TR NEWS

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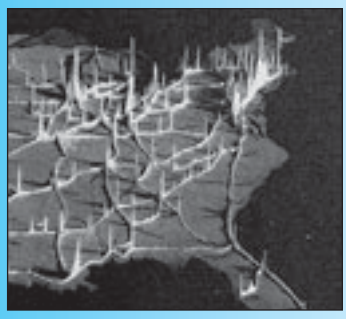
VISUALIZATION IN TRANSPORTATION: EMPOWERING INNOVATION



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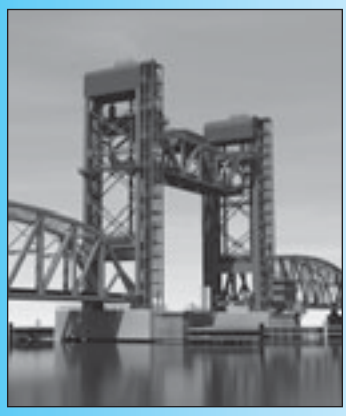

COVER: Visualization of a railroad lift bridge over the Thames River, near Groton, Connecticut, integrates a range of diverse purposes: design, construction, mechanics, planning, and public outreach. (Image courtesy of HNTB Corporation.)

TR NEWS

features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

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ALSO IN THIS ISSUE:

CORRECTION: Captions to three photographs in the May–June 2007 *TR News* (pages 3, 14, and 15) erroneously identified the roadway that crosses the Bay St. Louis Bridge in Mississippi as Interstate 90—the roadway is US-90.

COMING NEXT ISSUE

The U.S. highway infrastructure is aging and decaying; increases in traffic congestion are inconveniencing motorists and jeopardizing safety; the trained and experienced workforce is diminishing; high-quality materials are becoming scarce or inaccessible; environmental considerations and natural forces—including earthquakes and hurricanes—are key issues; and funding to renew and sustain the infrastructure is inadequate. The November–December *TR News* will feature forward-looking articles on the design, construction, and preservation of the highway infrastructure for 2020 and beyond, addressing many of these topics. The issue also will include TRB's 2007 Annual Report.

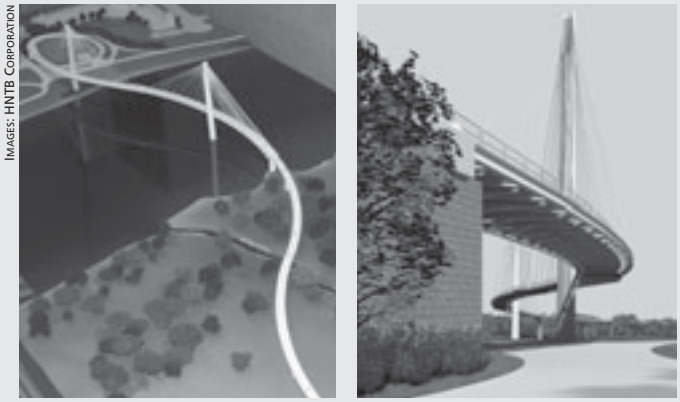
Bridge spans, like the Graves Avenue span over Interstate 4, northeast of Orlando, Florida, can be installed in minutes—the span is prefabricated adjacent to the site and driven into position with self-propelled modular transporters. Installing multiple-span prefabricated bridges complete with substructures is a practical strategy to reduce traffic disruption.

INTRODUCTION

Visualization *in* Transportation 101

What is visualization? The popular online reference, Wikipedia, defines and categorizes visualization in the contexts of psychology, "creating internal mental images" and "spatial visualization ability"; spiritual disciplines, "engaging … one's imagination … to effect changes in consciousness"; and technology, "creating images, diagrams, or animations to communicate [a] message."

The entry goes on to define scientific visualization as "an area of computer graphics … concerned with the presentation of potentially huge quantities of laboratory, simulation, or abstract data to aid cognition, hypothesis building, and reasoning" and identifies other subcategories: knowledge, product, and music visualization. Other references offer various permutations, expanded definitions, and additional subcategories to suit the needs of particular professions or industries.



Images: HNTB Corporation

Physical model and virtual model of Missouri River Pedestrian Bridge Project, linking Omaha, Nebraska, and Council Bluffs, Iowa.

Raising Awareness

For the purposes of transportation and for the articles in this issue, visualization is defined as

> Any progressive visual means of representing static or temporal spatial and geometric information.

This definition may be vague, but the articles in this issue make clear that the term, visualization, has become a catch-all for many visually enabled tools that have found a way into the transportation industry. Pulling them all together under visualization simplifies things.

The intent of this issue, therefore, is to introduce the transportation research community to an assembly of knowledge, perspectives, and references to visualization-related activities that are having an impact on transportation. The articles aim to enhance awareness of how visualization in all its forms can improve the ability to fund, develop, and deliver timely, cost-effective, and safe transportation systems in synch with society's transportation needs—and prompt discussion and ideas for targeted research.

More to Consider

One challenge in preparing this theme issue was deciding what to set aside. Machine control for more efficient construction; lidar scanning technologies for design, bridge inspection, accident reconstruction, and airport security; immersive simulators for testing designs and for vehicle operator training; and traditional physical models are just a few of the subjects not covered in these pages. But these and other varieties of visualization are playing no small part in advancing the delivery and operation of U.S. transportation infrastructure and will be part of ongoing discussions in the research community.

—Michael A. Manore
Chair, TRB Visualization Committee
Director, Infrastructure Visualization Center,
Bentley Systems, Inc.

Image, top right: Visualization of proposed changes to Los Angeles International Airport, produced by the Urban Simulation Team at the University of California, Los Angeles, for presentations of ideas to the airport's board of commissioners, at public meetings, in long-range planning sessions, and for modeling future expansion. (Image: Urban Simulation Team, University of California, Los Angeles)

Editor's Note: Appreciation is expressed to Richard F. Pain, Senior Program Officer, TRB, for his contributions to the development of this issue of *TR News*.

Visualization
Empowering Innovation

A Vision of Visualization

Communicating Problem-Solving Concepts to the Public

ALAN E. PISARSKI

The author, a transportation consultant in Falls Church, Virginia, is emeritus member of the Urban Transportation Data and Information Systems Committee and chairs the National Cooperative Highway Research Program Project Panel on Using American Community Survey Data for Transportation Planning. His book, Commuting in America III, *was published by TRB in October 2006.*

This has been a year for visioning among the transportation profession—searching for a compelling vision for America's future transportation system. The National Surface Transportation Policy and Revenue Study Commission has focused extensively on a vision for the future; Congress has held hearings to develop a national vision; and the American Association of State Highway and Transportation Officials (AASHTO), joining forces with seven other major transportation associations, held a three-day retreat in May to form a national vision.

We may have learned finally that asking for more money does not work if the public is not sure that officials have a clear vision of where we are going and a credible record of focusing resources toward a vision. The negative effects of Congressional budgetary earmarks have added to the need for a unifying vision that can replace a program of diverse projects.

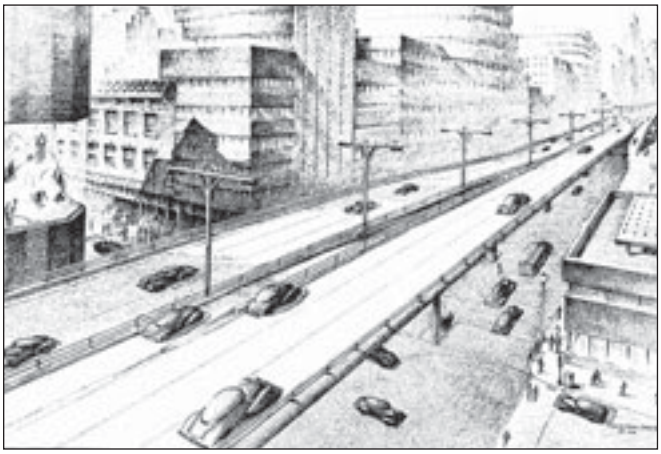
This is a valuable undertaking, demonstrating that the search for more money must rely on first establishing the credibility of the public agencies that will spend it, as well as provide a viable vision of what needs to be done and a workable plan to get us there. Then the funding of whatever form is appropriate for the vision, by whatever mechanism or level of government, will be much more likely to be forthcoming.

The task of visioning is linked to the need for visualization. If the public cannot visualize what we are trying to communicate to them, convincing them of the value of the necessary financial investments will be difficult. Although most of the applications of visualization techniques have been at the project level, we need to recognize the technology's value in other areas—such as the formation of programs; the demonstration of the benefits of projects and programs; and the education of the public and public officials on the need for and value of transportation investment.

Visualizing the Interstate

Last year, the nation celebrated the 50th anniversary of the funding plan for the Interstate Highway System. A review of that planning process provides insights into the power of visualization and visualization tools even in that era. When the Interstate system was being evaluated and designed, few Americans had experienced freeway travel. Using the tools available, sophisticated staff at the federal highway agency presented the needs and the concepts behind the plans in ways that public officials and the public alike could understand.

On April 27, 1939, transmitting to Congress the recommendations in *Toll Roads and Free Roads*, President Franklin D. Roosevelt stated:



Rendering of an elevated section of the proposed interregional highway system through a city, from *Toll Roads and Free Roads*, 1939.

PHOTO: FDR LIBRARY

President Franklin D. Roosevelt addressing Congress in 1938; he was an advocate for the value of comprehensive and comprehensibly presented data on highway travel.

> The report, prepared at the request of the Congress, is the first complete assembly of data on the use being made of our national highway network.…In its full discussion of the whole highway problem and the wealth of exact data it supplies, the report indicates the broad outlines of what might be regarded as a master plan for the development of all of the highway and street facilities of the nation.

Note that Roosevelt emphasized the value of the first complete and comprehensive data set for highway travel—perhaps that was the last instance of an American President discussing transportation data in a message to Congress. The report expressed the data in ways that could be comprehended by the average reader—ways that we would be challenged to equal today (see sample illustrations from the report, this page).

We are just as challenged today as they were then and just as much in need of effective tools for making our case. One of our great weaknesses in the transportation field has been the inability to explicate properly the benefits that accrue from public investments in transportation.

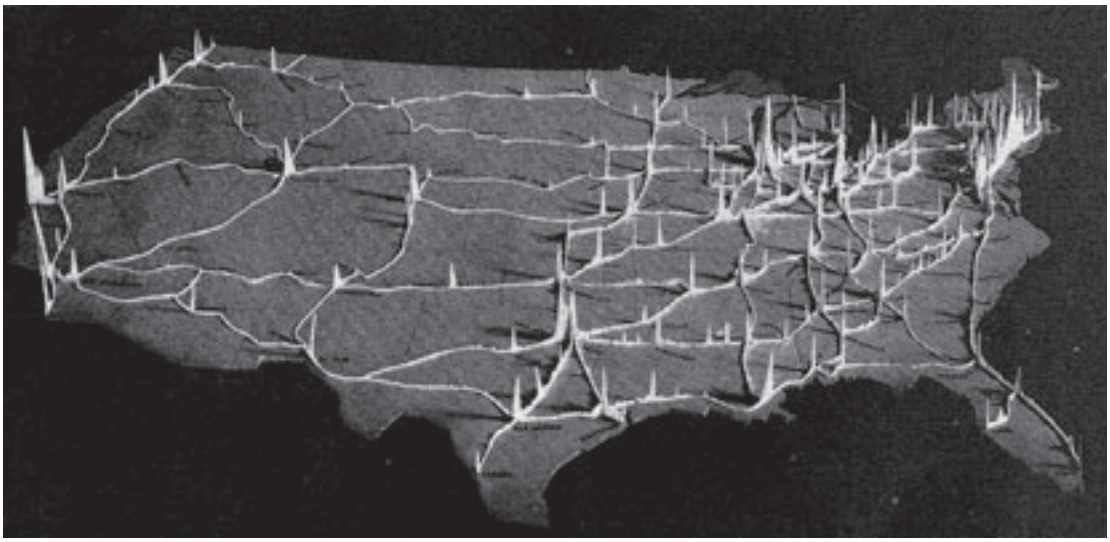
Visualizing Today's Issues

Today's issues and proposals would benefit from more effective visualization techniques. The first national freight-flow maps, developed early in the work of the Federal Highway Administration's Freight Office, had great impact, for example, showing that the "rust belt" was not all that rusty—that is, a concentration of manufacturing and heavy industry. The maps did more to create national recognition of the issue of freight needs than years of statistics and speeches—a great example of the effectiveness of skillfully presented ideas.

