EFFECTIVE VISUALIZATION TECHNIQUES FOR THE PUBLIC PRESENTATION OF TRANSPORTATION PROJECTS

Norman W. Garrick, Peter Miniutti, Mark Westa,
Jianhui Luo and Matt Bishop

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16. Abstract

The purpose of this project was to look at ways to develop more coherent and effective approaches for presenting transportation projects to the public. A detailed review of recent research on visual perception and visualization was conducted. We also conducted site visits to two consulting firms and one state DOT. In addition to field trips, we conducted mail-in surveys to the six New England DOTs and compared our survey results to a previous nationwide survey conducted in 1998.

The result of the study showed that image composite continue to be the most popular visualization techniques used in both DOTs and consulting firms. Animation, which is the most effective visualization technique, is expected to be used more frequently as the cost and time of production are reduced.

We also found that visualization techniques are mainly used in the public involvement process in the New England DOTs; they are rarely used in design and design development. We expect that this will change as Context Sensitive Design takes hold in the DOTs. As this occurs, we expect that visualization will be more frequently incorporated, not only in the public involvement stage, but also at all stages of design. Because transportation design and public involvement are parallel processes, DOTs will find that the usage of visualization in design will be invaluable in helping transportation designers evaluate and refine their design.

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Chapter 1

INTRODUCTION

Increasingly, transportation projects are being judged not only on strictly technical merits, but also on the basis of how well they fit into the social and natural environment [1]. Many local communities are asking tough questions about whether a proposed project enhances or degrades livability of the community. In particular, projects designed to expand the highway system are increasingly complex and are often slowed or even stopped by adverse public reaction [2]. These factors have contributed to bringing about a new approach to design: Context Sensitive Design (CSD) in highway design and construction. CSD is a collaborative, interdisciplinary approach that involves all stakeholders in developing a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources while maintaining safety and mobility. To be successful in this environment, transportation professionals must be skilled at presenting their ideas to the general public in a clear, unambiguous and accessible manner. The effective presentation of projects' impacts to the public has become an increasingly essential part of the planning and design of transportation infrastructure.

Concurrent with the need for more effective presentation has been the rapid change of the tools used in design. The principle shift has been from the traditional drafting room environment to the computer based "CAD" environment [2]. However, other advances in digital technologies have also enhanced the ability of transportation professionals to use sophisticated visualization techniques. These advances have transformed both how information is generated as well as how it is presented. This means that high quality visuals are now much easier to produce and display interactively. However, the generation of visuals for transportation projects is very resource- intensive, not only because we are typically dealing with complex vector drawings or raster images, but also because of the sheer magnitude of most transportation projects.

Just a few short years ago, advanced visualization techniques (such as 3D modeling and rendering) would require the purchase of high-end machines such as Silicon Graphics' Reality Engine. Today the typical desktop computer is capable of 3D modeling and rendering with their fast processors, plenty of RAM (>128 M) and generous disk drivers (>20 GB). Furthermore, over the past few years, digital scanners, cameras and color printers have become standard equipment in many offices at affordable prices. The widespread availability of these devices significantly enhances the potential for creativity and innovation in developing and making presentations.

With regard to presentations, laptop computers and Liquid Crystal Display (LCD) projectors provide powerful means to transform almost any forum with an interactive and educational presentation. "No longer are we tied to difficult-to-see visuals on mounted boards or the passiveness of a slide show in a darkened room" [1]. Presentations made from LCD projectors are visible to large audiences and can be easily customized to the special needs of any type of audience.

One of the important issues in visualization is to ensure that the visualization techniques are used in the most effective matter. Misunderstanding can result from poorly crafted presentations and visual aids. Issues such as building-in audience participation and effective use of colors and images are extremely important.

In this research, we will review studies in the field of visualization and visual perception in order to gain insight about the most important factors contributing to the effective use of visualization. We will also look at both the technologies of visualization and the techniques and procedures that are important in effectively using this technology.

In terms of the technology, our task is to categorize the methodology available for visualization and to ascertain how the New England DOTs could most effectively utilize these methodologies. To achieve this goal we characterized the state-of-the-art visualization practices by site visits to innovative firms in New England and extensive reviews of information on the web and literature. Based on these reviews we inventoried current visualization techniques in terms of the types of project, software requirement, project cost and benefits and limitations. We also conducted a survey of the DOTs to understand the environment in which visualization is currently conducted at the state level. This provided us with the background information we needed to develop recommendations for using the visualization techniques in the most effective manner. The rest of the report is arranged as follows:

> **Chapter 2**. **Public Involvement and Visualization**: this chapter describes the background relating to public involvement and visualization in the transportation industry.
> **Chapter 3. Visual Perception and Visualization**: this chapter provides the details of visualization technologies and the products related to each technology.
> **Chapter 4. Survey of Visualization State-of–The-Art in New England**: this chapter provides the results and summary of the field trips made to different agencies and mail-in surveys to the New England Departments of Transportation.
> **Chapter 5. Details of Technology and Products:** this chapter provides the details of visualization technology and products related to each technology.
> **Chapter 6. Conclusions and Recommendations**: this chapter draws conclusions and outlines future research.

