

Visualization: Where Should Our Focus Lie?

A DRAFT White Paper on the Perceived Role of the TRB Visualization in Transportation Task Force

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Visualization in the 'Mainstream'

Computer image generation and rapid database development technologies, once the sole domain of the military, defense, and intelligence communities, have now become 'mainstream.' (go to www.vis-sim.org). Persons around the world watch nightly as news commentators use high resolution databases created from satellite imagery and other sources to portray the spatial aspects of the modern battlefield (see on-line account of *ABC News Uses E&S Technology to Cover War with Iraq*, at

<http://www.es.com/news/2003+press+archive/031903.asp>

The imagery shown to the right was developed by Evans and Sutherland using its Environmental Processor, or EP™ technology, using satellite imagery from Digital Globe Corporation of Denver, CO and GIS Xpress, an imagery service provider for Photon Research Associates (PRA) of San Diego, CA.

According to Jeffrey W. Schneider, ABC News Vice President, "This new technology will give our viewers a heightened understanding of the geography of this region. It will be a terrific tool for ABC News to use in order to convey important information to the American People."



Figure 1. Imagery from Evans and Sutherland (2003)

Emergence of 'Visualization' Within TRB

Four internationally attended, US Transportation Research Board (TRB) symposia on the topic of ***Visualization in Transportation*** (Houston, 1995; Minneapolis, 1997; Orlando, 1999; and Salt Lake City, 2002) attest to the emergence of visualization as a core technology in transportation systems planning, engineering design, public involvement, and system evaluation.

In 2003, the Transportation Research Board Visualization in Transportation Subcommittee of TRB Technical Committee A3B08 (User Information Systems) was elevated to Task Force status, designated as Task Force A3B58, and formally charged with

Fostering and disseminating research that advances the development, application, and evaluation of visual simulation as an integrated, "core" technology in the life-cycle process of collaboration, system planning, design, operations, and maintenance across all modes of transportation.

The importance of visualization is increasingly being recognized as an essential element of "Context Sensitive Design" (go to: <http://www.fhwa.dot.gov/csd/basic.htm>) and thus places visualization in the mainstream of efforts within the transportation community to improve the collaborative aspect of system planning and design.

Charting the Direction of the New Visualization in Transportation Task Force

While rapidly becoming a viable 'core' technology within the transportation system field, there is much to be learned about the effective *application* of visualization in its various forms. While the four TRB visualization symposia have served as a useful forum for the exchange of 'lessons learned' and 'how-to's,' few published reports exist other than the work by Hughes, et al (1998) where the express purpose of the work has been the *evaluation* of visualization within actual project settings (see also Hughes 1999 NCDOT report on "*Visualization: Guidance for the Project Engineer*" and the 2001 AASHTO report on "*Visualization in Transportation: A Guide for Transportation Agencies*"). These two 'guidance' documents can also be found on the Internet at:

<http://www.hsrb.unc.edu/research/visual.html>

and

<http://www.transportation.org/committee/design/doc/VisualizationReport.pdf>

As an outgrowth of the Key West visualization study (FHWA-RD-98-173), Hughes worked with the Florida DOT on developing a draft 'strategic plan' for the integration of modeling and simulation within the state DOT work environment. That report is available on-line at:

<http://www.hsrb.unc.edu/pdf/hfactors/pdf/sim4.pdf>

Efforts on the part of the Florida DOT to put together a 'strategic plan' for simulation, modeling, and visualization reflect the recognition on the part of a growing number state many DOTs that these technologies and their integrated application are becoming increasingly important to the way in which they do business, both now and in the future.

While these research and program development efforts remain pertinent to the application of visualization tools within the state DOT environment, technology has advanced since the late

'90s. Although these 'advances' in technology have served to enhance to *'state of practice,'* within the transportation community there continues to be lack of published efforts serving to position visualization within the broader conceptual context of spatial data or the visualization of 'data,' per se.

Among the chief objectives of the newly formed TRB task force will be:

- To promote a more scientific, research-based understanding of the factors governing the effective application of visualization within the field of transportation
- To formally recognize and learn from the non-transportation development and applications of enabling technologies (e.g., computer image generation, visual display systems, database generation and management systems, real time image processing, etc.), and
- To encourage an evaluation of the conceptual and methodological 'intersections' of visualization as we currently understand the term, with issues within the broader area of spatial data itself.