Many of today's issues involve new concepts that the public—and even professionals in the field—have difficulty grasping. At the 2007 TRB Annual Meeting, Secretary Douglas MacDonald of the Washington State Department of Transportation sponsored a contest for the best way to explain maximizing traffic throughput to the public—a marvelous example of a difficult concept and the determination to explain it. Other examples of difficult-to-explain transportation problems are the following:

- How does traffic build up when a blockage occurs on a freeway? Why does the build-up take so long to dissipate after the blockage is gone?
- Why do ramp meters work? How does congestion pricing play a similar role?
- How would a high-occupancy toll lane work? How would it help nonusers?
- How do shrinking or expanding market sheds or economic corridors affect access to employment, employees, suppliers, or a greater range of housing choices?

Toll Roads and Free Roads included dramatic aerial views of grade crossings for the proposed Interstate highways.



Relief traffic map from *Toll Roads and Free Roads* indicates the average density of traffic to be expected at all points of the proposed Interstate system.

The *Commuting in America* series has used graphics, maps, and tables extensively, seeking to make the new patterns of transportation more comprehensible to a wide audience. Yet so much more could be done with more sophisticated mapping and visualization techniques to make the findings more accessible to readers.

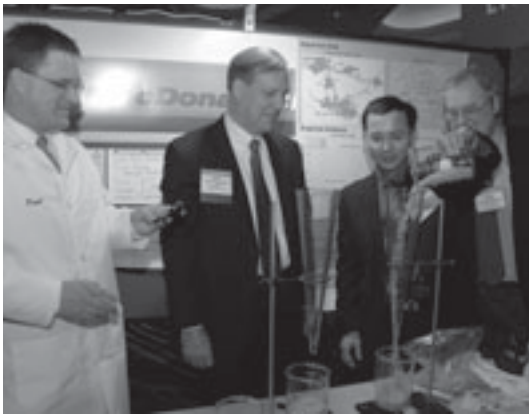
The dominant characteristic of contemporary commuting—the suburb-to-suburb flow—needs better explication, as does the concept of the dramatic rise in commuters leaving their home county to work. These also could be subjects for a small contest, to find the best and most emphatic ways to express the trends and findings.

Most of the proposals broached in the recent visioning discussions would benefit greatly from more effective means of visualization. The best example may be a recent National Cooperative Highway Research Program exploration of future options for the Interstate Highway System.[1] This next phase of Interstate expansion needs as much visualization as Phase 1 received in the advent to 1956.

Visualizing Tomorrow's System

In testimony before the Highway and Transit Subcommittee of the House of Representatives Transportation and Infrastructure Committee, January 2007, I presented an extensive list of concepts for the future, culled from current discussions and from my own vision. Every concept would benefit immensely from visualization:

[1] NCHRP Project 20-24(52), Future Options for the National System of Interstate and Defense Highways. http://www.TRB.org/TRBNet/ProjectDisplay.asp?ProjectID=558.



At the 2007 TRB Annual Meeting, Doug MacDonald Challenge winner Paul C. Haase *(left)* times a demonstration of maximizing traffic throughput, which compared rice poured into two glass funnels all at once and in a controlled flow. Huizhao Tu *(second from right)* of Delft University of Technology, the Netherlands, assists with the demonstration, monitored by TRB Executive Director Robert E. Skinner, Jr. *(second from left)*, and Douglas MacDonald *(right)*, Secretary, Washington State Department of Transportation.

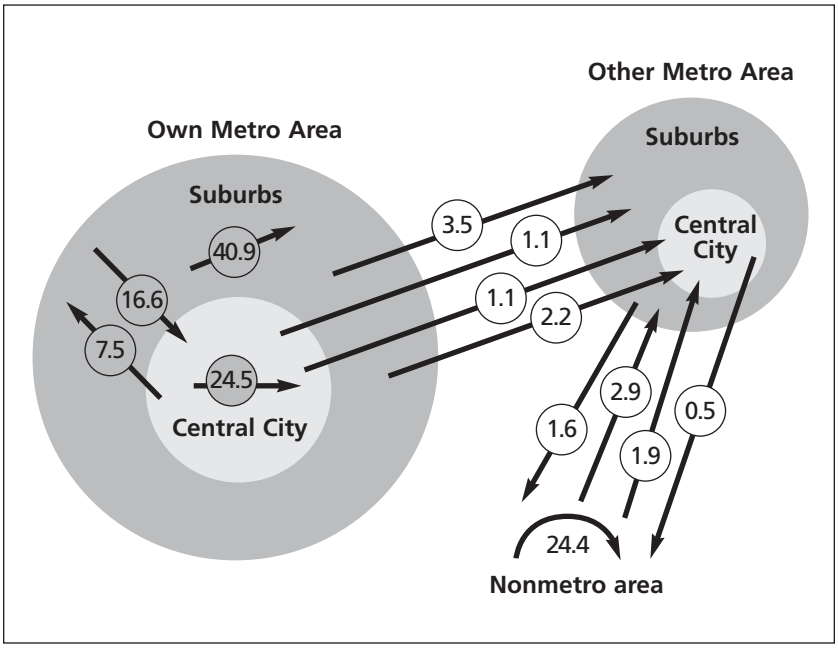
- An expanded Interstate system reaching more areas;
- Increased rings of beltways around metropolitan areas, supporting greater circumferential travel and increasing bypass opportunities;
- Improved access to the city center, including commuter railroad–like facilities;
- Improved rural two-lane roads for safety and mobility;
- Improved local circulation services in urban and rural areas that focus on integrating lower-income populations into productive society; and
- Safety and operations enhancements for safer and more effective use of facilities.

Other ideas—such as an automobiles-only national parkway system and a national truck network—also would be wonderful topics for visualization.

My testimony could not close without indicating the desperate need for better data and analysis tools, including visualization techniques and applications. Such a project would be an ideal tool to attract the computer-savvy younger generation of prospective analysts, engineers, and planners into our profession.

The articles presented in this issue provide the beginnings of a better understanding of what visualization is and what it can do. The TRB Visualization Committee, which started out as an exploratory task force, has made great strides in bringing this topic to our attention. More work needs to be done.

Graphic depicting the flow of commuters (in millions) between metropolitan areas and between metropolitan and nonmetropolitan areas, from *Commuting in America III*.



Visualization as a Common Language for Planning

Good Practices, Caveats, and Areas for Research

DOUG WALKER

The author is President, Placeways, LLC, Boulder, Colorado.

California-based transportation planner Charles Crocker was charged with developing a major new transportation corridor that would transform his region. In addition to the expected engineering and organizational challenges, he faced labor problems, environmental impacts, financial scandals, crime along the route, and local residents who objected so strongly that they sabotaged the work and attacked the construction crew—on horseback.

Crocker oversaw construction of the Central Pacific's portion of the Transcontinental Railroad in the 1860s (*1*). Although his problem-solving techniques were not exemplary—massive bribery, wholesale habitat destruction, and battling Native Americans with federal troops—the challenges he faced are still recognizable today.

Crocker dealt with issues involving context and stakeholders. Transportation planners today are aware that a corridor is affected not only by rights-of-way and access, but by its entire community context. Not only is the operational performance of a corridor heavily affected by surrounding land uses, but the entire project is influenced by community concerns and decision making. This growing awareness is reflected in the rise of the context-sensitive solutions approach and by initiatives like the Federal Highway Administration's Transportation, Community, and System Preservation program established under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).[1]

At the same time, local governments and land use planners are focusing on the vital role that transportation plays in their communities.[2] As the local Native Americans recognized in Crocker's day, transportation shapes, supports, and colors almost every aspect of the communities it serves, from the local economy's viability to the local residents' quality of life.

PHOTO: CALIFORNIA STATE LIBRARY

Charles Crocker

[1] Section 1117 of SAFETEA-LU, Public Law 109-59. http://www.fhwa.dot.gov/tcsp/.

[2] See, for example, the May 2007 special transportation issue of the American Planning Association's *Planning* magazine. www.planning.org.

Collaborative Planning

Because of this mutual interdependence, land use planners and transportation planners are looking for ways to work together. Both groups, however, are finding that collaboration is not easy. Any transportation project involves a variety of stakeholders, perspectives, systems, and points of view; as the project's context widens, its complexity grows. Bringing disparate components together, developing a shared understanding of goals and constraints, and finding mutually acceptable solutions to issues is a daunting task.

When it works, collaborative planning has ample benefits (*2*). These include earlier identification of problems and objections; better informed decisions that are more likely to meet a variety of project goals; better buy-in and less resistance throughout the approval process; and—ideally—reduced project time. These benefits accrue, however, only if the collaboration is successful—and as Charles Crocker and his descendants know, things may not go well.

A Common Language

Collaboration entails effective communication. The collaborating parties—for example, transportation and land use planners—do not need to be experts in each other's fields, but they do need to understand each other's goals, constraints, and priorities. These may range from the financial and technical to the political, emotional, and aesthetic. Stakeholders almost always speak different languages, employing unique terms of art, acronyms, data formats, expectations, assumptions, taboos, and unspoken rules. The diversity of conversations can range so far from effective collaboration that calling in federal troops may not seem inappropriate.

Yet everyone understands visuals. A well-rendered visual model can be almost miraculous in its ability to communicate complex, multidimensional information (*3*). Modern visualization software can span the computer-assisted design–centric tools of transportation and the geographic information system–centric tools of planning, as well as many other types of software and technology (see image, this page).

Visualization can speak engineering, politics, and poetry at the same time. Visualization is not a substitute for any of these fields, but a way of communicating about them. It engages broad audiences, bringing them to the table—or meeting, or workshop—to hear and be heard. Visualization provides a common point of reference, a world view that can be shared by all. A successful visual model acts not just as a showpiece, but as an active tool that facilitates collaboration.

Visualization technology has made remarkable progress in the past decade.[3] Adopted across industries, science, engineering, and popular culture, visualization is no longer a stunt or a novelty, but normal in a world of video games, digitally animated movies, and Google Earth. At the same time, visualization has crossed a threshold of practical and financial feasibility for transportation and planning projects. Although a high-quality project visualization may cost a few hundred thousand dollars, a workable visualization is also possible for a few thousand dollars or less (*4*).[4]

In short, visualization technology for collaboration is now readily available. The question is how to use it.

Safeguarding Credibility

In combined land use and transportation projects, visualization can engage wide audiences and can convey complex information in a way that promotes collaboration. Visualization can give people a way to experience and explore a world not yet built and to talk about what could be. A computerized visual model is like a shared editing environment for the future project.

Not all visualizations, however, are equally effective. Experience is yielding valuable lessons about techniques that work and about practices to avoid.

The credibility of visualization is perhaps the greatest impediment to its success as a tool for collaboration. Because any photo can be Photoshopped—that is, digitally altered—and any movie image can be a special effect, audiences often may suspect that a visual model is unrealistic or that the imagery has been modified to favor a particular point of view. Visual models can make a project look better or worse than it will be. For these reasons, modelers should consider caveats and follow good practices in their work.

IMAGE: PLACEWAYS, LLC

Demonstration of CommunityViz software, combining computer-assisted design, geographic information systems, and project scheduling technology into one visual model displayed in Google Earth.

[3] See article by T.-M. Rhyne in this issue.

[4] See article by C. Hixon in this issue.

IMAGE: PLACEWAYS, LLC

IMAGE: PLACEWAYS, LLC

Side-by-side comparison of the same vantage point with two different fields of view demonstrates how foreground roadway or background scenery can be emphasized.

Credibility Caveats

A yet-to-be-written guide, "How to Lie with Visualization," could include the following examples from planning and transportation practice:

◆ *Vegetation and landscaping*. Greenery is placed carefully to obscure unsightly features; or stumps and logs are left in the scene to emphasize clearing.