Chapter 2

PUBLIC INVOLVEMENT AND VISUALIZATION

In the transportation industry, visualization is a communication tool that is used to enhance participation within the context of public involvement. These days, public involvement in transportation decision-making is increasingly regarded as critical by all stakeholders [39]. Consequently many agencies have adopted visualization technology to facilitate public involvement and environmental analysis. The use of visualization is expected to grow rapidly as transportation departments seek more effective ways to design and communicate information about transportation to the public.

In this chapter, we will first discuss the issue of public involvement in transportation. Then we will give our understanding of the definition of visualization, the need for visualization and current use of visualization in transportation planning and project development.

2.1 Public Involvement in Transportation

Public involvement involves the two-way communication between citizen and government by which transportation agencies and other officials share information with the public and use public input as a factor in decision-making [40]. In the past decade, a radical transformation has occurred in the way transportation decisions are made. Public involvement is no longer an option in transportation planning; the public increasingly demands it and the Intermodal Surface Transportation Efficiency Act (and now the Transportation Equity Act for the 21st Century) mandate it. States and local governments have consequently developed protocols and guidelines to interpret these mandates. In 1993, the Federal Highway Administration and Federal Transit Administration Planning Regulations stated the following in reference to public involvement: "Public involvement processes shall be proactive and provide complete information, timely public notice, full public access to key decisions, and opportunities for early and continuing involvement". In earlier times, the focus of transportation planning and project development was largely on project design and construction; public concerns were peripheral. Now there is more focus on context sensitive design and getting the public involved in the decision process.

In 1995, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) jointly issued "Interim Policy on Public Involvement". In this policy, these agencies stated their strong commitment to public participation. The goal of this policy statement is to aggressively support proactive public involvement at all stages of transportation planning and project development.

In 1996, FHWA and FTA co-published "Public Involvement Techniques for Transportation Decision-Making". This report, currently available on the FHWA Internet site (www.fhwa.dot.gov/reports/pittd/cover.htm), emphasizes giving the public a real forum for transportation decision-making. The collection of public involvement techniques in this report provides the fundamental references that state and local transportation agencies can use to implement effective public involvement programs. In

this report, computer-based presentation (using visualization) along with interactive television, teleconferencing and interactive displays and information kiosks, are identified as new techniques that show promise for improving communication in public involvement.

Visualization technologies can be effectively used at all stages in a public involvement process. They help people visualize potential impacts and operations. They are used in corridor studies, long-range planning, transportation improvement programs, or other project tasks [39]. Visual communication is not only very useful at the beginning of a project but also at critical time when decisions are being made in public involvement. Later in this chapter, we will discuss the reasons why visualization is so important in transportation and what types of visualization techniques are used in public involvement.

Public presentation is an important element of the public involvement process. Through public presentation, transportation agencies and other officials can give notice and information to the public and use public input as a factor in decision-making. The purpose of traditional public presentations is to comment on the completed design. More common now this process is also used to allow the public to provide input at all stages of design. Some presentations are designed to solicit public input. A well-conceived and well-implemented public presentation can bring major benefits to the public involvement process and lead to better decisions. Beneficial results include public sustainable and supportable decisions, decisions that reflect community values, efficient implementation of transportation decisions and enhanced agency credibility [40].

As public expectations for better, safer roads have increased, a growing awareness of communities' needs has also emerged among designers. These factors have contributed to bringing about a transformation in transportation design and construction, which in turn has lead to the proposition of a new philosophy known as Context Sensitive Design (CSD). CSD is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical environment and preserves scenic, aesthetic, historic resources, while maintaining safety and mobility [30]. It is an approach that considers the whole context within which a transportation improvement project will exist. CSD integrates projects into the context or environment in a sensitive manner through careful planning, considering different factors, and adapting designs to particular project circumstances.

CSD also requires an early and continuous commitment to public involvement, flexibility in exploring new solutions and openness to new ideas. The public plays an important role in identifying local and regional problems and solutions that may better meet and balance the needs of all stakeholders.

2.2   Visualization in Transportation

Over the last ten years, computer based visualization technology has developed into a powerful aid for studying a variety of natural phenomena and has become an indispensable desktop technology in professional areas such as medicine, architecture and engineering.   Continuous   advances   in   computer   technology   have   made   these

sophisticated visualization techniques available and affordable to the transportation industry.

In transportation, visualization is a science that combines a variety of different applications and technologies such as composite image, video overlay, animation and Geographic Information System (GIS) to realistically generate and portray existing and proposed project conditions. Effective visualization significantly improves our ability to assess complex planning scenarios and proposed alternatives. It can be used to identify and solve potential problems early in the project development process, produce and evaluate alternatives faster and facilitate early public involvement and feedback.

