, real time refers to the computer's ability to redraw an image 30 to 60 times in a second.

Defining the Agenda
In 2005, a paper in the Transportation Research Record: Journal of the Transportation Research Board contained a preliminary research agenda for the application of visualization in transportation (1). The agenda represented the collective input of members of the TRB Task Force on Visualization in Transportation. The research needs reflected members' areas of expertise, which ranged from transportation to military and defense to aerospace. The agenda subsequently appeared in NCHRP Synthesis 361, Visualization for Project Development (2).

The 2005 inventory of research needs addressed 17 issues grouped into four categories:

1. Foundations for applied research,
2. Management-oriented and institutional issues,
3. Integration of modeling and simulation, and
4. Social-psychological and cognitive elements.

These research needs were reviewed again at the 2006 TRB Visualization in Transportation Symposium and Workshop.

Surveying Practitioners
After the symposium, attendees completed a structured, online survey focusing on perceptions of the research needs from the agenda. Attendees ranked establishing foundations for research as the highest priority. Second was research addressing the integration of modeling and simulation; third was the need for research addressing management issues; last was research addressing the cognitive elements of visualization.

In establishing a foundation for research, high importance was attached to defining the real and perceived value of visualization. Also of high importance was research that would aid organizations with both the technical and organizational tasks related to start-up and for research products that would provide guidance to practitioners.

In the integration of modeling and simulation, high importance was given to research addressing the visualization of system operation instead of system appearance. This reflects general advances in database modeling and the need to enable users to visualize how the system works—for example, to visualize traffic generated from an underlying model.

The need to establish a research-based foundation

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Interactive proceedings are online at
for the application of visualization in transportation has parallels in the field of scientific visualization. Using a phrase from an earlier article by Hibbard (3), one editorialist recommended that researchers should “engage … ‘foundational problem[s]’” in the field and continued:

As da Vinci understood the need for practitioners to study their own practices, whether the art of science or the science of art, so too did he comprehend the need to theorize those practices … to understand them and hence to strengthen them: “…he who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast.” (4)

Entrance of Planning
The 2006 Symposium and Workshop differed from previous meetings by attracting almost equal participation from the planning side of the transportation community as from the engineering and design side. Planning participants represented a range of organizations—for example, the Federal Highway Administration (FHWA), the Federal Transit Administration, metropolitan planning organizations (MPOs), and consulting firms. Past symposia had focused almost exclusively on the engineering and design components of project development.

The 2006 symposium also formally recognized the relationship between the notion of visualization within the transportation community and developments in information visualization and scientific visualization, as well as with the evolving area of visual analytics.3

This expansion of interest was timely, because the new transportation system legislation, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), requires the use of visualization techniques in MPO participation plans. The legislation also calls for accessible public visualizations—to be available via the Internet. Visualization would be an integral tool in addressing scenario planning, community impact analyses, links between planning and the National Environmental Policy Act (NEPA) process, green infrastructure planning, transportation and land use integration, context-sensitive solutions, and many other approaches described in the legislation.

Effects on the Agenda
How then does this expanded notion of the role of visualization affect the research agenda? Does the SAFETEA-LU focus on visualization in planning suggest new and different research needs, or can the agenda accommodate the increased scope of visualization applications? What needs to be changed or added?

Although the agenda was developed without significant consideration of planning applications, much is still relevant. The following needs still apply:

- Guidance for practitioners—in some cases, using engineering and design tools, and in other cases, tools unique to the planning domain;
- Data on cost and effectiveness—going beyond the cost of equipment and personnel to include data on the labor intensiveness of various applications and data requirements for each visualization application; and
- Measures that reflect the multidimensional nature of effectiveness.

Planning Requirements
Research on the planning applications of visualization will focus more on the human and environmental context of a project. FHWA’s focus on context-sensitive solutions is appropriate—the human context must be sensitive to stakeholder needs. Visualization can link stakeholder needs, which often may be ambiguous, to project design alternatives before the alternatives take form. How does one visualize for stakeholders such concepts as urban sprawl, walkable communities, connectivity, the economic impacts of blight, or the effects of noise?

The visualization of physical structures cannot violate the rules of constructability; similarly, visualization of the complex underlying relationships that mediate the concerns addressed in the NEPA process cannot violate basic environmental principles. How something looks, whether addressed as an engineering or a planning need, is no longer sufficient. The stakeholder wants to see how it works and to be convinced that the underlying engineering and science responsible for the visualization are correct.