◆ *False traffic*. Roadways are shown with far higher or far lower levels of service than are expected.

◆ *Field of view*. Zooming in can make a feature look larger, or distant landmarks look closer; zooming out can make a project look small in context.

◆ *People*. Cheerful pedestrians, well-mannered cyclists, and happy children with balloons put a project in a positive light—but is their presence realistic?

◆ *Technical stunts*. Wowing an audience with state-of-the-art technology can make the medium itself take on more importance for the viewer than the project on display.

Many other malpractices can be added to the list.

Such practices may be unethical and can have negative repercussions (*5,6*). Some members of the audience are bound to see through the tricks. Even if they do not, the truth will come out, and if the project ends up looking different from the model used for approvals, long-term damage is done to the credibility of the model creator and to the reputation of visualization in general.

An inappropriate or inaccurate visualization can taint the credibility of an entire project. If the visual model shows an exaggerated view, viewers will wonder if the project's science and engineering are similarly untrustworthy.

Finally, inaccurate visual models risk crossing what can be called the "reality gap," the brain's perceptual divide between fiction and nonfiction.[5] Visual models are attempts to create nonfiction, but if done poorly, can make an audience categorize the effort as fiction and think of the model as a game.

Good Practices for Credibility

◆ Include the existing context—that is, the present-day landscape, corridors, and buildings in the project area—to help the viewer orient to the scene and build a mental connection between the model and the real world.

◆ Provide the fairest, most balanced presentation possible, even if it does not fully support the favored objectives. Illustrate all visually important aspects with the same degree of quality and care (see images, this page).

◆ Whenever possible, use fly-through, fully navigable, or real-time models instead of stills or rendered videos that follow a single, set path. Navigation gives an audience the reassuring ability to look "behind the curtain" and gain a sense of place.

◆ Provide the ability to toggle between the before and after or alternative scenarios. This gives audiences the chance to develop trust in the model by looking at what they know before making the leap to what they are expected to imagine.

◆ Recognize that the visual model is not an end in itself but a tool for presenting information and promoting collaboration. Its role is to inform, not persuade; to support dialogue, not monologue.

Visualization Priorities

In addition to safeguards for credibility, several other lessons are emerging from experience with visualization, particularly from planning projects. For example, some model characteristics are surprisingly unimportant:

◆ *Attractiveness*. Although beautiful models attract attention and make a project look desirable, the model's beauty becomes unimportant if it does not facilitate communication after the first few minutes.

[5] This phenomenon is similar to what Japanese roboticist Masahiro Mori dubbed the "uncanny valley." See www.arclight.net/~pdb/nonfiction/uncanny-valley.html.

IMAGE: WINSTON ASSOCIATES

A high degree of detail is not always required. This screenshot of an interactive 3-D model uses many hand-sketched elements but still conveys important aspects of the design.

◆ *Detail*. Engineers often want to include details that make a model closer to reality, to illustrate diligence and depth of understanding, and to convey the most information possible. Considerable discipline therefore is required to decide what *not* to put in a model to save time and money by placing priority on objects that are material to the discussion (see image, this page).

Experience also has identified several surprisingly important characteristics of visualization:

◆ *Interactivity*. To promote collaboration, visualization must be a tool that audiences can use, change, question, and address. The most effective models include what-if scenarios, reference comparisons, real-time measurement and verification tools, real-time modifications, and other features that support interaction.

◆ *Context*. Showing recognizable landmarks and existing conditions is critical.

◆ *Practicality*. Real-world experience constantly reinforces the merits of practical, proven technology that is neither too new, too expensive, too arcane, nor too time-consuming to use reliably in actual projects.

Research Needed

Responsible visual modeling must convey established facts and information, but the degree to which people's decisions are based on information versus emotion is still a matter of uncertainty. Modern visuals are a more emotional medium than are traditional formats like maps and charts, and much remains to be learned about how visualization influences audiences (*7,8*).

The merits and ethics of collaboration also need more study. One of the results of visualization is that more people, including nonexperts, are involved in planning and decision making. Whether this is beneficial is a topic of debate (*9*).

Testing the Bridges

Done well, visualization can help build better bridges between transportation planners, land use planners, and all other stakeholders in a project. It can serve as a shared language for collaboration, supporting a process that results in more informed decisions, fewer delays, less resistance, and more buy-in at each step of the way.

But the bridges that visualization tools are creating are still new and relatively untested. Along with the opportunities come pitfalls to avoid and risks to assess. Transportation planners and others should move quickly, but carefully, into this new realm.

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Visualization
Empowering Innovation

Visualization Issues for Transportation Agencies

Approaches and Challenges

CHARLES L. HIXON III

The author is Business Development Manager, Bergmann Associates, Jacksonville, Florida. He was the consultant for NCHRP Synthesis 361, Visualization for Project Development *(2006).*

The transportation design community is using visualization tools for a variety of purposes—from public involvement to traffic analysis to planning and design. Visualization technologies are making an impact on the planning, design, and maintenance of our roadway systems.

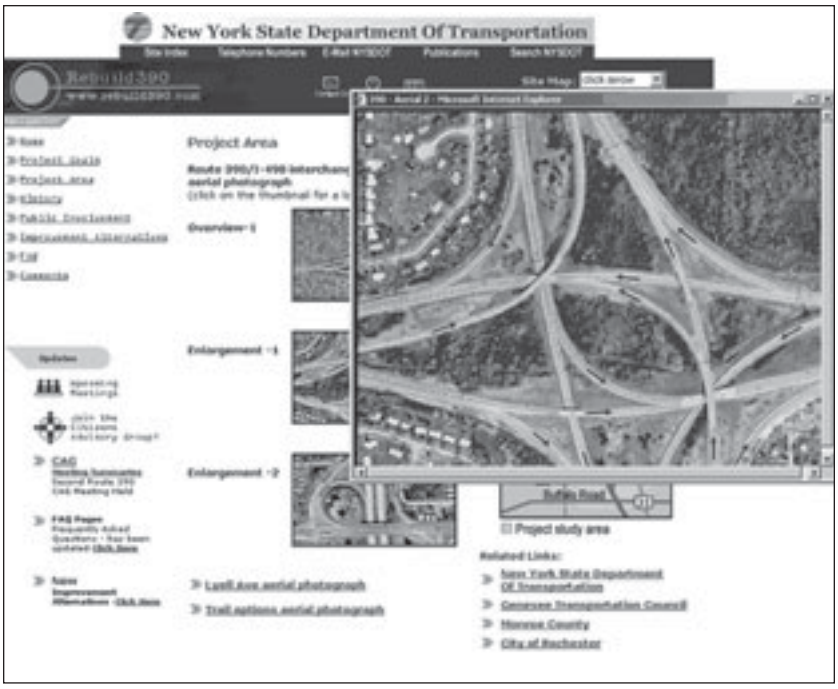
Nevertheless, project managers and department heads in state agencies often ask what visualization is and how it is used. Visualization is difficult for most people to understand because it encompasses many definitions and uses.

Essentially, visualization is the use of graphics to explain any planning or design issue. It can be a simple rendering by hand, a physical model, or a three-dimensional (3-D) computer-generated animation. The visual tool box encompasses many tools, and the choices are predicated on a project's budget and production schedule.

Agency Initiatives

Transportation agencies are using visualization technologies in three primary categories:

Visualization of a proposed gateway traffic circle.



Public outreach websites, like this by New York State DOT, allow access to up-to-date project information and offer ways to post comments; the sites are updated with such information as project milestones, analyses of traffic impacts, alternative solutions, meeting reports, and schedules.

- Public involvement and stakeholder approval,
- Context-sensitive design, and
- 3-D computer-aided design and drafting (CADD).

Public involvement is the primary use. The general public has become aware of visualization techniques through the media and entertainment industries and expects to see these same types of sophisticated applications when reviewing proposed projects. Many departments of transportation (DOTs) have found that visual tools are a necessity for large projects, not only to convey the goal clearly but also to advance an image of the DOT as sufficiently innovative and sophisticated to develop and manage such a project.

Visual tools are gaining widespread use in the planning process for context-sensitive design. Many DOTs are attempting to involve key stakeholders and the public earlier in the planning process, to ensure that projects are more readily accepted and approved. Visual tools such as photo editing can play an important role. Design charettes—small group meetings to collaborate in problem solving—are common ways to review design ideas with the public and often rely on visualization.

Because the public has become better informed and more sophisticated, the days of an agency unilaterally designing, announcing, and defending a project are past. Context-sensitive design and visualization are helping to bridge the communication gap between transportation agencies and the public.

Some agencies are beginning to plan and design projects in 3-D, allowing planners, designers, and engineers to improve their understanding of the design issues and impacts. With 3-D CADD applications, for example, engineers have made 3-D digital terrain models for machine-controlled cut-and-fill operations. The visual application has improved construction accuracy and saved significantly on construction costs.

Choosing Tools

What kinds of visual tools are transportation agencies applying? Most agencies rely on key department personnel or consultants for advice and recommendations. Decisions typically are made case by case and often are determined by the project size, budget, and schedule.

A range of tools is available. Traditional tools, such as physical models and 2-D renderings, are still prevalent. More advanced applications—such as photo editing to show before-and-after images, and web-based or multimedia graphics—have become commonplace. Once considered extras, these applications are now integral to the planning and design process.

Larger projects with robust budgets tend to rely on higher-end applications, such as 3-D animation and virtual reality. These applications are more expensive and take time to produce, but the results offer high-quality imagery that can render the proposed designs realistically.

Planners can use visualization to resolve construction sequencing issues and present cost-efficient approaches.

Implementing Visualization

Despite increased use, visualization remains misunderstood. No standards or guidelines are available to assist agency project managers, who must make fundamental decisions each time a visual need arises. These decision makers often have limited knowledge or understanding of the technology, leading to ineffective use or misapprehension of the benefits.

The primary hindrance to the development of standards and guidelines is that visualization is not yet considered part of the planning and design process. Visuals often are not addressed until the end of the planning process, when public involvement issues arise. As a result, the visuals become extra expenses that usually have no set budget. To be more effective, the technology must become part of the planning and design processes.

Quantifying Value

A valid cost–benefit analysis is needed for visualization technology. Project managers require some kind of a reference to determine how much an application will cost or how long it will take to create. In addition, quantifiable data are needed to back up the perceived values of visualization.

For example, what were the positive effects of the technology on the quality of the design? Did the technology save on productivity, enhance the production schedule, or speed the approval process? Most project managers want to know the return-on-investment. Empirical data to support the effects of visualization technologies are lacking. Project managers value the uses of visualization but have difficulty explaining what that value is.

Another issue is the lack of understanding of the technology among decision makers. Most project managers and decision makers are unfamiliar with the processes of visualization, making it difficult for them to determine schedules and budgets. Often they rely on outside consultants for advice and decisions. The combination of an insufficient understanding and minimal references for guidance has kept project managers from embracing the technology.

Establishing Units

Most transportation agencies do not have units responsible for visualization but instead rely on key personnel to produce visualization content. For the most part, these assignments have no formal job descriptions or defined career path. Without formal job descriptions and distinct business units, training personnel to advance their skills in visualization is difficult.

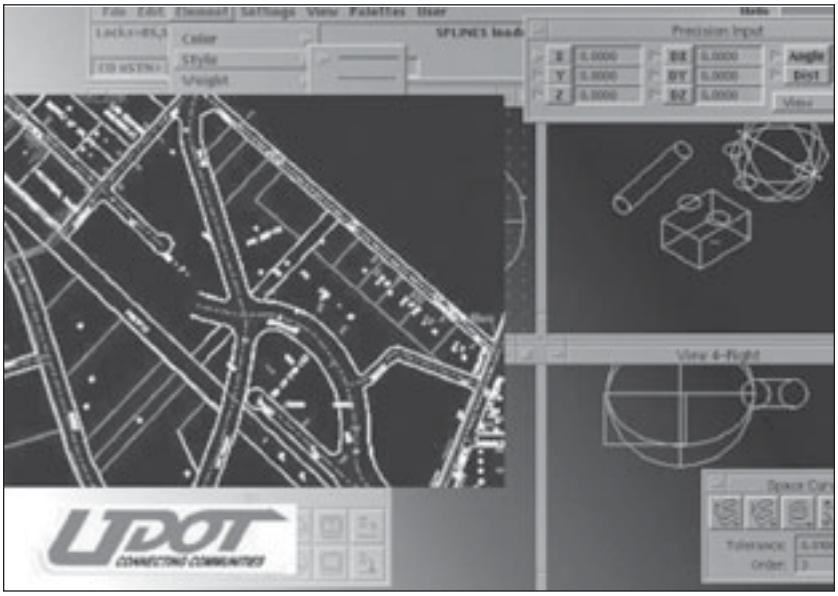
Often the staff who are familiar with visualization are assigned to other business units, such as landscape architecture. This makes it difficult for transportation agencies to track, hire, or start up visualization units.