2.2.1 The Need for Visualization in Transportation

Because of the difficulty in communicating the complex nature of transportation projects, visual aids are necessary for public presentation. The intent of visualization in public presentation is to help the public understand the context, to add insight to problem solving and to communicate with the public. It is used to communicate the effects of future changes and modifications to our transportation system. Visualization can be effectively employed to communicate the reasons that make the project necessary. It needs to be incorporated into the public presentation process to give the visual nature of the project and the effect it will have on the environment. Visualization can also be implemented to evaluate the cost and functional effectiveness of alternative solutions, the advantage of the project to the public as well as the anticipated impact.

Geometrical data in transportation is often characterized by a high level of complexity that makes it difficult for even designers to understand the full spectrum of issues. For example, the complexity of horizontal and vertical alignments, sight distance and traffic operations in some large-scale projects (such as interchange construction) cannot be fully understood without visual support. Due to the complexity of the geometrical data, the need to analyze and test the design idea is growing in importance for transportation engineers. Traditionally, the testing of a design was accomplished through CAD drawing, which is based on numerical models [10]. However, this traditional procedure illustrates little about the project performance, which is determined by experiencing the design and simulating its operation. Through various visualization technologies, design ideas can be visualized by providing a real time visual representation.

In addition, the need to communicate design alternatives, issues of accessibility, visibility, as well as other important issues (such as environmental and historical considerations) must be addressed. The designers need powerful visual tools to develop and refine the design concepts and must also communicate these concepts with others in their organization. Finally, they must communicate design possibilities to an increasingly interested and concerned public.

Some specific and detailed assessments of the design are especially important to those who live, work or own property adjacent to the proposed project [3]. These details include such issues as the integration and aesthetics of the project, the open spaces and other infrastructures that surround the proposed project. Other context sensitive issues,

such as construction material, material texture, and scale of individual design element (such as lane width, sidewalk length) can best be addressed using visualization techniques.

Visualization products provide information in a stimulating, visual way. They convey complex information in easily digested segments [8]. Visualization enables people to deal with information by taking advantage of our innate visual perception capabilities. By presenting information more graphically, we make it possible for the human brain to use more of its perceptual system in initially processing information, rather than immediately relying entirely on the cognitive system. In Chapter 2, we will provide some insight into the relationship between perception and visualization.

2.2.2   Current Use of Visualization in Transportation

Many types of visualization techniques now exist, ranging from traditional 2D, artistic rendering based on interpretation of conceptual project ideas to 3D, fully detailed, animated simulation that completely illustrates all aspects of the project. Visualization techniques that are commonly used include artist concept and rendering, image composite, video overlay, video, computer animation, Geographic Information System and traffic simulation. In practice, these technologies are seldom used independently, but are combined into a presentation where each technology serves a specific purpose in the most cost-effective manner [2]. Detailed discussions of these techniques and related products will be provided in Chapter 4.

According to surveys conducted by Ron Hughes in 1998 and Harlow C. Landphair in 1996, visualization in the public involvement process remains limited to the use of image composites presented in the traditional large format, wall-mounted board displays. The use of video as a means of presenting the visualization products is reported to be the second most often used format.

Animation, while foreseen by the majority of the DOTs as being increasingly important in the future, is not yet widely used. It is clear that questions remain as to the effectiveness of animation. The perceived effectiveness of animation is likely to be weakened by the current difficulty of its production [4]. Producing animation with a highly detailed 3D model, texture maps, shadows and vehicular motion is time consuming and can require significant resources. However, because animation is the most powerful of communication media for transportation visualization, there is no doubt that this 3D technique will be applied more in the near future as the production cost decreases. In Chapter 5, we will provide a more detailed discussion about current state-of-the-art practice of visualization in New England. This review is based both on an in depth on-site study of selected firms and agencies and a survey of New England DOTs that was designed to give a comprehensive picture of visualization in the New England states.

Chapter 3

VISUAL PERCEPTION AND VISUALIZATION

As stated by Bertin and Beyond, "Visualization is a joint function of computer graphics and perception". Visualization processes must incorporate both a formal theory of computer graphics and a theory of human perception. Therefore, successful visualizations require an understanding of the human perceptual system: "just because a technique displays data in a graphical form does not mean the display will be useful" [18]. Displays need to be designed to harness the capabilities and overcome the limitations of the human perceptual system.

It is important to understand the relationships between visual perception (the message received by the viewer) and visual stimuli (the product of visualization technique). Having a working knowledge of the basic principle of visual perception will allow us to attack the problem of effective visual communication at a fundamental level, rather than merely reacting to the current state of affairs.

Rudolf Arnheim, an international authority on visual perception and author of Visual Thinking, provides some insight on how knowledge should be represented: "Thinking is done by means of structural properties inherent in the image, and therefore the image must be shaped and organized intelligently in such a way as to make the salient properties visible" [8]. Albert Einstein provides his understanding of the visual perception: "If we trace out what we behold and experience through the language of logic we are doing science; if we show it in forms whose interrelationships are not accessible to our conscious thought but are intuitively recognized as meaningful, we are doing art".

Effective visualization techniques help to change information that needs more conscious thought to graphics that need much less conscious thought and are easier to understand intuitively. Therefore, visualization techniques for the public presentation of transportation projects require us to accurately identify, thoroughly understand and to graphically communicate the properties of the projects that will make the important aspects of the project more accessible to the public.