The new Task Force shall not only seek to foster an increased recognition of visualization's R&D history and its 'roots,' but to increasingly, and more directly, involve those pursuing these technologies outside the surface transportation field, per se, (e.g., aviation . . . both commercial as well as military/defense; national security, maritime, 'gaming' and 'virtual reality,' etc). And within the surface transportation field itself, a chief purpose of the Task Force shall be to foster increased 'integration' of visualization with computer aided design (CAD) on the engineering side and with Geographic Information System (GIS) applications on the planning side; in essence, to foster the creation of a 'seamless' digital capability for expressing the spatial components of design. As such, it is anticipated that the visualization task force will seek to involve itself more directly in the NCHRP work on spatial data accuracy and with efforts within those within the Bureau of Transportation Statistics in data visualization.

And as we shall point out later in this paper, an additional goal of the Visualization Task Force shall also be to work toward the integration of real time image generation capabilities with micro-simulation/modeling efforts, historically the domain of those within traffic engineering whose primary focuses have been, and continue to be, on traffic modeling and system capacity issues. For as we shall point out,

. . . . visualization cannot be solely about how something 'looks,' but also about how it 'works.'

And while a chief focus as a TRB task force shall be upon the development and support of a strong research agenda in the area of visualization and its application, the task force shall also have a responsibility for fostering the dissemination of information to practitioners in the field, and as such shall work to establish strong ties with both state and federal agencies and organizations in the transportation field (e.g., AASHTO and FHWA respectively).

Background

Attempts by man to create visual images of the world around him date back to pre-historic times (Eberhard, 2003) where images found in early cave dwellings often depicted animate objects (e.g., images of mammoth, bison, reindeer, horses, etc.) or figurines of fertility

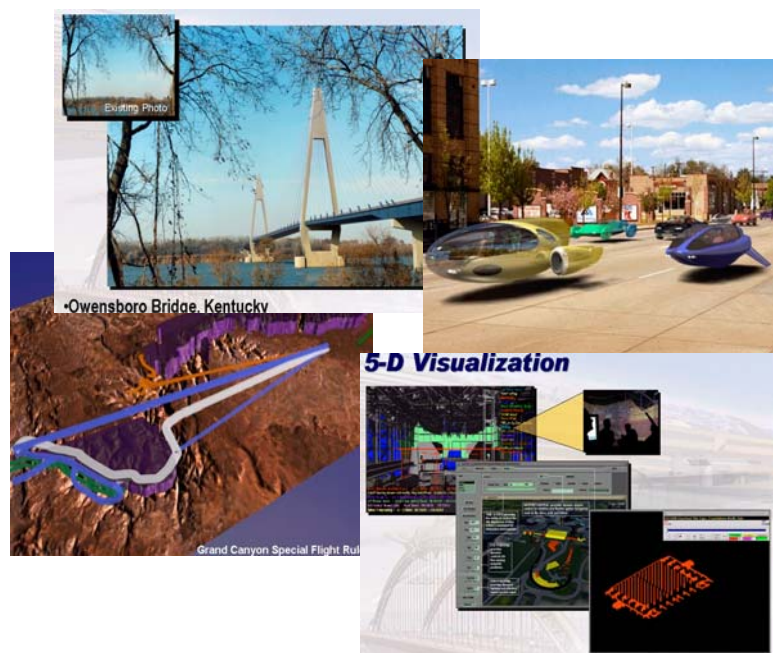
(aphrodites). Throughout recorded history, man has continued to create images of his environment as well as his notions of those spiritual forces believed to be in control of it. The role of visualization continues to serve as a vital link between that which is 'real' and that which is 'imagined' or 'hoped for.' Eberhard's 2003 TRB presentation (see Eberhard, 2003) tracks the evolution of modern visualization technologies and provides a forecast of its future.



Figure 2. Source: Horst de la Croix et al. eds *Gardner's Art through the Ages*, 9th ed. (Fort Worth: HBJ, 1991).

Perhaps visualization also represents a key component of traditional wisdom embodied in the statement that, 'whatever the mind of man can *conceive* and believe, it can achieve.' To the extent that 'to achieve' is synonymous, at least in part, with 'to build' in an engineering sense, visualization represents an important intervening step between concept and reality.