Planning often must deal with a level of vagueness and ambiguity not present in the consideration of alternative engineering designs. Yet the processes and rules of planning are nonetheless rigorous. The effective use of visualization in a planning decision support system will require the development of ways to convey difficult concepts visually, along with the variables that affect them. Geographic information systems (GIS) are not the complete answer, nor is the evolution of 3-D within the GIS field.

This raises another research need: how to influence the requirements process that results in new visualization tools and methodologies for use by planners or project engineers. Within TRB, clearly

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3 See the presentation by M.-T. Rhyme,
www.teachamerica.com/ VIZ/02g_Rhyme/index.htm.
written, well-substantiated, statements of research need should be developed.

Environmental Justice
The planning focus of visualization introduces the concerns of environmental justice. According to FHWA, environmental justice supports the following goals:

- To avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority populations and low-income populations; and
- To ensure the full and fair participation by all potentially affected communities in the transportation decision-making process.4

Is it possible that socioeconomic status can have a bearing on the way in which visualization tools are used in the planning process? Everyone does not see the same thing when presented with the same image. Not all stakeholders have the same ability to process complex spatial information.5 The images presented in the course of public involvement are viewed, processed, and understood within a context of individual cognitive abilities and experiences. Despite every effort to convey the value and benefit of a project clearly, the stakeholder still may hear something completely different.

Visualization, carefully used, can benefit communication with a diverse stakeholder population in which socioeconomic factors play a major role. Environmental justice introduces a broader range of considerations than those typically dealt with in current applications of visualization for project design.

Environmental justice is more clearly aligned with planning than with engineering. Yet many of the factors involved—such as demographics and socioeconomic levels—are traditionally represented by GIS mapping techniques.6 The common ground is growing between GIS and more traditional visualization. The role of visualization in environmental justice is an area with a great need for research-based guidance for transportation planners and developers.

Visualizing Research
If a body of visualization research could be visualized—the issues, the products, and the methodologies—what would that image convey? According to the survey results from attendees at the 2006 Visualization Symposium and Workshop and to input from members of the TRB Visualization Committee, the image would depict needs for research at many levels within engineering and planning applications:

- The collection and synthesis of case studies and lessons learned from the systematic application of visualization methods and technologies to high-profile transportation system projects, producing practical guidance for practitioners;
- The multidimensional measurement of effectiveness in terms of (a) project and program development; (b) public involvement and communication; and (c) organizational goals, particularly addressing costs, both in terms of workforce—including training and time—as well as equipment; this research should be integrated into the visualization support for high-profile projects and should capture labor and equipment costs;
- The behavioral, psychological, and marketing factors that mediate the application of visualization methods and their observed outcomes; and
- The identification of functional requirements for future capabilities and tools and the communication of those requirements to developers of new system capabilities.

Products of basic and applied research in these areas should provide practitioners, project and pro-

5 For an overview of the problem in the field of geoscience, go to www.ldeo.columbia.edu/edu/DLESE/maptutorial/introduction.html.
gram engineers, and senior transportation system officials with insight into

- The goals to be achieved on a project;
- The value of visualization in achieving the goals;
- The visualization methods and techniques indicated by the goals;
- The project costs associated with the methods and techniques;
- The influences on the effectiveness of the applications; and
- The measures for evaluating the effectiveness of the visualization.

Because of the SAFETEA-LU focus on incorporating visualization into the transportation system planning process, attention should be on planning instead of on the already demonstrated engineering and design applications.

Aid to Understanding

The core of the research agenda for visualization in transportation remains relevant, with major additions or increased focus in the area of planning applications to come. Visualization research must recognize the dynamic, interactive, and collaborative nature of the planning process. Visualizations already have enabled stakeholders—usually in a public involvement setting—to review design alternatives, but applied research into planning applications will need to focus on applications that can clarify user requirements in a predesign setting and that can facilitate the translation of those requirements into scalable dimensions and effective designs.

GIS plays a major role at this stage but often is more relevant to the planner than to the stakeholder. GIS capabilities therefore must be incorporated into new and evolving drawing tools that can rapidly generate and modify the visual approximations of a result. The resolution and detail of the image are not paramount, but the extent to which the sketch embodies the stakeholder-defined needs. Several presentations at the 2006 Visualization Symposium and Workshop indicated that such efforts already are under way.