The human visual perception system is very complex and must be taken into account in the design and use of visualization systems. The way we interpret a display is dependent on our conception of the data and the display, our background and previous experience and our cultural grounding. Gregory [18] notes that "Perception is not determined simply by the stimulus pattern; rather it is a dynamic searching for the best interpretation of the available data" or "Perception is a matter of making the best bet on the available evidence". People may interpret the same visual image quite differently. To improve the visualization process, one must understand how the visual system perceives visual information. The following two sections describe ways by which we can improve image interactivity and the visualization process by better understanding human perception.

3.1   Improving Image Interactivity

Interactivity is the great challenge and opportunity of computer-based visualization. An important advantage of computer-based visualizations over traditional paper-based visual expositions is interactivity. Visualization technology can provide transportation professionals with a great range of image types that can be used in the presentation. In large part, the way in which these images are used is what makes them more or less interactive. Based on Minuitti's research [16], images can be categorized along an interactivity continuum in the following way:

Illustrative Image

Illustrative images are those that are used frequently in public presentation to illustrate existing conditions and project context. These digital images are analogous to slide projector images, and have been modified the least. An illustrative image can be generated by scanning photographs, reproductions, and other materials, and then using it to illustrate a concept. The main advantages of these digital images over slides are consistent quality through digital enhancement and greater ease of in-presentation retrieval.

Prepared Images

Prepared images are those that the presenter has altered before presentation. The two types of images that are used extensively are modified illustrations and digital-created schematics. Modified illustrations are scanned illustrations that have been digitally manipulated in some way other than simple enhancement of the original scanned image. Such modifications can highlight features to stimulate communication between image and audience. For example, Figure 3.1-a is a scanned photograph of the Washington Monument in Washington, DC, while Figure 3.1-b, the second in the presentation sequence, diagrams the spatial and visual forces of the monument. Finally, Figure 3.1-c shows the diagram with the original photo withdrawn. Through sequencing of these presentation images, the content of the images is increased gradually in a way that makes it easy to understand. The abstract design concept is "pop out" from the real environment in the digitally created schematic. This process can facilitate and clarify visual and abstract thinking about real spaces.

Both modified illustrations and digitally created schematics are examples of the logical pictures that are essential to presentation [11]. Gombrich states, "The easier it is to separate the code from the content, the more we can rely on the image to communicate a particular kind of information." A selective code that is understood to be a code enables the maker of the image to filter out certain kinds of information and to encode only those features that are of interest to the recipient. Such a rendering may be described as a transition from a representation to diagrammatic mapping. The ease with which we can separate annotation code from content has vastly improved with the use of digital tools. As shown in Figure 3.1, these codes are used to help highlight the context of the project.

| a). Photograph of Washington monument from Capitol | b). Diagram of spatial and visual forces overlaid onto original photograph | c). Diagram of spatial and visual forces with original photograph removed |

Figure 2.1 Example of Images and Interactivity (Source: [16])

Annotation codes of graphics are important to facilitate the interaction between images and audiences. These codes direct audiences to pay attention to the important elements of the graphic during the presentation. Table 3.1 lists an example of annotation codes that can be used to make prepared images for public presentation. The annotation codes in this example are used to state existing problems and analyze alternatives for a proposed transportation improvement. Figure 3.2 shows examples using this annotation codes. Figure 3.2-a shows a summary of transportation and water systems in the proposed project area on an oblique background. Figure 3.2-b illustrates the proposed alternative for the new construction, while Figure 3.2-c shows all the impacts of this alternative. Annotation codes are not limited to this example; they can be expanded to fulfill the project needs.

Processed Images

Processed images are those modified in real-time during presentation. Audiences can be more or less involved in interacting with the image, with the presenter acting as an "enlightened technical intermediary". So, for example, if a participant asks a question about a concept, the presenter may respond by doing some virtual drawing on a schematic to clarify.

Processed images involve cutting and moving areas of images, distorting, changing colors or textures. The special editing abilities of digital systems combined with the traditional tools of cut and paste allow a high degree of visual 'violence' to be perpetrated to the original subject. Through such 'violent' digital analysis perceptual concepts can be explored with audiences as active subjects. Minuitti suggests that process images are much more memorable for audiences than the equivalent slide-based discussions.

🔴	Major problem area
🟡	Less significant problem area
🟢	Non-problem area
∿➤	Linear one direction, major route (Transportation system)
∿➤	Linear one direction, minor route (Transportation system)
➤	Linear one direction (Water system)
☐	Study areas
⚡	Location where has major impact
⚡	Location where has less significant impact
🚦	Adding signal to intersection
STOP	Adding stop sign to intersection