The Continuing Evolution of Visualization Within Transportation



Within the engineering world of transportation, the range from real to imagined has been documented over the years in visual representations (plan views) of detailed engineering designs, in artists' 'renderings' of the end products of those designs, and in artists' 'concepts' of innovative approaches to current and future modes of travel. Such visual images enable engineering and non-engineering individuals alike to 'grasp' not only how things might 'look' (their 'form'), but also how they might actually 'operate' (their function). The latter is important, since form without function fails to adequately convey the 'dynamic' essence of the basic concept of transportation itself.

Figure 3. Images from D. Eberhard's 2003 TRB Presentation, *Evolution and Trends in Visualization*

While the visualization of structures and facilities characterizes present notions of visualization within the transportation community, there is a growing recognition of the value of visualization in representing 'operations' as well as harder to grasp concepts within the areas of transportation planning, growth management, and 'smart growth.'

Visualization: An "Integrating" Technology

While visualization work in the planning and land use area has focused to date mostly on two dimensional efforts to represent socio-political and economic 'boundaries,' there is a growing body of work described on-line by Michael Kwartler of the Environmental Simulation Center in New York City (line (go to: <http://www.sustainable.doe.gov/toolkit/TCDDM/Kwart1.htm>) that is attempting to

... (combine) 3-D modeling with GIS, so communities can experiment with urban designs and see quantified environmental and fiscal impacts (Kwartler, Environmental Simulation Center)

The Center, a not-for-profit product of New York City's New School for Social Research, employs PC-based software that allows citizens to model various site-specific development scenarios in a manner similar to the well-known Sim-City software program. It accomplishes this by linking two and three-dimensional visual representations of places with databases and spreadsheets. These "new tools" for community design and decision making integrate 2-D mapping information from a GIS platform with fully interactive 3-D visualization, policy simulation and impact analysis modules.

These 'new tools' are about more than simply visualization of the structures involved. Visualization tools, per se, become an important means to an end and not an end product in themselves.

An important component of this process is its focus on the quantification (and visualization of) environmental and fiscal impacts. Consider the two figures below from Kwartler's review.