Without a tracking mechanism, visualization decisions and budgets often are incorporated into other project budgets or are categorized as CADD applications. These challenges are daunting and have led most transportation agencies to refer visualization-related projects to consultants instead of developing a specific in-house group for visualization.

Screen shot of a virtual reality simulation of a proposed reversible lane corridor in Florida.

Positive Trends

Although the challenges are many, the prospects for the use of visualization technologies within transportation agencies are positive. Within the past 10 years, software and hardware costs have decreased



The Utah DOT visual technologies web page documents the use of visualization in design projects.

Rendering of a towboat in a replacement lock proposed near Nashville, Tennessee.

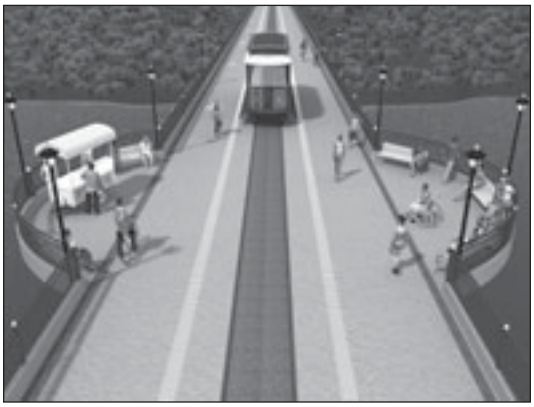
dramatically, and analysts say this trend will continue.

Formerly an expensive and exclusive undertaking, visualization now can be accomplished by a wider range of personnel. The trend is analogous to the evolution of computerized word processing from expensive systems operated by typing specialists to a commonplace and inexpensive application usable by most personnel.

Enhancements continue in CADD applications, with integrated 3-D tools and visualization capabilities, as tool sets become easier to use and much more powerful. Transportation agencies already have made substantial investments in CADD hardware and software, facilitating the integration of visual tools. Many agencies are beginning to develop projects using 3-D design techniques. With the design already in 3-D, visualization output, such as photosimulation, becomes easier and more cost-effective.

Transportation agencies also are using visual tools for analysis. Several traffic microsimulation programs, for example, link 3-D models to traffic data, so that traffic engineers are able to analyze potential traffic scenarios in 3-D.

Geographic information systems applications are also becoming more prevalent in the analysis and design process. A major initiative with the technology is the output of data into visuals such as aerial maps and overlays. These applications and others support the trend to the increased use of visualization tools in planning and design.



Proposed rehabilitation of a rail bridge over the Hudson River.

Into the Mainstream

Visualization technologies have become more of a mainstream application for transportation agencies in the planning and design process. Today, most visualization applications require a specialist, but as CADD applications continue to mature, engineers, designers, and technicians will be able to produce visuals themselves. The visuals will become part of the design process, adding value to the application and to the project.

In 2006, the Federal Highway Administration (FHWA) drafted interim guidance for implementing provisions in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) on planning, environment, and air quality:

> As part of transportation plan and TIP [transportation improvement plan] development, MPOs [metropolitan planning organizations] shall employ visualization techniques. States shall also employ visualization techniques in the development of the Long-Range Statewide Transportation Plan. States and MPOs must employ visualization techniques prior to adoption of statewide and metropolitan transportation plans and metropolitan TIPs addressing SAFETEA-LU provisions.

This guidance makes visualization applications part of the future for the planning and design process.[1]

The challenge for most agencies is how to implement the technology effectively into their processes. The Transportation Research Board, the American Association of State Highway and Transportation Officials, and other organizations will need to help guide and inform transportation agencies on how best to implement the technology. Agencies will need to determine what investment to make in implementing visualization technologies—not only the hardware and software applications, but the training.

Visualization technologies have evolved from a niche service to become part of the planning and design process in most transportation agencies, and the uses will expand. Computer graphics are being used in information kiosks in stores, Hollywood movies, and video games. Transportation agencies need to understand and implement this powerful tool.

[1] A detailed version of the SAFETEA-LU guidance is available at www.fhwa.dot.gov/hep/igslpja.htm.

Visualization
Empowering Innovation

Visualization to Solve Problems in Freight Transportation

ROLF R. SCHMITT, RAINER DRONZEK, AND LAURENCE ROHTER

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In 2002, the U.S. transportation system moved 19 billion tons of freight worth $13 trillion, to meet the logistical needs of 19 million households, 7.2 million business establishments, and 88,000 units of government. According to forecasts, this tonnage will increase 2.0 percent each year, almost doubling in three decades.

The transportation system must accommodate not only growth in volume, but also an increased demand for timely, reliable shipments over complex and far-flung supply chains. The value of goods to be moved is forecast to grow in constant dollars by more than 190 percent between 2002 and 2035—a significantly faster rate than growth in terms of weight. As the value of the goods to be moved grows, the cost of keeping inventory in warehouses or in transit grows. Many industries are shifting to just-in-time delivery to minimize inventory costs and maximize responsiveness to fickle markets, and just-in-time systems depend on fast and reliable transportation.

This increase in freight must compete for space on a crowded transportation system. At least 28,000 miles of highway are already subjected to recurrent congestion, and the mileage could reach 128,000 by 2035. Class 1 railroads and major ports are also experiencing congestion. How is the freight generated by a growing economy to be accommodated?

Understanding freight movement is a first step. How much freight is anticipated on a facility or in a corridor? How much of that freight is local versus long distance? How much is time-sensitive versus cost-sensitive?

Depicting Commodity Flows

The Federal Highway Administration (FHWA) integrated several data sources into the Freight Analysis Framework (FAF), a comprehensive picture of commodity flows in the United States. The FAF estimates the value and tons of commodity movements among 114 metropolitan areas and states and 17 international gateways, dividing each flow by 6 means of transportation and 43 types of commodities. The results are enormous matrices of estimates and forecasts for 1997, 2002, and 2006, and for 5-year intervals from 2010 to 2035. For 2002 and 2035, the flows by truck are assigned to individual highways and compared against congestion. This mass of numbers quickly overwhelms analysts.

An earlier and smaller version of the FAF was completed during the deliberations that led to the Safe,

IMAGES: FHWA

FHWA Freight Analysis Framework maps showing truck traffic volumes as band widths in 2002 *(left)* and in 2035.

IMAGE: CCDTT AND TRANSYSTEMS

Simulation model for analyzing movement of freight along the Victorville Corridor between the Ports of Los Angeles and Long Beach and an inland port.

Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, Public Law 109-59). That earlier mass of numbers was summarized in four maps:

- Truck volumes in highway corridors, shown as band widths, in 1998;
- The same highways color-coded by congestion levels during 1998; and
- The two maps with projections for 2035.

These maps illustrated the anticipated growth in trucking and congestion, and helped inspire Congress to include $4.6 billion in programs for freight in SAFETEA-LU.

The Coming Crunch

An update of the four maps will reaffirm the importance of dealing with freight, but more sophisticated visualizations are needed to indicate solutions to the coming crunch.

- Where does long-distance freight contribute to local congestion, and where does local congestion impede long-distance freight?
- Do areas of congestion align in corridors that could be served by new routes or bypasses?
- How do temporal patterns of freight movement match with the diurnal peaks and valleys of commuting?
- How do congestion patterns on highways relate to congestion on railroads and at intermodal connections?
- Where can performance be improved by separating passenger travel and freight movements?
- How does international trade interact with domestic transportation?

Insights to some of these questions can be found in the maps and tables of FHWA's Freight Facts and Figures and on its website, but these are only a beginning. New ways of visualizing freight movement and its consequences are needed to gain new insights into effective solutions to meet the demand for freight in a crowded world of transportation.

Simulation Modeling

One technique to analyze and visualize the flow of freight is simulation modeling, which employs either commercially available or customized software applications to describe freight systems or processes. The analyst uses the model to test alternative scenarios and quantify the results. With a simulation model, systems with complex interactions can be analyzed, and changes to the processes can be tested that otherwise would be difficult to assess. For example, a simulation model can help to predict the impact of a natural disaster or other service disruption on the transportation system performance.

Simulation models are applied to many areas of the freight transportation infrastructure, including

- Ports and intermodal terminal operations,
- Rail yards and main lines,
- Pedestrian and passenger flow,
- Vehicle traffic, and
- Manufacturing facilities and distribution centers.

For example, the Center for the Commercial Deployment of Transportation Technologies, at California State University, Long Beach, used a simulation model to help analyze the movement of freight between the Ports of Los Angeles and Long Beach and an inland port (see image, this page). The model tested and quantified port-related road diversion strategies and included freight traffic profiles along the primary rail and highway links.

One scenario tested the transport of containers via a magnetic levitation system, reducing congestion on the highways and speeding the transit times to and from the ports. The model enabled estimates of the reduction in the number of trucks on the highway system, the time phasing of movement during peak congestion periods, and transit times and cost savings. Many of the scenarios would have been difficult or impossible to analyze without a simulation model.

Model Characteristics

Although there are many different types of simulation tools and approaches, most simulation models share a common set of characteristics. A simulation model is dynamic, modeling the movement of individual transportation elements such as rail cars, trucks, or ships. It also tracks the system over time, allowing the system to react to changing conditions instead of operating in a static mode, as in a spreadsheet analysis.

Most models accommodate variation, a key to the efficiency of any system, which produces more accurate representations. The level of detail in a simulation model affects the amount of data that must be collected and validated, the development and testing time, and the final cost.

For example, a simulation model of freight movement in a metropolitan area could calculate the speed of trucks progressing through the transportation network with adjustments for the truck horsepower, the weight of the cargo, and the topography. Nonetheless, the average speed also could be used to model the flow of trucks through the system; but if the model

timetables are specific, and congestion plays a key role in on-time arrivals, or if trucks slowing in a mountainous area are critical to the analysis, a more detailed model of truck movement may be warranted.

Simulation modeling also is used to determine the optimal location of facilities and to select the most cost-effective freight movements. Optimizing the supply chain involves all the elements in the flow of freight, from raw material to manufacturing to distribution to point of sale. The location of each of these components and the availability of regional labor and transportation, plus costs and incentives, can make the task of siting a facility difficult. With a computer-based model of the network that takes into account all parameters affecting performance, the analyst can exercise the supply chain and gain insight into cost savings and service improvements.

Adding Animations

A simulation model of a system often contains a two- or three-dimensional dynamic animation. An animation can add more fidelity to a model that already accounts for the mathematics and statistics of the system. The animation depicts the system in operation in a way more easily understood by visual thinkers. A dynamic representation often can help a community understand the future state or condition under a proposed system.

For example, to visualize the look and feel of a proposed port (see image, this page), a three-dimensional (3-D) animation included ships, docks, containers, trucks, and cranes. The next step can add the underlying process characteristics and create a dynamic simulation of the system. The model might add ship arrivals and departures, container loading and unloading times, the movement of containers via cranes and trucks, and a detailed understanding of the port's container storage capacity.

Extending Models

A simulation model is most effective if it can be applied to more than one phase in the life cycle of a system or process. A model developed and applied during the conceptual or requirements definition or conceptual design phase of a project can be enhanced for the later phases of detailed design or operations. Because the costs of maintaining or enhancing a model are a fraction of the cost of the initial development, the model can grow with the project and provide a testing ground for changes and new ideas.