Table 3.1 Examples of Annotation Codes

Figure 3.1-a. Diagram for Summarizing Systems
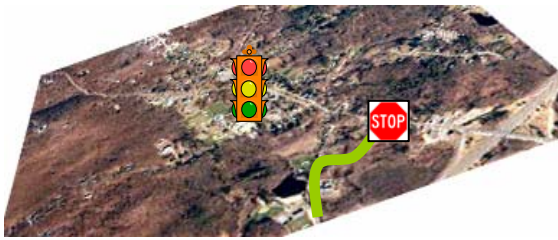
Figure 3.1-b. Diagram of Proposed Alternative
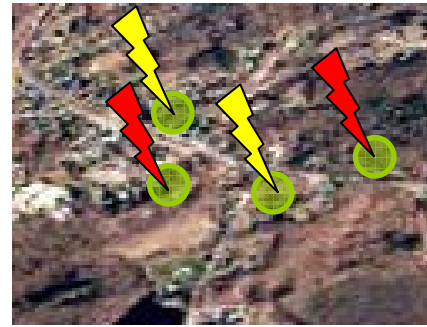
Figure 3.1-c. Diagram of All Impacts

Figure 3.1 Examples of Using Annotation Codes

3.2 Understanding Human Perception

3.2.1 Conscious and Preconscious Vision

In order to better understand visual perception, Friedhoff and Benzon [28] divide visual processing into a conscious and a preconscious domain. The conscious visual process involves thinking and analysis while the preconscious process is performed by the eye before the brain performs active processing. In visual perception, "The conscious mind receives information after it has been processed by the preconscious visual system" [29]. For example, analyzing patterns of data represented by numbers in a table is a conscious process. In contrast, recognizing trends in the same data represented by a plot or a graphic invokes a mainly preconscious process that is easier and faster than conscious processing.

Because the preconscious processes involve much less thinking and analysis, the visualization process becomes more effective when it relies more on the preconscious vision. Visual properties that are processed by preconscious vision can be used to highlight important image characteristics. Many visual properties, such as color, flicker, size, texture, width and brightness have been identified as being related to the

preconscious vision. These properties have been used to perform many preconscious tasks that include target detection, boundary detection and number counting [33]. To improve visualization efficiency, we need to reveal the important feature of a problem by allocating as much of the information processing as possible to the preconscious visual system. In the following sections, we will discuss issues related to human perception that may increase the share of preconscious processes. These issues include color perception, flicking of two images and other perception issues in visualization presentation (label, title etc.).

3.2.2 Color Perception

As a property of preconscious vision, color is one of the most powerful visual properties in visualization presentation. When using color to represent data, each value or range of values of data is transformed to be associated with a color. The correct use of color can be a great aid to the understanding of information in visualization presentation. However, in many instances, misuse of color can lead to serious misinterpretation of data. For example, the same data viewed as an image looks different depending upon both the color map and the transformation function (linear or logarithmic) employed to map them onto the color space.

The properties of color that are inherently distinguishable by the human eye are hue, brightness and saturation. Figure 3.2 is an example showing color bands of hue, brightness and saturation, respectively. This figure shows that hue is described by its wavelength: red at left end of the visible spectrum and violet on the other end. Brightness corresponds to how much light appears to be reflected from a surface in relation to nearby surfaces. No brightness will appear as black. Saturation represents the purity of color -- the amount of white mixed in with a pure color. If white is added to a given hue, saturation will be decreased. In other words, no saturation will appear as white. In this example, the pink color in the middle can be thought of as having the same hue as red but being less saturated.

Figure 3.2 Example of Hue, Brightness and Saturation

As discussed above, hue effectively determines the dominant wavelength of the reflected light from an image. It enables us to identify basic colors, such as blue, green, yellow, red and purple. Because hue is a retinal variable that can be perceived immediately and effortlessly by the human eye, hue differences are best used to differentiate between two items that have no inherent order; that is, objects that differ in kind and not amount are best represented by varying hue.

The rainbow color scale is the most commonly used scale [6]. In this hue-based colormap, the lowest value is mapped to blue, the highest value is mapped to red and the middle value is mapped to yellow. Yellow tends to attract the eye more than red and perceptually takes on a high value despite red's position at the top of the color map [29]. This is appropriate in applications where the location of middle values is of particular interest. However, such applications are not very common. More frequently the high or low values are of greatest interest, and middle values are of least interest. In such situations, a double-ended color map might be appropriate. A double-ended color map would map the middle value to some unobtrusive color (such as Grey) while mapping the high and low values to distinct bright colors. The major advantage of a double-ended scale is the clear visual classification of values as high, middle or low. Figure 3.3 shows an example of using a double-ended color map to show the family income of West Coast states. This figure divided values into two groups that can emphasize both extremes -- low and high of the data range [36].
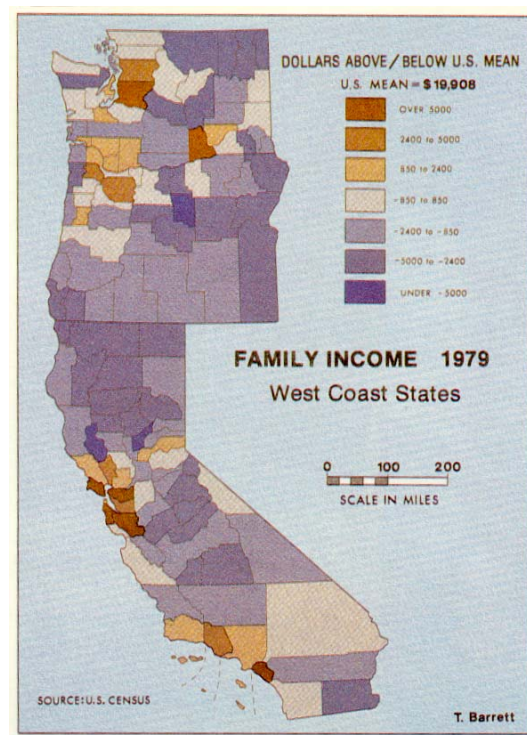

Figure 3.3 Example of Double-Ended Color Map [36].