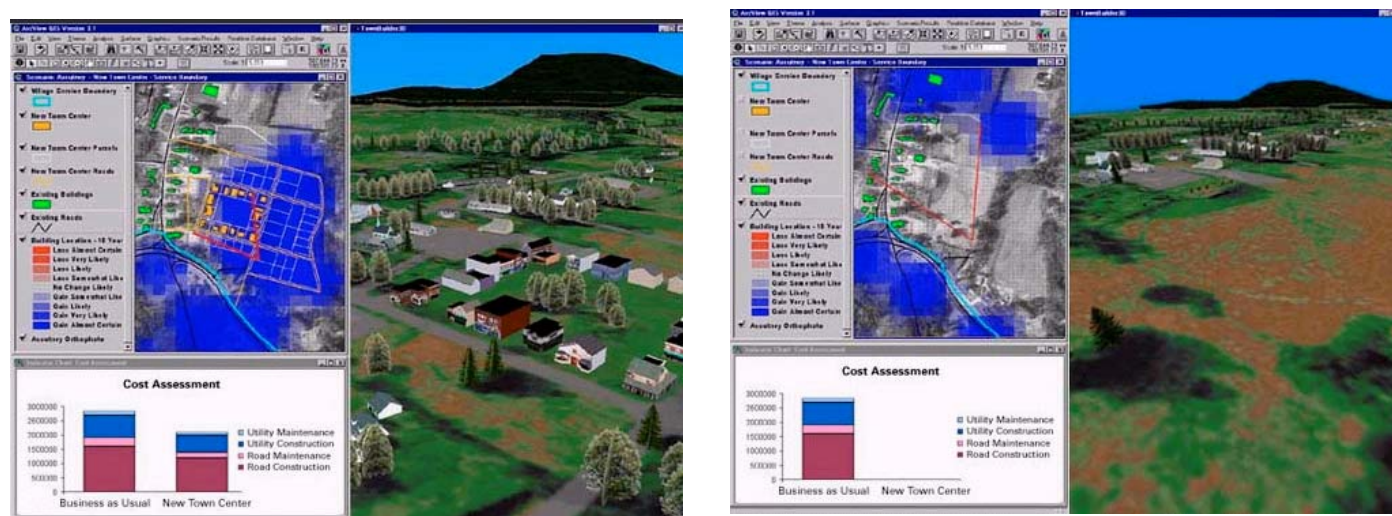


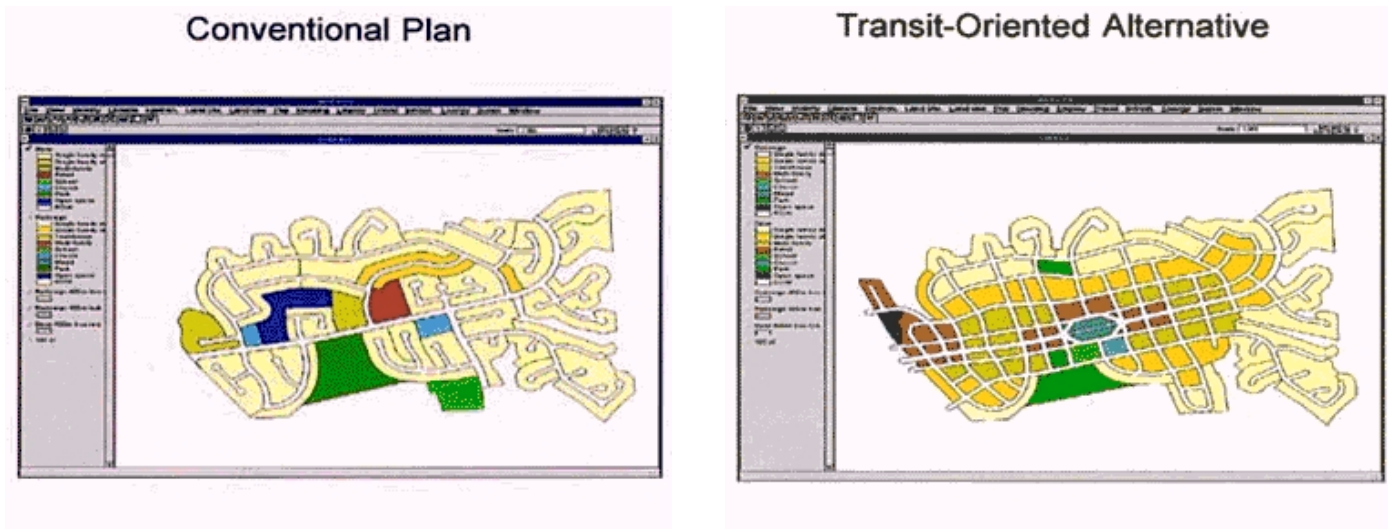
Figure 4. From M. Kwartler , "New Tools for Community Design and Decision Making"
<http://www.sustainable.doe.gov/toolkit/TCDDM/Kwart1.htm>

The Environmental Simulation Center (ESC) and the Orton Family Foundation have been working with the citizens of Ascutney, Vermont to test CommunityViz. an innovative software package designed to provide citizen planners of communities like Ascutney with the tools they need for intelligent planning. The 2-D and 3-D databases have been used to model the demographic profile of the people who would want to live in a compact community, the jobs created, the savings in infrastructure operating costs, and the appearance of an expanded village center. The two examples shown here not only help citizens visualize the appearance of the before and after alternatives presented, but more importantly help them visualize, if you will, differences in the calculated road and utility infrastructure costs associated with each.

In the series of figures below, Kwartler describes how two development scenarios for a neighborhood can be compared with charts measuring the relative performance of selected indicators. In this case, graph bars show changes in employment, commercial building, and residential densities; job balance; and proximity of recreational areas.

These images show how a single 2D visualization of (GIS) data combined with a clear quantification of land use and socio-economic variables can provide decision makers with a powerful, visually-based aid in evaluating multi-dimensional problems associated with growth and development.

These examples represent how visualization (here, simple 2D mages) can be effectively used to visualize 'data' if your will (versus the appearance of physical structures, neighborhoods, streets, if you will). More importantly, the 'data' are directly related to core values associated with urban form and use, housing, employment, travel, energy, water, solid waste, and pollution. These are the core values upon which physical infrastructure are built.