Planning tools must enable planners to use visualization extemporaneously and collaboratively as an aid in developing stakeholder awareness of the relationship between stakeholder-defined needs and the attributes of alternative design solutions, including operational trade-offs and system costs. The notion of environmental justice suggests that these tools blending visualization and GIS must take into account socioeconomic differences in stakeholder communities.

Not everyone can read maps, interpret data presented in charts and graphs, and comprehend with equal facility complex 3-D and 4-D presentations. The typical stakeholder may not understand the underlying structure of the rules that provide the basis for the models and simulations. Transparency should not mean simply being able to access these underlying rules, but the ability to grasp readily the nature of the complex relationships they define.

Visualization first and foremost must serve as an aid to understanding, making relationships intuitively apparent, but not to increase complexity or confusion. Research therefore should focus on the information value of visualization, not on the technology. A visualization is a means to an end and not an end in itself.

References


Additional Resource

Visualization and the Larger World of Computer Graphics

What’s Happening Out There?

THERESA-MARIE RHYNE

Visualization based on computer graphics and interactive techniques was formally defined 20 years ago in a landmark report sponsored by the National Science Foundation, “Visualization in Scientific Computing” (1). Visualizations frequently involve large displays and stereoscopic environments to immerse the viewer in an examination or exploration process. The Internet has facilitated collaborations among explorers at distributed and remote sites.

Visualization requires computationally intense visual thinking. The premier arena for presenting visualization research is the Institute of Electrical and Electronics Engineers (IEEE) Visualization Conference Week, held annually in October since 1990.

Subfields of Visualization
Ongoing research and publication in visualization now includes two defined subfields—scientific visualization and information visualization. A third subfield, visual analytics, is emerging.

Scientific Visualization
Scientific visualization produces visual displays of spatial data associated with scientific processes, such as the bonding of molecules in computational chemistry. As noted in the landmark report of 1987, “visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe the simulations and computations” (1).

The methods of scientific visualization are well suited to transportation. They can enhance traffic data to microsimulate scenarios that support decision making—for example, for evacuations, diversions, and rerouting schemes. The figure on this page shows how scientific visualization techniques are applied to examine spatial and temporal speed profiles for a freeway bottleneck (2).

Information Visualization
With the evolution of visualization and of technologies for human and computer interaction in the early 1990s, the subfield of information visualization took shape. The focus was on developing visual metaphors for noninherently spatial data. A goal was to facilitate the exploration of text-based document databases. In 1991, researchers at Xerox published findings on the information visualizer system, which began to articulate a difference between scientific and information visualization (3).

The first IEEE Information Visualization Symposium was held in conjunction with the IEEE Visua-
The symposium continues to occupy the first part of the conference week, with the main Visualization Conference sessions later in the week. For the field of transportation, information visualization methods are well suited to address community planning scenarios that combine diverse data sets from geographic information systems (GIS), visual impact assessments, and transportation analyses.

**Visual Analytics**

The subfield of visual analytics, defined in 2004 and 2005, is emerging to supply the need for visual interfaces to explore analytical data in response to terrorist attacks and natural disasters. The landmark report, *Illuminating the Path: The Research and Development Agenda for Visual Analytics,* published in 2005, defined visual analytics as “the science of analytical reasoning facilitated by interactive visual interfaces” (5).

The first IEEE Symposium on Visual Analytics Science and Technology was held during the 2006 IEEE Visualization Conference. Still an emerging arena of research, visual analytics methods are being developed to assist in emergency responses and rapid evacuations of transportation arteries in densely populated communities. Visual analytics methods also are applicable to transportation planning and design.

In 2005 and 2006, with the maturing of scientific and information visualization and the emergence of visual analytics, the National Institutes of Health and the National Science Foundation sponsored a reexamination of research issues in visualization. The 2006 report, *NIH-NSF Visualization Research Challenges,* presents the findings (6).

**Examining Geovisualization**

All three subfields of visualization provide insights and methods applicable to transportation planning, implementation, and evaluation. Cartographic and geographic information techniques also span all three research subfields.