The characteristics of the cones of the eye also impact the way hue should be used for visualization. The human eye has the least number of cones that are sensitive to blue so that humans are relatively insensitive to changes in blue [33]. These blue sensitive cones are also much more evenly distributed across the retina than the other cones. Therefore, blue is appropriate for displaying large areas or backgrounds but not for providing detailed illustrations. On the other hand, cones sensitive to red and green are larger in numbers and are more centrally located [33]. These two colors can be used to highlight small areas and more detailed information.

Unlike hue, differences in brightness do imply order. Brightness variation, thus, is one of the most intuitive and powerful ways to represent ordered data, like rainfall totals and traffic density. Figure 3.3 presents an illustration of the rate of glucose metabolism in two brain slices. The data of the two slices are mapped to two color scales: brightness and hue. Clearly the scale at the top of Figure 3.3, which is based on brightness, gives a better presentation of the information in the data.
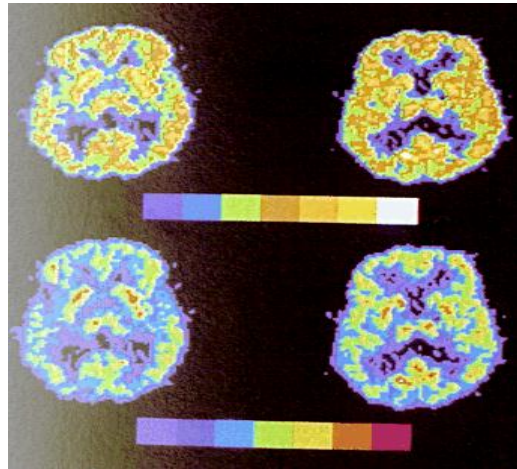
Figure 3.4 Rate of Glucose Metabolism In Two Brain Slices Using Two Color Scales
(Top Based On Brightness Contrast – Bottom Based On Hue Contrast)

The perceived brightness is not linearly proportional to reflectivity. Psychophysical experiments indicate that the perceived brightness increases approximately as the logarithm of the luminous flux, which is a measure of the actual reflected light. Figure 3.4 shows the diagram of relationship between perceived brightness and reflectance. A scale from 0 to 10 is used to represent perceived brightness. A doubling of the reflectance (or luminous flux) leads to an increase of about 1.5 units on this brightness scale. This phenomenon is important when mapping data to brightness contrast; care should be taken so that the brightness will be perceived linearly with the actual data that is mapped.

Studies also show that bright objects on a dark background look bigger than the same objects depicted with dark colors on a bright background [33]. This means small objects can be made more visible by making them brightly colored against a dark background.

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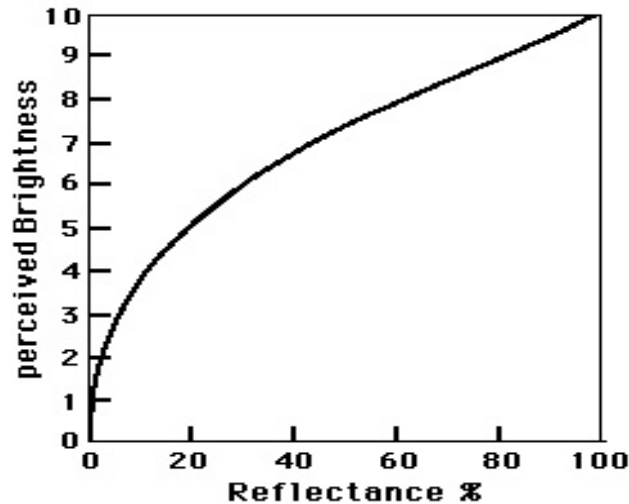
Figure 3.5 Relationship Between Reflectance and Brightness (Adapted from [36])

Based on Trumbo's research [36], there are some other considerations when selecting colors. Significantly different levels should be represented by distinguishable colors. In addition, a color and brightness should be chosen which contrasts most with the colors in the background for visual presentation.

The human eye can successfully discern as many as seven different hues or seven different brightness on a single display. If a visual display requires more classes than seven, other visual properties, such as texture or shape differences should be exploited. The third color property, saturation, can be used to describe how pure the color is. It refers to the dominance of hue in the color. Saturation is the least understood of the three properties of color. Saturation differences are the least discernable by the eye, and thus this property should be used sparingly for visual displays.