Figures 5 and 6.
**From M. Kwartler , "New Tools for Community
Design and Decision Making"**
<http://www.sustainable.doe.gov/toolkit/TCDDM/Kwart1.htm>

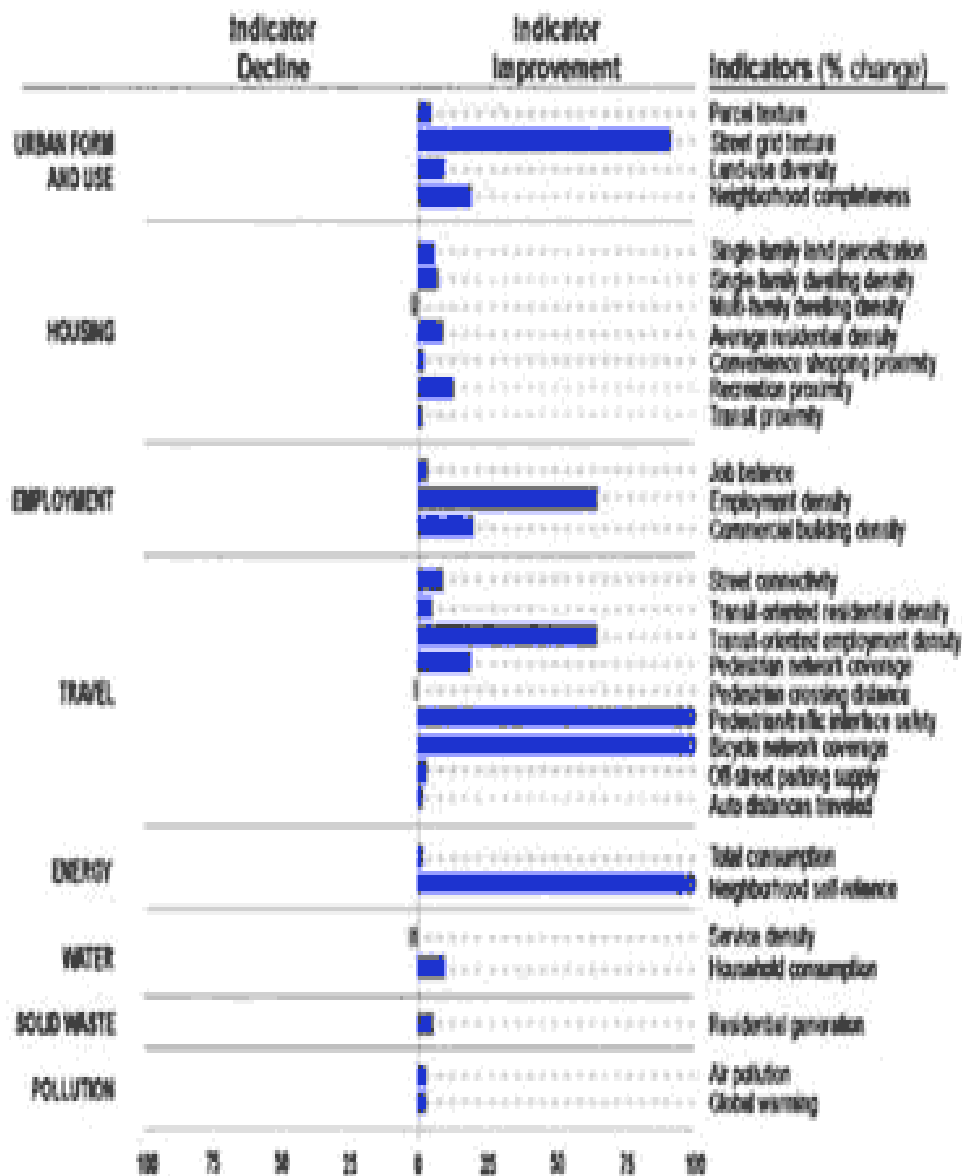


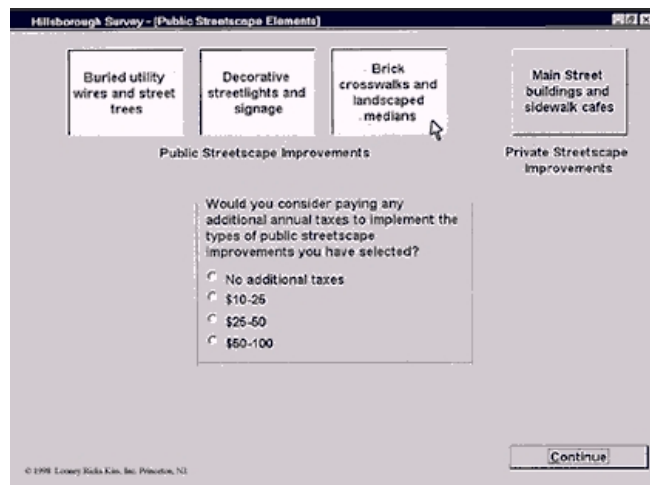
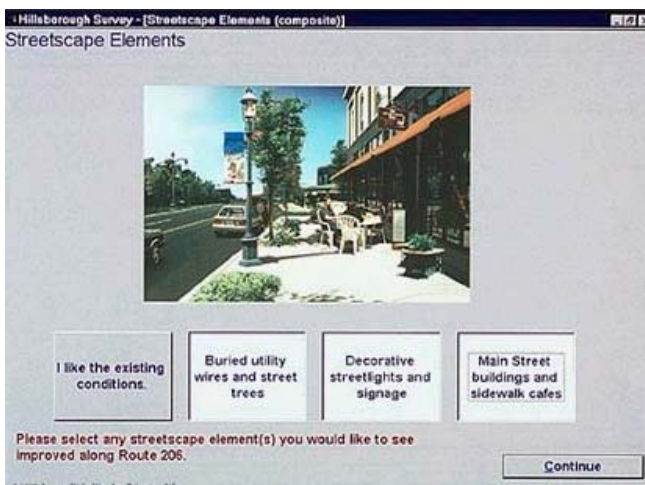
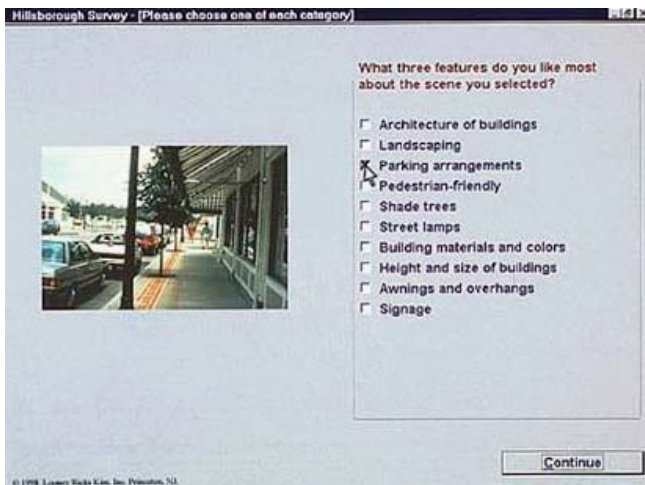
Figure 7. An Example of Quantifying Key Dimensions/Core Values From M. Kwartler , "New Tools for Community Design and Decision Making"

<http://www.sustainable.doe.gov/toolkit/TCDDM/Kwart1.htm>

How often has visualization been used to present proposed transportation plans to stakeholders only to have the stakeholders say, 'No.' A more intelligent approach would be to start with attempting to achieve a consensus among stakeholders and developers about those dimensions important to the community. The community knows best what it 'values.' The developer knows best the costs associated with different approaches. Consensus will be achieved once developers have a clear notion of what is 'important' to the community and the community has a clear notion of how different plans and approaches affect the costs associated with an end product that is consistent with those values.

Too often costly visualization support efforts are presented to the public by a project engineer who, at the end of the presentation, risks the question of, 'Well, how do you like it?' If you don't know by then, it is a clear indication that you have not involved the public in the process.