Cartography has produced extensive theory and writings on the spatialization of data and information. GIS consists of efficient repositories of layered spatial data. Geovisualization—the merger of GIS and visualization technologies—embraces specific domains of application, particularly in transportation (7).

**Other Graphics Tools**

The transportation community has created many examples of visualizations with high-end computer graphics tools and methods. Computer-aided design (CAD) has become an essential tool for establishing an accurately registered roadway, including the bridges and other infrastructure, for transportation engineering projects. GIS also is used for planning, as well as for design and construction.

Animation techniques allow the production of high-end movies that depict how a proposed transportation project will be integrated into the community infrastructure. The image on the next page employs photorealistic computer graphics to display a proposed roadway project.

**Online Resources**

Online resources and communities have provided new tools for the visual examination of data. Google
Earth and Virtual Earth, for example, are powerful tools for geovisualization.¹ The website images can serve as a base for overlays of visual elements from online databases, to produce what are called “mashup” visualizations.² The mashup visualizations can be shared and enhanced readily via online communities associated with Google Earth and Virtual Earth or via social networking websites like My Space.³

In addition to text-based social networking sites, three-dimensional (3-D) virtual worlds allow for building personal avatars—images that serve as personal signatures or identifications on the web—and for arranging possessions in a defined cyberspace. Second Life is one of the more popular examples of an online 3-D virtual community.⁴

Specialized examples of 3-D virtual spaces have been developed for public participation across the web. Virtual London is an application currently under development by the University College of London’s Centre for Advanced Spatial Analysis, with funding from the Greater London Authority and London Connects.³ This large-scale 3-D GIS and CAD model of the city uses Google Earth, as well as a variety of photorealistic imaging and photogrammetric methods.⁵

Serious Games

One of the more widely known traffic simulation games enjoyed by the general public is SimCity’s Rush Hour Expansion Pack.⁶ The module allows players to control vehicles on the streets of their own designed city and to fix transportation problems in their own virtual world.

The popularity of these computer games has led to a repurposing of the technology to educate and train students at all levels. Simulations aimed at examining management and leadership challenges in the public sector are known as “serious games.”⁷

Combined with visualizations of specific and targeted transportation issues, serious games provide an opportunity for an interactive examination of transportation scenarios (8). These scenarios can assist with key evaluation and decision-making efforts as well as with public participation activities.

Top Problems in Visualization

At the IEEE Visualization 2004 conference, a panel of leaders in the field examined future directions in a session, “Can We Determine the Top Unresolved Problems of Visualization?” (9–13) Each panelist prepared a list of the top 10 unresolved problems; as a panelist, I identified the following:

1. Effectively and accurately simulating Mother Nature and human behavior. Attempts to use visualization and numerical computational methods to create virtual scenarios are always challenged by real-world solutions or events never before considered or modeled.

2. Usability of the visualization system. Can visualization tools gain use beyond the computer graphics experts who developed them? How well do these tools fit into the ongoing work in departments of transportation?

3. Evaluating the effectiveness of visualization tools. How can visualization methods be assessed for their helpfulness in resolving problems, and how can the methods be modified accordingly?

4. Addressing perceptual and cognitive issues. Can the effects of visual displays on viewers be understood and applied to improve the designs?

5. Supporting multidisciplinary collaborations. Experts from many disciplines provide the content for visualizations and contribute to resolving concerns about a visualization’s details. How can ongoing collaborations be facilitated?

6. Evolving graphics hardware and platform development. The hardware for producing computer

² For an example of a mashup visualization of census data in Google Earth, see www.juiceanalytics.com/writing/2006/03/census-data-in-google-earth/.
³ www.myspace.com/.
⁵ http://casa.ucl.ac.uk.
⁷ www.seriousgames.org.
Finally, visualization faces many key problems. Readers are encouraged to examine the other papers in this issue and to seek other viewpoints from the visualization field.

References

Additional Resources

Expanding Views
Visualization involves computationally intense visual thinking. Visualization consists of three subfields:

- Scientific visualization—the visual display of spatial data;
- Information visualization—the visual display of nonspatial data; and
- Visual analytics—analytical reasoning facilitated by visual interfaces.

Online resources, such as Google Earth and Virtual Earth, serve as starting points for mashup visualizations. In addition, serious games are repurposing computer game simulations and technologies to educate and train professionals.