Simulation models work at the macro level for systemwide analysis, as well as at the micro level for specific processes or equipment. A macro level model, for example, was used to depict the movement of containers loaded onto railcars at ship terminals across the Tideflats of the Port of Tacoma, Washington. The simulation showed the arriving and departing container traffic, the ship calls and train movements to and from each terminal, the train movements to and from the terminal staging yards, the outbound train blocking and departures, and the inbound train arrivals and separation. The model put into perspective the performance and points of congestion across the entire Tideflats rail network and supported understanding of the benefits of the proposed multimillion-dollar enhancements to the infrastructure.

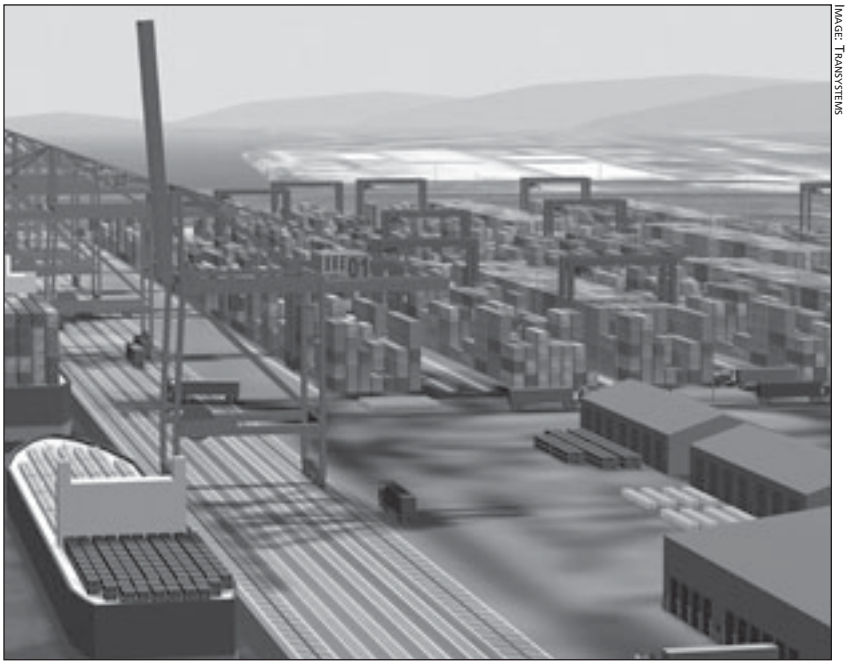

IMAGE: TRANSYSTEMS

3-D animation of a port can be used to create a dynamic simulation of the system for analysis of processes and capacity.

In particular, the macro study identified a terminal and staging yard that were underperforming and experiencing congestion. A plan proposed increasing the available staging track space for the terminal. In addition, a microlevel model was developed to focus on the operations of the terminal and the staging yard arrivals, departures, and operations. As a result, operational changes were identified that have introduced significant improvements without incurring infrastructure costs.

Another microlevel model was used at Massport's Conley Terminal in Boston to understand the impact of new security and inspection requirements, equipment, and procedures on the capacity of the port traffic gate. The model was developed to test operating scenarios, project the capacity and staffing requirements, design a new secondary inspection area, determine the size and number of lanes, and optimize the system's operation.

Distribution centers are critical in the flow of freight. Simulation models are applied to these facilities to understand the trade-offs between throughput,

Image: Animagraph Arte Digital

Visualization of an intermodal port, showing transfer of containers from railcars to cargo ship.

capacity, inventory carrying costs, and service levels, such as customer response times. In the design phase, the models often are used to determine the size of the facility. In the procurement phase, for example, the models can ensure that a vendor providing conveyors or automated storage and retrieval systems can meet the performance requirements. Such a model may include the facility, racking, equipment, staffing, and material flows, and the inbound, outbound, and intrafacility schedules.

Advantages for Analysts

Simulation models offer several advantages over other more traditional analysis techniques, by allowing the user to

- Experiment without mock-ups,
- Avoid disturbances to systems and people's routines,
- Visualize a variety of conditions, and
- Understand complex interactions.

The models provide quantifiable data for decisions that previously relied on gut feelings or best guesses.

Developing novel processes for the movement of freight is another step to prepare for the future. An example would be alterations in the strategies for moving containers.

Image: Skytech Transportation, Inc.

Containers moving from trucks to rail or ships via an overhead latticework.

Intermodal Models

Intermodal freight—the movement of containers and trailers by rail, truck, or water carriers—has been the fastest-growing major segment of the U.S. freight rail industry, rising from 3.1 million trailers and containers in 1980 to 12.3 million in 2006 (*1*). In the record-setting year of 2006, 76 per cent of the intermodal rail traffic was moved in containers, taking advantage of the efficiencies of double stacking and close coupling (*2*).

Intermodal freight includes a variety of consumer goods, as well as industrial and agricultural products. More than half of U.S. rail intermodal traffic consists of imports or exports, reflecting an international role for supply chains (*1*). Indications are that all-container shipments will continue to grow rapidly.

Visualization can assist not only in depicting the global logistics, but in developing and improving processes, providing a platform for solutions yet to be articulated, as well as shortening the time to bring a project on-line. A freight transportation project has a different clientele from the typical highway project—usually private industry, like the railroads; logistic suppliers, like ocean carriers or large trucking companies; and land developers. Local governments may have an advise-and-consent role.

But the facilities to be built and the transportation processes involved are out of the general sight of the public and are poorly understood. Moreover, freight projects are fragmented and diffuse, with many independent operators of varied scale in diverse locations. The goal is to move as much freight as possible in a timely and efficient manner, with minimized costs and without adding to the levels of traffic in key highway and rail corridors, highways, and ports.

Three-dimensional toolsets can allow both clear depiction and interactive involvement in describing solutions. Engineers and planners may work in 2-D, but most citizens and decision makers can comprehend what is involved more quickly in a more realistic 3-D environment. An interactive environment enhances the speed of comprehension.

Visualizing a Rail Yard

Facility design and redesigns can be proposed and evaluated quickly with advanced visualizations. Specific sites can be evaluated, and concepts tested. For example, the reuse of a rail yard in Gary, Indiana, strategically located on two major intermodal railroads, can be presented on a platform with universal mapping applications, such as geographic information systems or Google Earth. The in-city effects cover a range of concerns, such as highway access, lakefront usage, redevelopment, and collateral impacts in an established urban area.

The civil design would move two main rail lines

owned by CSX and Norfolk Southern (NS), one to the north end of the trackside yard and one to the south end, so that the two companies can conduct intermodal operations in the center of the two main tracks. The proposed yard would be the size of CSX's Bedford Park intermodal facility, the busiest in the Chicago area. According to the proposal, the NS would be elevated, with an underpass at the center of the yard to allow trucking operations north of the trackside region. The design would require deceleration and acceleration tracks east and west of the site to allow for constant operations of the main lines. The area currently is part of a railroad yard and underutilized industrial facilities.

A novel approach is the solution mentioned earlier—containers driven by magnetic levitation or linear induction motors. The intermodal rail yard interface could be constructed and operated with shuttles specially equipped with lifting and communications technology, for a completely automated operation. Not only could special electric motors handle the endpoint-to-endpoint move of the container, but the entire rail yard could be covered by an overhead lattice structure supporting lift-on, lift-off moves and storage operations.

A variety of visualization techniques enabled consideration of a systemwide capital-intensive solution, moving containers from any one to another of Chicago's 20-plus rail terminals. The system also could connect many of the rail terminals to industrial parks and trucking terminals. Chicago's intermodal facilities are spread over several thousand acres, and intermodal demand is projected to double in 7 to 10 years, necessitating a variety of approaches.

One proposed approach would transform the rail yard in the gateway city of Gary, on the east side of Chicago, from a traditional loose-car facility to handle intermodal operations as well. This interconnection via novel technologies would enhance efficiencies but would have a dramatic effect on the region and would require in-depth reviews.

The transfer system would be built above railroad rights-of-way or above Interstate highways, so that it would not require new rights-of-way or interfere with other ground transportation. The design of the automated transport system includes the technologies to pick up and deposit containers efficiently, reliably, and safely, operating like a monorail—quietly, at high speed, and environmentally sound—and covering operational needs within and between rail yards.

Demonstrating Solutions

At the lower end of the change-in-technology scale is the development of an idea called ThruPort. This project involves special cranes that can move containers among intermodal trains, allowing for quick and easy resorting, similar to what airlines do in hub-and-spoke systems. This kind of facility revision could take place wherever intermodal railroad routes converge and diverge. The goal is to move containers from one train to another without having to move the rail cars or blocks of cars within a train; this also would decrease train length substantially. The solution is well suited to the complex urban areas that house most current intermodal facilities.

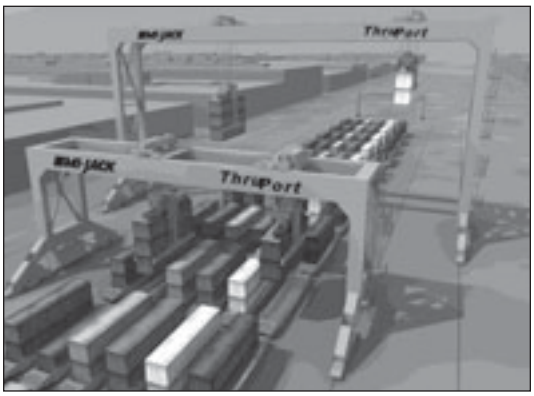

Image: MiJack Products

By moving containers efficiently between trains, ThruPort would allow an urban rail yard to function like an airport freight hub.

The ThruPort design has three main attributes. First, the design is evolutionary, not revolutionary—it does not involve advances in engineering. Based on conventional technology, the designs will not be expensive to build, and the performance, maintenance, and repair will be predictable.

Second, the operating scheme allows more than one rail company to utilize ThruPort, increasing its effectiveness. ThruPort would act as a central hub for intermodal rail traffic.

Third, ThruPort requires a location that is large enough, that can provide the necessary resources, and that would be convenient for the rail companies. A recycled rail yard, a new greenfield site, or even a strategic brownfield that can be made usable may be able to accommodate all six major rail companies serving Chicago. Visualization can assist in developing the possibilities and alternatives.

The major advantage of this type of intermodal operation would be to reduce substantially the number of on-street truck moves—known as rubber-tiring—which in a central location like Chicago can represent thousands of trucks on the highways per day. Visualization can help to explain and inform the discussion of ideas like this and can introduce process improvements that can help to move trucks off the highway.

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Visualization
Empowering Innovation

Visualization and the Larger World of Computer Graphics

What's Happening Out There?

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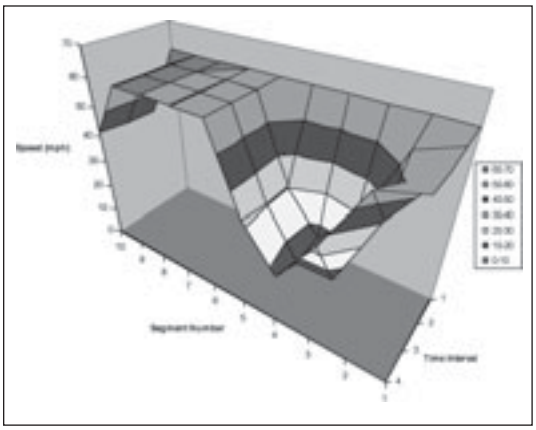
Visualization based on computer graphics and interactive techniques was formally defined 20 years ago in a landmark report sponsored by the National Science Foundation, "Visualization in Scientific Computing" (*1*). Visualizations frequently involve large displays and stereoscopic environments to immerse 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.



Scientific visualization of spatial and temporal speed profiles upstream of a freeway bottleneck. [Created by Nagui M. Rouphail with FREEVAL, Institute for Transportation Research and Education (ITRE), 2007.]

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 Visual-

Information visualization from an online GIS database of fatal crashes involving trucks in North Carolina, 2001–2005. (ITRE, North Carolina State University, maintains this site with funding from the North Carolina Motor Carrier Safety Assistance Program. http://vams.itre.ncsu.edu/truckcrash/.)

ization Conference in 1995 (*4*). 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*).