A good example of how visualization can be used in an interactive, and iterative manner in reaching stakeholder consensus is shown in the following figures, again taken from Kwartler's presentation. The example is from Hillsborough, NJ where citizens were asked to choose from a range of possible streetscape improvements. As participants click on different design options, the images evolve into a more 'pedestrian friendly' streetscape (e.g, different street furniture and signage, landscaping, lighting, different parking arrangements, and different building placements). As part of the interactive survey process, respondents were asked if they would be open to an increase in taxes to fund the changes for which they had expressed a preference.



Figures 8-11. Soliciting Public Interaction and Structured Feedback in Conjunction With Visualization
From M. Kwartler , "New Tools for Community Design and Decision Making"

<http://www.sustainable.doe.gov/toolkit/TCDDM/Kwart1.htm>

A similar interactive process has been used by The Research Triangle Institute. The statistical basis for the method is called 'conjoint analysis'. Conjoint analysis is a stated-preference research technique used to quantify the impact of different design or treatment attributes on

respondents perceptions of value, utility, risk, or whatever. Conjoint analysis involves a series of scenarios that represent the key characteristics of a product, a service, a design, etc. Respondents rank, rate, or choose scenarios so that their preferences for scenario characteristics can be determined. Conjoint analysis has been used extensively in the marketing research field to help with new product development and marketing decisions.