3.2.3 Comparing Two Images by Flicking

Simultaneously display of two or more images is a process quite frequently done visually by putting them side-by-side and visually comparing them with the same background locations. This is quite useful in comparing existing and proposed conditions at a transportation site. This process provokes conscious processes of analysis that involves comparing two images and finding differences between them. A better way to achieve this correlation is to show these two images one after the other during the presentation. This way, the correlation of the differences between these images is done automatically and is relatively easy to interpret by the visual system through preconscious processing.

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3.2.4   Other Perception Issues in Visualization Presentation

Change to Oblique

Photomontages, with aerial photographs as background images, are widely used for public presentation. Rather than using ground level photographs, it is considered that oblique aerial photography would offer a better medium for showing the impacts of the transportation projects on the locality, which are environmentally sensitive. Oblique photography has more of an aesthetic appeal. It is generally used for brochures, cards, wall display, and advertising. Smedes et al. [23] reported on the use of oblique photography for participation in land-use planning decisions and considered it to be extremely effective for informing lay persons of the need for action and visualizing the effects of different strategies.

Number and Shade

The representation of number, as physically measured on the surface of the graphics itself, should be directly proportional to the numerical quantities represented [18]. Varying shades of gray sometimes show varying quantities better than color because they have natural visual hierarchy. When shading is used, the lightest ("unfilled") regions should represent "less" and the darkest ("most filled") regions represent "more".

Title and Label

A title for each slide of presentation is necessary. The title should state clearly what is to be graphed or represented. It should be recognizable and should not be close enough to any line to be grouped perceptually with it. In addition, when presenting graphs or charts, each axis should be labeled. The labels should be placed closer to the axis they label than to anything else, ensuring that they will be grouped perceptually with the right axis. In addition, labels should be parallel to their axes. Clear, detailed, and thorough labeling should be used to defeat graphical distortion and ambiguity.

Chapter 4

SURVEY OF VISUALIZATION--STATE OF ART IN NEW ENGLAND

This chapter, separated into two parts, gives the results of the survey we conducted of the current state- of- the -art of visualization in the New England region. The first part of this chapter summarizes the result of the field trips to two consulting firms in New England and to one Department of Transportation (DOT). The second part presents the results of our mail-in surveys that we sent to all six New England DOTs. The format of this mail-in survey is based on a survey first conducted by the North Carolina DOT and the University of North Carolina Highway Safety Research Center in 1998.

4.1   Overview

We made field trips to two private companies and one governmental agency so that we could better understand the state- of –the- art practice of visualization. The site visited included Sasaki Associates, Inc (Sasaki) in Boston, MA, Wilber Smith Associates (Wilber Smith) in New Haven, CT and the Connecticut Department of Transportation. Sasaki is a multidisciplinary, international firm that integrates the disciplines of urban design and planning, landscape architecture, architecture, civil engineering and traffic analysis. In our estimation, Sasaki represents the high end in terms of the use of visualization in transportation.   Wilber Smith is an international consulting firm providing specialized planning, design and construction engineering inspection services for transportation. These site visits allowed us to conduct an in depth evaluation of the use of visualization in these organizations.

We also conducted mail-in surveys to all six New England DOTs (only five responses were received) to better understand the current technology as well as the immediate and future needs for visualization technologies in the DOTs.   These mail-in surveys complemented the site visits in providing comprehensive information on the use of visualization.

4.2   Field Survey

a.)   Sasaki Associates, Inc.

Sasaki Associates is located in Watertown, Massachusetts. It is an international design and consulting firm offering interdisciplinary design services to meet the requirement of each project for planning, landscape architecture, urban design, civil engineering and graphic design.

Sasaki has been using transportation visualization in selected projects for many years. Their urban designers are seeking to create a vision of civic form that integrates multiple elements such as public space, transportation, and individual buildings.

Advanced visualization products, such as animations, are widely used in this company. During one recent project - the design of the American World Trade Center in Puerto Rico (left), an intensive 3D model of roads, the new Tren Urbano rail system and adjacent landscape was built. An animation video with background sound was generated from the model. The video was saved in MPEG file format, and then linked as an object

in the PowerPoint presentation file so that one click can launch this file during the presentation. This project adopted the highest level of visualization techniques such as 3D modeling, rendering, and real time animation. The real time animations include walk- through, drive- through and fly -through. This kind of visualization project normally requires the longest time to produce and several professional 3D modeling personals. At Sasaki, several individuals are available in-house with extensive 3D modeling experience that provides the core skills required for this project. A typical 3D visualization process includes three steps: 1). Using AutoCAD to generate a 2D image. 2). Using freehand to format and edit the 2D image. 3). Using 3D Studio Viz to generate a 3D model.

Americas World Trade District, Puerto Rico

Because of the time constraints, budget and expertise required, 3D modeling is only used for very large projects at Sasaki. Other than animation, the corporation also uses a great deal of manual artists' concepts during the initial design stage. Their landscape architects report that those artists' concepts are cheaper and faster to produce than other visualization products (such as video and animation) and that artists' concepts may be the most suitable products to analyze and test design. In the initial design stage, many design concepts or alternatives are generated by manual drawing and rendering. After the design concepts are accepted by the client and the public, computer graphics and more complex visual products (such as video and animation) are generated for further evaluation and for public relationship applications.