Visual analytics 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. The imagery was developed in collaboration with Thomas Fischer, New York State Department of Transportation (DOT). Several static views from driver and pedestrian vantages are available for online review at www.itre.ncsu.edu/NCHRP378/.

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*).

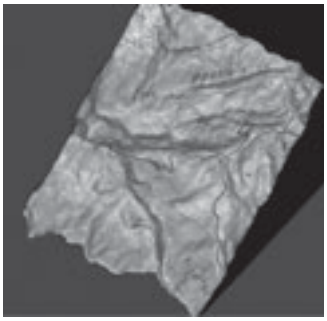
Other Graphics Tools

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



Geovisualization of topographic data from the U.S. Geological Survey's website. (Image created by Theresa-Marie Rhyne and Thomas Fowler at the United States Environmental Protection Agency's Scientific Visualization Center in the late 1990s.)

Transportation visualization for the US-15–501 and Erwin Road–Europa Drive Intersection Improvement Project, Chapel Hill, North Carolina. (Image created by Chris Parker, courtesy of North Carolina DOT. For more information, www.ncdot.org/projects/Superstreet/.)

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]

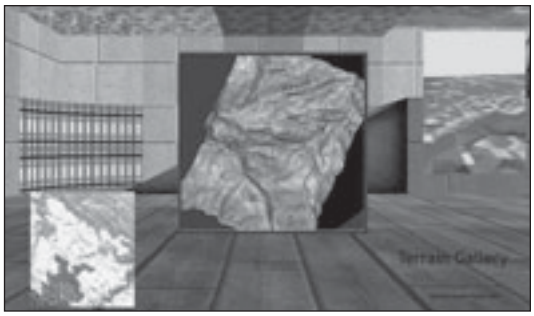
Specialized examples of 3-D virtual spaces have been developed for public participation across the web. Virtual London is an application currently under development by the University College of London's Centre for Advanced Spatial Analysis, with funding from the Greater London Authority and London Connects.[5] 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.

[1] Google Earth, http://earth.google.com; Virtual Earth, www.microsoft.com/virtualearth.

[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/.

[4] http://secondlife.com.



Terrain gallery—geovisualizations defined as elements in a 3-D virtual world. (The image and 3-D virtual world were created by Theresa-Marie Rhyne in 2002.)

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

[5] http://casa.ucl.ac.uk.

[6] http://simcity.ea.com/about/rushhour/overview.php.

[7] www.seriousgames.org.

IMAGE: ELECTRONIC ARTS

The computer game SimCity offers a module for engineering traffic flows and addressing the problems that develop.

graphics and visualization is constantly changing. The time frame for resolving application problems may be longer than the computer platform's life cycle—how can users keep up with these changes?

7. Driving forces in the computer games and entertainment industries. In the arena of computer graphics, visualization is secondary in both economic and consumer demand to the requirements of the computer games and entertainment industries. What can be done to ensure the development of effective visualization tools?

8. Supporting expert domain knowledge. How can common practices and existing expertise be incorporated into visual displays?

9. Facilitating insight. Can visualization methods be readily available to support new discoveries and inquiries?

10. Accepting the unexpected. Events occur that are beyond control, and situations can evolve to supersede anticipated and planned outcomes—can this be accommodated? (*14*)

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.

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.

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Visualization Education and Training

Learning the New Tools—and New Tools for Learning

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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.

PHOTO: PENN STATE

The Immersive Construction (ICon) Lab at Pennsylvania State University harnesses visualization technology to teach engineering students complex tasks such as design reviews and optimized scheduling for construction.

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;

IMAGE: HNTB AND INTELISUM

Visualization with lidar to plan and explain innovative accelerated construction for a bridge replacement on I-215 East in Salt Lake City, Utah. (For details, contact Rukhsana Lindsey, Utah DOT Director of Research, 801-965-4196.)

- 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,

The Engineer of 2020: Visions of Engineering in the New Century, produced by the National Academy of Engineering, engaged a diverse group of stakeholders to gather facts, make forecasts, and develop scenarios of world conditions for the 2020 engineer. The companion volume, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, offers recommendations on how to enrich and broaden engineering education in a constantly changing global economy. (For ordering information, see www.nap.edu.)

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-

[1] www.fta.dot.gov/planning/programs/planning_environment_5925.html.
[2] Proceedings may be found at www.teachamerica.com/viz/viz2006.html.

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

Classes in the Icon Lab at Penn State have produced measurable improvement in student performance.

Screen for the NIU-Torcs video game, developed at Northern Illinois University to teach principles of engineering.

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 caliber 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 to rethink 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.

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Visualization
Empowering Innovation

Research Agenda for Visualization in Transportation

Incorporating New Legislative Directives for Planning

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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.

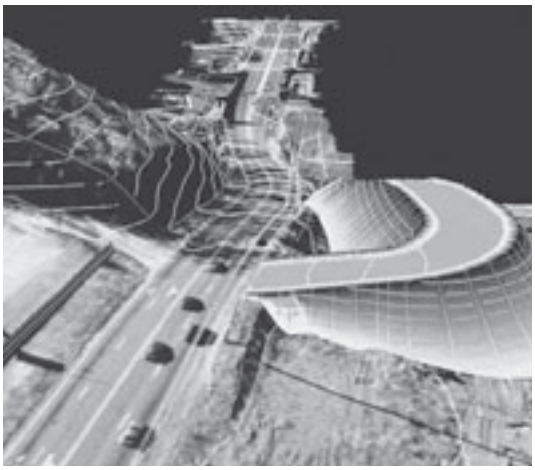


PHOTO: URS CORPORATION

Wire-frame overlay showing visuals for ROC 52 (U.S. Highway 52) reconstruction design-build project, near Rochester, Minnesota.

Computer-generated imagery from early General Electric flight simulator (late 1970s).

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.[1] Early computer image-generation database systems were, in large part, extensions of two-

[1] http://mbinfo.mbdesign.net/CAD-History.htm.

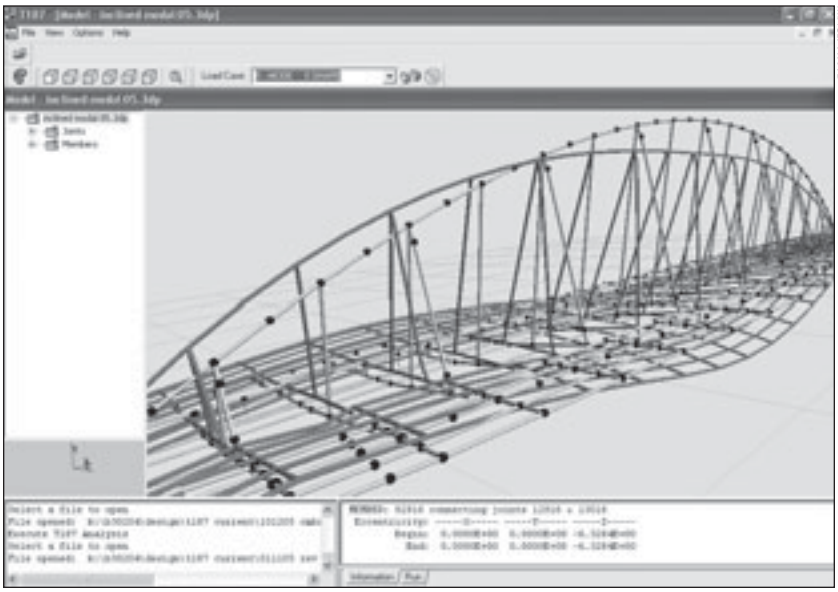


IMAGE: HNTB

Computer analysis of a design for the Main Street Bridge (*above*) over the Scioto River in Columbus, Ohio, and a model (*below*) that was subjected to a wind tunnel test supplemented computer-generated 3-D visualizations for the project. The bridge is now under construction.

IMAGE: HNTB

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.[2]

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 applied 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

[2] www.teachamerica.com/VIZ/23d_Hughes/index.htm. Interactive proceedings are online at www.teachamerica.com/viz/viz2006.html.

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 meetings and for information—and by implication, 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.

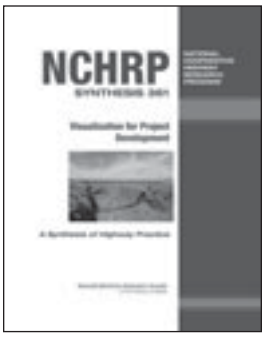
Planning Requirements

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



NCHRP Synthesis 361: Visualization for Project Development includes the 2005 research agenda developed by the TRB Task Force on Visualization in Transportation, as well as several case studies and a glossary of terms. To order, contact the TRB Bookstore at www.TRB.org/bookstore/, or view the book online at http://onlinepubs.TRB.org/onlinepubs/nchrp/nchrp_syn_361.pdf.

[3] See the presentation by M.-T. Rhyne, www.teachamerica.com/ VIZ/02g_Rhyne/index.htm.

The Virtual L.A. project of the Urban Simulation Team, University of California, Los Angeles (www.ust.ucla.edu/ustweb/projects.html), incorporates design, planning, and public information, and includes transportation projects, such as a proposed metro station for Chinatown featuring traditional Chinese and international design motifs reflecting the neighborhood's history.

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-

[4] www.fhwa.dot.gov/environment/ej2000.htm.

[5] For an overview of the problem in the field of geoscience, go to www.ldeo.columbia.edu/edu/DLESE/maptutorial/introduction.html.

[6] See J. Aguilar and J. Haracz, Environmental Justice: Visualization and Analyses with GIS to Facilitate Informed Decisions, http://gis2.esri.com/library/userconf/proc01/professional/papers/ pap523/p523.htm; also J. Mennis, Using GIS, Spatial Statistics, and Visualization to Investigate Environmental Justice, http://astro.temple.edu/~jmennis/pubs/mennis_asaej99.doc.

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.

IMAGES: HNTB

Visualizations showing two of several lighting options for the U.S. 90 bridge near Biloxi, Mississippi—ribbon floodlights and ribbon jar lights with lit piers.

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.

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Additional Resource

Hughes, R. Visualization in Transportation: Current Practice and Future Directions. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1899*, Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 167–174.

Treatment of Soils with Compost to Mitigate Pavement Cracking

Texas Tests and Applies Stabilization Method

ANAND PUPPALA, RICHARD WILLIAMMEE, NAPAT INTHARASOMBAT, AND SYED QASIM

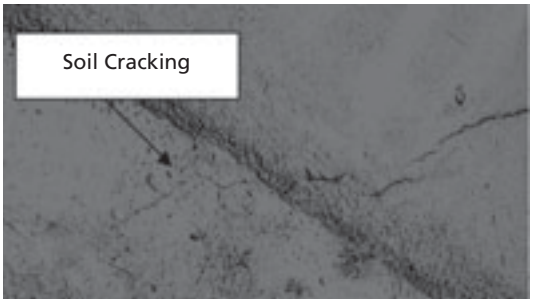
Puppala is Professor, Civil and Environmental Engineering, University of Texas at Arlington; Williammee is Materials Engineer, Texas Department of Transportation, Fort Worth District; and Intharasombat is a former doctoral student, and Qasim is Professor, Civil and Environmental Engineering, University of Texas at Arlington.

Cracks form in swelling soils in Texas generally during the dry conditions in summer and winter. The surface cracks appear when the soils dry under high temperatures or high rates of evaporation, or both. If these adverse conditions prevail for extended periods, the soil adjacent to pavement shoulders dries and cracks (see photo, this page).

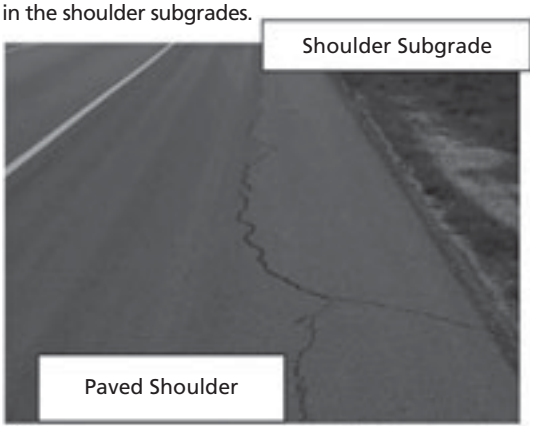
Problem

Uncontrolled cracks in the soil extend to the subgrades beneath the paved shoulders and ultimately under the pavements. The cracked subgrades lose strength when moisture infiltrates. As a result, paved shoulders and pavements over the softened subgrades undergo differential movement, producing longitudinal and transverse cracks (see photo, this page). The erosion of the subgrade also may accelerate cracking (Figure 1).