While most RTI applications of conjoint analysis have been in the health care field, the method has also been used in conjunction with RTI visualization capabilities to assist in the design of commercial motor vehicle driver interfaces. Visualization methods were used to construct high fidelity representations of alternative design configurations. Alternative configurations were presented to respondents in all possible pairs. Respondents were asked to indicate the degree of preference for a chosen alternative.

The design decision support application is simple and straightforward and results in a quantification of the respondent's or stakeholder's stated preferences. Kwartler's planning examples represent an effort not only to solicit preferences, per se, but preferences as defined in terms of the recognized underlying dimensions related to stakeholder definitions of value and/or utility.

What's different about the process described by Kwartler and the process that continues to characterize most DOT's use of visualization. Kwartler's examples are not about visualization in the sense of creating high resolution images of final products. Visualization in the examples provided above is about using images to clarify basic concepts and the community values underlying those concepts. Visualization is not used, as an example, to depict what the light rail vehicle is going to 'look like' but rather to help members of the community to conceptually 'see' how different light rail alternatives help achieve basic values like convenience, reduced travel time, reduced infrastructure cost relative to other alternatives, traveler safety, and the like. The value of a design to the user is not embodied in the physical appearance of the 'thing' as much as it is in the underlying attributes that make the thing 'valuable' to its user. The essence of this relationship lies in a well known manufacturer's slogan,

***We don't make (the thing); we make (the thing) 'better'
(from BASF)***

It's the dimensions along which users judge a design to be 'better' (better as perceived by the user, not necessarily the designer) that should be the focus of visualization, and not solely the visual appeal of the project, per se. How to identify those dimensions at the outset and how to solicit public comment and reaction in such a way that reactions are consistent with the overall likelihood of public acceptance is key. How to do this is not within the current engineering school curriculum of those being trained to enter the field of transportation engineering.

Visualization and Context Sensitive Design/Solutions

The movement toward context sensitive design /solutions (see: <http://www.fhwa.dot.gov/csd/>) embodies the philosophy of Kwartler and his colleagues, but 'without the tools.' Those who advocate CSD/CSS recognize that design is about more than the effective visualization of form and function. It is about achieving a consensus (or shared belief) about the alignment between the value of a design and the values of those for whom the design is intended. Context sensitive design (CSD) is a collaborative, interdisciplinary approach that involves all stakeholders to

develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility.

Up to this point, visualization (at least how it has been conveyed in the course of the four TRB symposia) has been almost exclusively concerned with the 'scenic' and aesthetic components of this process. Preserving historic and environmental remains, for the most part, the domain of the Environmental Impact Statement (EIS), while system operation remains almost exclusively within the technical domain of traffic engineering and its reliance on microscopic simulation traffic models. The design process, even with the increased use of visualization, remains highly compartmentalized. Visualization continues to be used in most instances to present final designs to the public for its approval rather than as a basis for more effectively involving the public in those parts of the process leading up to design.

Perhaps most ironic is that while most would say that they use visualization to facilitate communication with the general public/user/stakeholder, etc. few if any make any overt effort to sample how the public relates to the proposed design along the multiple dimensions that ultimately govern their preference for the design. That sort of feedback is not the kind of feedback obtained in traditional public involvement presentations. In the typical public meeting, only those profoundly 'for' or 'against' the project voice their opinions 'for the record.'

While visualization may facilitate public involvement, improved methods need to be developed that successfully document the preferences of all who are involved, not just those who are most outspoken. And the feedback needs to be structured along the lines of public position on the key objectives of the design (not only the key design elements). It would seem that the 'planners' have begun to understand this need more so than the design community.

Technology Advancement: A Necessary but not Sufficient Condition for Effective Application

Advancements in the technologies that make visualization practical from an engineering design and public involvement standpoint while necessary are not sufficient for visualization to be an 'effective' tool. The programs of the four TRB symposia held to date attest to the rapid advancement in computer image processing technologies and their increasing affordability. One suspects that this rate of advancement will continue. But will these advances serve to increase further their effective application within the transportation field?

Too often visualization is used by those in charge of a project to ensure that the factual elements of the design are presented to the public (i.e., number of and width of lanes, presence or absence of a median, lighting, curb and gutter, sidewalks, etc.). Even though the public may not find anything wrong with the design, per se, they may still object (if for no other reason than the anticipated disruption associated with going from what is present to what is being proposed. No amount of increased resolution, scene content, or animation will serve to convince the user of the value/benefit of the proposed design, if the design is not consistent with the core values of the user.

Some are under the mistaken notion that the key element missing in earlier technical attempts at visualization was the interactive, real time element. There are those who act as if the real time, immersive aspect of what is called 'urban simulation' represents the key missing ingredient. While the interactive, real time aspect provides additional means to maneuver

in/around/over/through the proposed design, such capabilities are not a substitute for a 'good' design . . . one that is responsive to user needs and requirements and that is consistent with the community's core values. Those in the field have argued that 'animation' was not worth it. So why would one suspect that real time immersive environment methods (however cost effective their development) would suddenly be the key. The effectiveness of visualization depends not upon the technologies so much as it does upon their application . . . their application in support of *communicating* the 'concept' and its 'value' to the user.

Are Current State DOT Visualization Objectives Missing the Mark?

The typical state DOT sees visualization as a tool that can increase the likelihood of early public acceptance. Early public acceptance and less need for redesign and a lengthy public involvement process translate into 'reduced project costs.' While many DOTs are embracing visualization and the process of context sensitive design, it is important that one not see visualization as the sum total of that process. Visualization is a tool that can prove extremely helpful when used as part of a process of context sensitive design to facilitate the type of communication and interaction that is necessary to a successful project.

Visualization is about a 'process.' It is not just about creating high resolution images of transportation system facilities and their operation. Its effectiveness is not necessarily increased by the addition of animation or real time immersive simulation methods. Neither should one expect the effective use of visualization to increase now that information can be disseminated via the Internet. Effectiveness is not about the 'medium' but rather the 'message' and the manner in which the message is presented. It is about helping designers and end users focus on those elements of the design that contribute to a common, mutual 'concept' of the project that both meets the stated needs and requirements of the user as well as the stated, or often unstated, values of the user community. User benefits reside in the perceived value of the project to the user, not in the engineering facts and figures associated with the design. Just as the slogan of Context sensitive design is 'beyond the pavement,' so much the mindset of those who employ visualization be, 'beyond the representation of engineering facts.'

So Where Can the New Task Force Help?

Because of the key role of computer graphics within the overall computer and gaming industry, it is likely that these technologies will continue to rapidly advance without the aid of the TRB task force on visualization. And it is likely that as the costs of acquiring and applying these technologies continue to drop, state DOTs will increasingly embrace their use. The task force can play an important support role in ensuring that information about advances in technology and its informed application reach the end user at the state DOT level (i.e., working to raise the general level of technical competence in the area of visualization).

However, the task force needs to 'get out in front' of the curve. It cannot afford to assume technology transfer as its key TRB role. The task force needs to define the 'issues' with respect to how this technology is effectively applied, and to encourage applied research that focuses exclusively on 'effectiveness.'

The present paper suggests that 'effectiveness' is not defined solely in terms of improved resolution, scene content, real time image generation, and the like; but rather in terms of the user community coming to understand how these technologies collectively can be used to aid in

the communication of operational design concepts that are consistent with the core values of the users for whom these designs are intended. Visualization is first and foremost about communication between planners and designers, between designers of different disciplines, and between the engineering community as a whole and those in the user community for whom an effective design is one that is consistent with the real or perceived 'values' of the community. Context sensitive design, context sensitive solutions, collaborative planning, etc. are all steps in the right direction. The right direction . . . the right process, if you will, is not an engineering issue, but rather an issue about communication.

To this extent, visualization as a core technology within the transportation engineering curriculum is not something that currently exists within the curriculum per se. It is not a 'technology' course, although engineers need to understand the technology and its limitations. It is not a computer science issue alone. Knowing how to do the 'programming' is not sufficient to ensure effective applications. Effectiveness currently lies in the 'gray' areas of knowing how to interpret stakeholders' needs and the way that ones proposed design solution not only meets those needs, but does so within the context of their real and/or perceived core values.

We're not there yet, but we're beginning to get a sense of the direction(s) in which we should be going.