Several chemical treatment methods, including traditional cement and lime additives, have been used to stabilize swelling soils. These methods are expensive for treating soil adjacent to paved shoulders, however, and are not suitable if the swelling soils contain sulfates. The normal practice at the Texas Department of Transportation (DOT) is to seal cracks on paved shoulders and travel lanes each year; the crack-sealing program costs approximately $10 million annually. A less expensive stabilization technique therefore is needed to mitigate the cracking caused by the movements of soil next to paved shoulders, to mitigate cracks in paved shoulders and pavement.



Soil cracking on unpaved shoulder subgrade, extending to paved flexible shoulders (transverse cracks), Texas State Highway 108. *(Below:)* Longitudinal and transverse cracks on paved shoulders; the cracks started in the shoulder subgrades.



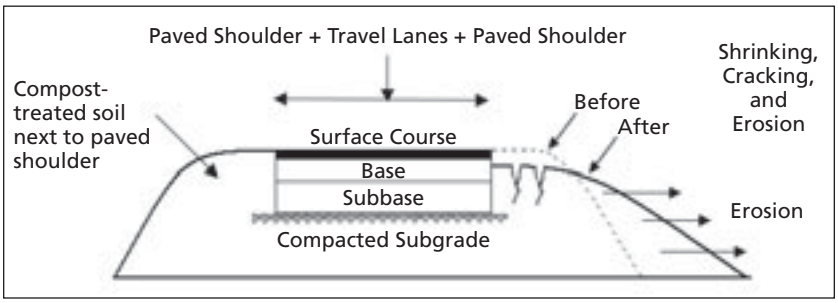
Solution

Compost consists of disinfected and stable decomposed biosolids, manures, yard wastes, and waste food processed into a useful product free of odors and pathogens. The United States generates 8 million tons of biosolids and 32 million tons of manures annually; almosts 40 percent of biosolids and approximately 50 percent of manures are disposed in landfills. Some manures can pollute waterways.

Compost has an affinity for water, low permeability, and fibrous characteristics. Compost has potential, therefore, to reduce the swell and shrinkage behavior of natural soils.

A Texas DOT–sponsored research project investigated the potential benefit of treating swelling soils to

FIGURE 1 Schematic Showing Subgrade Cracking and Erosion That Could Lead to Pavement Cracking (not drawn to scale).



mitigate cracking. In 2003, the engineering properties of biosolids compost (BSC), dairy manure compost (DMC), compost-treated or manufactured topsoils (CMT), and swelling soil from Stephenville, Texas, were analyzed to determine the compost dosages for field treatments. Design- and compaction-related construction specifications were developed and were used to construct 16 CMT plots by mixing BSC and DMC with the soil and then compacting. One control plot also was constructed.

The plots were constructed on Texas State Highway 108, near Stephenville, in 2004. The test sections differed in the percentage, width, depth, and type of compost treatment. Field monitoring determined the extent and pattern of the cracking, the erosion potentials of CMTs, and the characteristics of the leachate in the runoff from the test plots.

Field data were collected for two years and were analyzed with statistical comparison techniques. The results are as follows:

- BSC-amended CMTs had lower moisture and temperature variations than either the control or DMC-amended CMT plots.
- No new cracks were observed on the paved shoulders adjacent to seven out of eight BSC plots, while the DMC materials did not reduce the cracking but developed new cracks in paved shoulders (see photo comparison, this page).
- Vegetation did better in the BSC plots than in the DMC and control plots.
- BSC plots experienced approximately 20 percent less erosion than the control plot. The DMC plots showed 50 percent more erosion than the control plot.
- Concentrations of total suspended solids and biochemical oxygen demand in leachate from the DMC and BSC plots—100 parts per million (ppm) and 30 ppm, respectively—were less than the limits established by the U.S. Environmental Protection Agency (EPA). Chemical oxygen demand and total nitrogen values exceeded the EPA threshold values of 120 ppm and 2 ppm, respectively, in leachate from the DMC plots only. Therefore the recommendation was to reduce the percentage amount of dairy manure additions to soils.

Because of its high amounts of organic fibrous material, BSC encapsulated and reinforced the soil particles and reduced the cracking of the soil. The wood chips acted as soil connectors, holding the soil intact longer during periods of drought. DMC has low amounts of organic fibrous material, however, and was not effective in reducing cracking. Therefore DMC performance may be improved by adding fibrous material during the composting process.

Applications

Texas DOT implemented the research findings in Corpus Christi, Lubbock, Bryan, Tyler, and Yoakum Districts in 2005. Eight different compost types were used, and in all but Bryan District, the findings agreed with those from the Stephenville project. In Bryan District, the lack of vegetation allowed the erosion of the CMTs within a short time after construction.

Benefits

New cracked areas on the paved shoulder and the pavement next to BSC-treated swelling soils developed on average less than 50 percent as often as those observed for the control section. Moisture and temperature data, elevation surveys, and visual observations indicated that BSC treatment has mitigated the cracking of soil and pavement. Reapplication of the BSC may be required once every 7 to 10 years; in contrast, crack sealing typically must be applied every 1 to 3 years.

Like most state DOTs, Texas DOT keeps comprehensive records of maintenance costs but does not have detailed records that would show the cost of maintenance related to pavement failure caused by subgrade heaving. A few Texas DOT districts are now conducting life-cycle cost analysis (LCA), which requires more detailed tracking of maintenance repair costs, to compare the life of the compost treatment against the crack-sealing method.

Crack sealing in Texas has proved to be costly and ineffective since the materials do not last more than three years, and many fail after only one year. A pavement with considerable cracking from subsoil movements will deteriorate faster and will develop ruts and alligator cracks. An LCA comparing the compost treatment of soils versus crack sealing will provide better insight into the long-term performance of the two methods.

Texas DOT is considering implementation of the BSC stabilization method as a pavement preservation technique on most highway reconstruction and maintenance projects in all 25 districts. The findings of this project are applicable to any area with similar soil and weather conditions.

For more information contact Anand Puppala, Professor, University of Texas at Arlington, Department of Civil and Environmental Engineering, Box 19308, Arlington, TX 76019, 817-272-5821, anand@uta.edu; or Richard Williammee, Materials Engineer, Texas Department of Transportation, Fort Worth District, P.O. Box 6868, Fort Worth, TX 76115-0868, 817-370-6675, rwillia@dot.state.tx.us.

EDITOR'S NOTE: Appreciation is expressed to G. P. Jayaprakash, Transportation Research Board, for his efforts in developing this article.

(a)

(b)

(c)

Cracks in paved shoulders and vegetation growth on adjacent soil two years after treatment: (a) BSC plot; (b) DMC plot; and (c) control plot.

Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).

Charles E. Howard, Jr.

Puget Sound Regional Council

A forward thinker, Charles Howard is always looking for ways to expand the traditional role of transportation planning to prepare transportation systems for the challenges of the future. In his 27-year career, he has served the Federal Highway Administration, the Washington State Department of Transportation (DOT), and the Puget Sound Regional Council in such roles as transportation planner, transportation planning manager, director of planning and policy, and director of strategic planning and programming. He is an expert in collaborative planning processes for statewide transportation policy development and systems planning; growth management policies and requirements; transportation air quality requirements, including state implementation plan development, transportation control measures, emissions inventories, and dispersion models; and technical methods for transportation planning.

"If one looks at transportation investment patterns, more investment goes to preservation, maintenance, and operations than to expansion."

Currently transportation planning director for the Puget Sound Regional Council, Washington State, Howard is working to develop, update, and implement a long-range transportation plan for the growing Puget Sound region in accordance with federal, state, and regional policies and laws; to develop and execute a work program that can achieve the transportation planning goals for a variety of programs and studies; to organize, direct, and cultivate staff to carry out the planning responsibilities of the agency; to function as an agency liaison to the public; and to monitor and provide input to the development of state and federal legislation.

A highlight of Howard's career occurred in the late 1990s, when he worked with a group of transportation planners on Washington State DOT's Washington Transportation Plan (WTP). The 20-year plan identified investment guidelines and set priorities for future statewide system improvements for all modes of transportation.

"Transportation planning often focuses on expansion needs," Howard explains. "If one looks at transportation investment patterns, more investment goes to preservation, maintenance, and operations than to expansion. The WTP was the first effort in Washington State to seriously examine investment categories carefully and to develop priority approaches for each of the categories. The broad assessment of the Washington State transportation system in the WTP has transformed transportation planning into a true asset management tool."

As a result of the WTP, transportation planning in Washington State has expanded to incorporate a wide range of transportation-related issues: sustaining infrastructure for the long term; reducing deaths and disabling injuries; making the system more secure; incorporating smart technology and ensuring reliability and smooth operation; accommodating persons with special transportation needs; improving walking and biking options, as well as land use patterns that affect transportation; and planning for system growth and expansion.

Howard maintains that good transportation planning involves making long-term decisions in a public and political environment, in addition to managing the technical processes. He advises transportation students and young transportation planners to think about long-term transportation planning and to "focus on how information can be used to enlighten policy makers about the potential effects of decisions; they should avoid getting caught up in technical issues."

Active in TRB for more than 15 years, Howard chairs the Statewide Multimodal Transportation Planning Committee; the National Cooperative Highway Research Program (NCHRP) Project Panel on Cost-Effective Measures and Planning Procedures for Travel Time Variation, Delay, and Reliability; and the NCHRP Project Panel on Best Methods and Practices of Data Integration for Transportation Departments (Synthesis). A past chair of the Conference Steering Committee for Smart Growth and Transportation, he currently serves on the Strategic Highway Research Program 2 Technical Coordinating Committee for Capacity Research and on the Technical Activities Transportation System Policy, Planning, and Process Section, as well as on several other NCHRP project panels.

In addition to his work with TRB, Howard serves on the Policy Committee of the Association of Metropolitan Planning Organizations and on many American Association of State Highway and Transportation Officials panels. He is a member of the Phi Beta Kappa society and the recipient of an award of honor from the American Planning Association for the State Transportation Policy Plan for Washington State in 1990, as well as the Sense Award from the Institute for Transportation and the Environment, in 1992, for land use–transportation research funding at the University of Washington. Howard received a bachelor's degree in geography from Ohio State University in 1978, and a master's degree in city and regional planning from Harvard University in 1980.

Susan A. Ferguson

Ferguson International, LLC

Highway safety researcher and independent consultant Susan Ferguson has worked for more than 15 years to reduce deaths, injuries, and automobile accidents on U.S. highways. Ferguson earned a Ph.D. in experimental psychology from The George Washington University, Washington, D.C., in 1991 and began her career in highway safety as a research analyst at the Insurance Institute for Highway Safety (IIHS), Arlington, Virginia.

During her 15 years at IIHS, Ferguson conducted highway safety research on young and older drivers, alcohol and driving, vehicle safety, gender issues, child-occupant protection, and on countermeasures to the three factors associated with motor vehicle crashes—human, vehicular, and environmental—as well as interventions that can occur before, during, and after crashes. As Senior Vice President for Research, she also served as a spokesperson, communicating developments in IIHS research to the transportation community and the general public through the media and presentations in the United States and abroad.

"Nothing is more satisfying than fostering public understanding of the ways people can improve their safety when operating an automobile."

"A strong communications function distinguishes IIHS from other highway safety research organizations," Ferguson explains. "Research is communicated to the media, disseminated in newsletters, and published in peer-reviewed journals. Nothing is more satisfying than fostering public understanding of the ways people can improve their safety when operating an automobile."

A focus of Ferguson's research has been teen driving—specifically, the investigation of teen automobile crash rates and of the countermeasures for reducing the number of crashes. Ferguson has published many papers on the subject and continues to undertake research in this area; she serves on the Allstate Foundation Teen Driving Program advisory board.

"I first became interested in teen driving when my daughter was old enough to start driving," recalls Ferguson. "I implemented my own graduated licensing program with her before the formal adoption of graduated licensing in many states. Graduated licensing programs have been very effective in reducing crashes among teenage drivers, but more needs to be done."

Maintaining that highway safety is a challenging and rewarding area of research, Ferguson encourages transportation students and young researchers to enter the field. She calls on highway safety professionals to do more for students entering highway safety by providing mentoring and opportunities to network and interact with others.

"Highway safety is challenging because a researcher doesn't always have the data needed to answer questions of interest, and countermeasures are implemented in ways that are not straightforward to evaluate," Ferguson points out. "The field is rewarding because one can see the immediate benefits of one's work, especially when countermeasures are shown to reduce crashes and injuries. Highway safety professionals need to do more to convince young researchers that highway safety is an exciting and rewarding career path; in spite of great progress, the United States is still faced with 43,000 highway deaths per year and many more injuries."

Ferguson has been involved with TRB since 2000. She serves as secretary for the Alcohol, Other Drugs, and Transportation Committee and has participated as a member of the Task Force on Women's Issues in Transportation, the Women's Issues in Transportation Committee, and the National Research Council–appointed (NRC) Research on Women's Issues in Transportation Conference Committee. She contributed to policy studies as a member of the NRC-appointed Committee on Motor Vehicle Rollover Rating System and the Committee for the Review of the Intelligent Vehicle Initiative: Phase 2.

In addition to her work with TRB, Ferguson chairs the Blue Ribbon Panels on Advanced Airbag Performance and the Development of Advanced In-Vehicle Alcohol Detection Technology, and she is a member of the International Council on Alcohol, Drugs, and Traffic Safety Executive Board, the Airbag 2000+ International Advisory Committee, and the Advisory Board to the Campaign to Eliminate Drunk Driving.

As a credit to her research and communications work in highway safety, Ferguson has received the Driving School Association of the Americas' H. B. Vincent Leadership Award for outstanding contributions to the field.

GREAT LAKES ECOLOGY—Members of the Committee on the St. Lawrence Seaway: Options to Eliminate Introduction of Nonindigenous Species into the Great Lakes, Part II (*right to left*:) M. Gordon Wolman, Johns Hopkins University; Ann Zimmerman, University of Toronto; Steven Popper, Rand Corporation; Tom Waite, Florida Institute of Technology; and observers discuss management of aquatic invasive species during a July 30 meeting at the National Academies' Keck Center, Washington, D.C.

THEORY AND PRACTICE—William Strawderman, Rutgers University, initiated technical discussions at the second Safety Symposium of the Strategic Highway Research Program 2 (SHRP 2), July 26–27, at the National Academies' Keck Center, Washington, D.C., with a presentation that addressed theoretical aspects and practical implications of statistical analyses in the SHRP 2 program.

Program contractors and more than 100 members of the highway safety community discussed plans for safety research projects and made presentations on work in progress—including the design of the in-vehicle driving behavior study—as well as methods for analysis of the largest data set ever collected on the study topics. The third SHRP 2 Safety Symposium is scheduled for July 17–18, 2008.

COOPERATIVE RESEARCH PROGRAMS NEWS

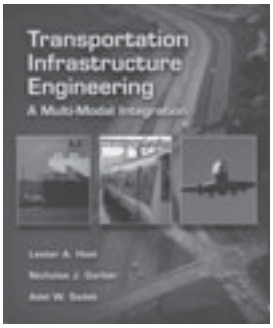
Predicting Scour at Bridge Piers

Current methods for predicting local scour at bridge piers were developed in small-scale laboratory studies that did not consider factors relevant to wide piers and long, skewed piers. As a result, current prediction methods are limited and generally overpredict local scour, requiring the use of unwarranted and costly foundations or countermeasures. There is a need for data to aid in developing improved methods for the design, operation, and maintenance of highway bridges and to evaluate current methods for predicting local pier scour, as well as the applicability of current prediction methods to wide piers and long, skewed piers.

Ocean Engineering Associates, Inc., Gainesville, Florida, has been awarded a $298,982, 27-month contract (National Cooperative Highway Research Program Project 24-32, FY 2007) to develop methods and procedures for predicting time-dependent local scour at wide piers and long, skewed piers, for consideration and adoption by the American Association of State Highway Transportation Officials.

For more information, contact Amir Hanna, TRB, 202-334-1892, ahanna@nas.edu.

Transportation Infrastructure Engineering
Lester A. Hoel, Nicholas J. Garber, and Adel W. Sadek. Thomas Nelson, 2008; 674 pp.; $123.75; 0-534-95289-5.



Developed as a resource for undergraduate and graduate students of transportation engineering, this book provides an overview of transportation engineering from a multimodal perspective. Emphasis is placed on the environments in which transportation systems operate, as well as their role in a global society.

Chapters include An Overview of Transportation; Transportation Systems Models; Human, Vehicle, and Travelway Characteristics; Transportation Capacity Analysis; Transportation Planning and Evaluation; Geometric Design of Travelways; Structural Design of Travelways; Transportation Safety; and Intelligent Transportation and Information Technology.

Hoel is the L.A. Lacy Distinguished Professor of Engineering, the director for transportation studies at the University of Virginia (UVa), a member of the National Academy of Engineering, and a past chair of the TRB Executive Committee (1986) and of the Subcommittee for National Research Council Oversight. Garber is Henry L. Kinnier Professor, Department of Civil Engineering at UVa, a member of the TRB Executive Committee, the Work Zone Traffic Control Committee, and the Operational Effects of Geometrics Committee. Sadek is an associate professor in the school of engineering at the University of Vermont and a member of the TRB Artificial Intelligence and Advanced Computing Applications Committee and of the Task Force on Surface Transportation Weather.

Editor's Note: The Bookshelf item on *Transportation Decision Making: Principles of Project Evaluation and Programming* (Wiley) in the July–August 2007 *TR News* (page 38), appeared without a credit for book authors Kumares C. Sinha and Samuel Labi. Sinha is Distinguished Professor of Civil Engineering, Purdue University; emeritus member, TRB Transportation Programming, Planning, and Systems Evaluation Committee; and a past member of the TRB Technical Activities Council. Labi is Visiting Assistant Professor, School of Engineering, Purdue University.

The books in this section are not TRB publications. To order, contact the publisher listed.

TRB PUBLICATIONS

Test Methods for Characterizing Aggregate Shape, Texture, and Angularity
NCHRP Report 555
Presented is a method for classifying aggregates used in highway pavements by shape, texture, and angularity. A test method for measuring these characteristics is recommended to improve the specification of aggregates for hot-mix asphalt, hydraulic cement concrete, and unbound base and subbase layers of highway pavements.

2007; 86 pp.; TRB affiliates, $32.25; nonaffiliates, $43. Subscriber categories: pavement design, management, and performance (IIB); materials and construction (IIIB).

Superpave Mix Design: Verifying Gyration Levels in the N_{design} Table
NCHRP Report 573
Gyration levels in the N_{design} table (Table 1) of AASHTO's Standard Practice R 35 are examined to verify applicability to four 20-year design traffic levels: less than 0.3 million; 0.3 million to 3 million; 3 million to 30 million; and greater than 30 million equivalent single axle loads.

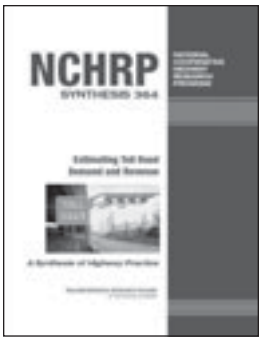
2007; 62 pp.; TRB affiliates, $28.50; nonaffiliates, $38. Subscriber category: materials and construction (IIIB).

Legal Truck Loads and AASHTO Legal Loads for Posting
NCHRP Report 575
The development of new legal truck loads and the recommended revisions to the legal loads for posting are presented in the contexts of the *Manual for Condition Evaluation of Bridges* and the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*.

2007; 74 pp.; TRB affiliates, $30.75; nonaffiliates, $41. Subscriber category: bridges, other structures, and hydraulics and hydrology (IIC).

Estimating Toll Road Demand and Revenue
NCHRP Synthesis 364
This synthesis assembles information on the state of the practice for forecasting demand and revenues for toll roads in the United States. Travel demand fore-

TRB PUBLICATIONS *(continued)*



casting models are presented, and the application of these models to project revenues as a function of demand estimates is considered.

2006; 105 pp.; TRB affiliates, $26.25; nonaffiliates, $35. Subscriber category: planning and administration (IA).

Preserving and Using Institutional Memory Through Knowledge Management Practices
NCHRP Synthesis 365

Practices in the preservation and use of institutional memory through knowledge management in U.S. and Canadian transportation agencies are documented. Practices are identified that effectively organize, manage, and tranfer materials, knowledge, and resources formerly in the exclusive possession of individual offices and employees.

2007; 113 pp.; TRB affiliates, $33; nonaffiliates, $44. Subscriber category: planning and administration (IA).

Elements Needed to Create High Ridership Transit Systems
TCRP Report 111
(with supporting material on CD-ROM)

Transit agency strategies to increase ridership are described, and case studies that demonstrate increased or high ridership are presented. The accompanying interactive CD-ROM includes a database of transit agency ridership strategies and a brochure outlining key elements for increasing and sustaining ridership.

2007; 126 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber category: public transit (VI).

Center Truck Performance on Low-Floor Light Rail Vehicles
TCRP Report 114

Guidance is provided for minimizing or avoiding performance issues—such as excessive wheel wear, noise, and derailments—observed in the operation of low-floor light rail vehicle (LFLRV) center trucks. Also included is information on LFLRV specifications, maintenance and design, and related infrastructure design and maintenance that maximizes performance of LFLRV center trucks.

2006; 76 pp.; TRB affiliates, $25.50; nonaffiliates, $34. Subscriber category: public transit (VI).

Bituminous Materials and Nonbituminous Components of Bituminous Paving Mixtures 2006
Transportation Research Record 1962

Papers in this volume are sorted into two sections. Part 1: Bituminous Materials addresses such topics as binder stress sensitivity, binder oxidative aging, and low-temperature cracking of asphalt binders. Part 2: Nonbituminous Components of Bituminous Paving Mixtures presents research on the degradation resistance of stone matrix asphalt mixtures, the addition of polymers to crumb rubber–modified binders, and evaluation of recycled asphalt pavement mixtures using the *Mechanistic–Empirical Pavement Design Guide*.

2006; 120 pp.; TRB affiliates, $36.00; nonaffiliates, $48.00. Subscriber category: materials and construction (IIIB).

Inland Waterways, Ports, and Shipping
Transportation Research Record 1963

Studies address waterway lock performance; the implementation of e-transport river information services to facilitate increased inland waterway transport; the feasibility of hub-and-spoke networks to improve the cost-quality level of container-on-barge transport services in existing and new markets; waterway traffic variations caused by lock closures and how this affects user demand changes; the implications of port growth for the ports of Long Beach and Los Angeles, California; and more.

2006; 75 pp.; TRB affiliates, $33; nonaffiliates, $44. Subscriber categories: multimodal freight transportation (VIII); marine transportation (IX).

Network Modeling 2006
Transportation Research Record 1964

The 2006 Fred Burggraf Award–winning paper presented in this volume proposes a heuristic to address a defined vehicle routing problem with solution shape constraints. Other papers present research findings on the expansion of a new capacity–reliability index for the design of a new reserve capacity model for a signal-controlled road network; a framework for the simultaneous optimization of evacuation traffic distribution and assignment to increase emergency evacuation efficiency; the use of a stochastic equilibrium formula to address commuter travel time uncertainty; the use of a cell-based network model to identify critical characteristics associated with staged emergency evacuation operations; and more.

2006; 269 pp.; TRB affiliates, $48.75; nonaffiliates, $65. Subscriber category: planning and administration (IA).

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RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes, whether they pertain to improved transport of people and goods or provision of better facilities and equipment that permits such transport. Articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by one or two illustrations that may improve a reader's understanding of the article.

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