El Paseo Del Canal, Puerto Rico

b.) Wilbur Smith Associates
Wilbur Smith Associates is an international transportation consulting firm that provides transportation planning, community planning and design. We believe the firm is representative of middle to high-grade level of visualization expertise for transportation firms in New England. Many of their projects involve a significant degree of pubic involvement. We visited their New Haven office in Connecticut. During the interview, they emphasized that visualization should not be considered an independent technique to solve specific transportation problems but should be integrated into the design process. They believe that the visualization product is very important to help the public understand the impact of the project.

Wilbur Smith's major visualization products are graphics on wall-mounted boards. The graphics include artist's rendering, composite image and GIS analysis. The software they use falls into two categories. One category includes typical transportation software used for design, planning and impact study including Microstation, Corsim, Freesim and TransCAD. The other category includes typical commercial graphic software including PhotoDraw and Photoshop. No 3D software is used in the New Haven office although they are used at other Wilbur Smith locations.

Image composite, also called photomontage, is widely used for visual impact study of projects at Wilbur Smith. The background photographs of image composite can be aerial photographs taken from a helicopter or just digital photos taken on the ground.

In the recent bus rapid transit (BRT) project in Hartford CT, a sequence of twenty new BRT station drawings were generated and mounted on display boards as presentation formats in order to evaluate the design of the BRT stations at the public meeting. An outside contractor produced these manually rendered artists' concepts. Figure 4.1 and Figure 4.2 are examples that show conceptual views of BRT stations. They provide visual perspectives of the "after" images of the BRT stations that help the public to understand the impact of the construction. The Wilbur Smith staff felt that these visual products were very helpful for decision-making on this project.

Figure 4.1 Conceptual View of Station

Figure 4.2 Aerial View of Station Concept

For the BRT project in Hartford, Wilbur Smith also used maps and GIS tools to visualize the impacts of the design. Figure 4.3 shows the BRT project map. ArcGIS software was used to identify all the bus station locations and bus route of the proposed BRT system. Figure 4.4 show the 2D GIS map of the BRT project. These maps were used to help the public understand the context of the project and potential impact of the construction.

Figure 4.3 Map for BRT project
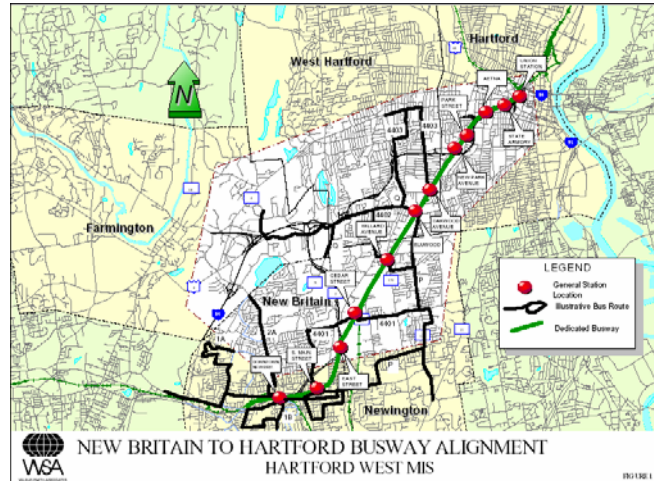
Figure 4.4 2D GIS map for BRT project

In Wilbur Smith, traffic simulation is widely used by their transportation designers to evaluate their design as well as to present the result to the public. Large transportation networks are modeled in CORSIM to simulate the traffic operations. Zoom command can be used to locate individual intersection or interchange. Figure 4.5 is a traffic simulation example developed in CORSIM. 3D traffic simulation software VISSIM is also used in the firm. Figure 4.6 is a traffic simulation of a roundabout developed in VISSIM.
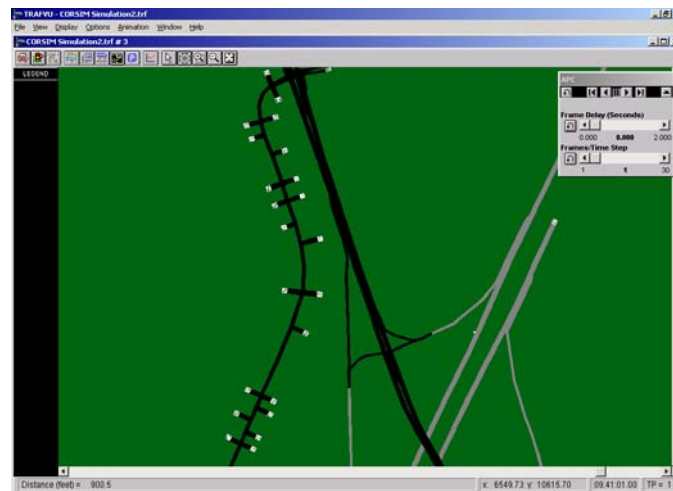
Figure 4.5 2D Traffic Simulation of a Network
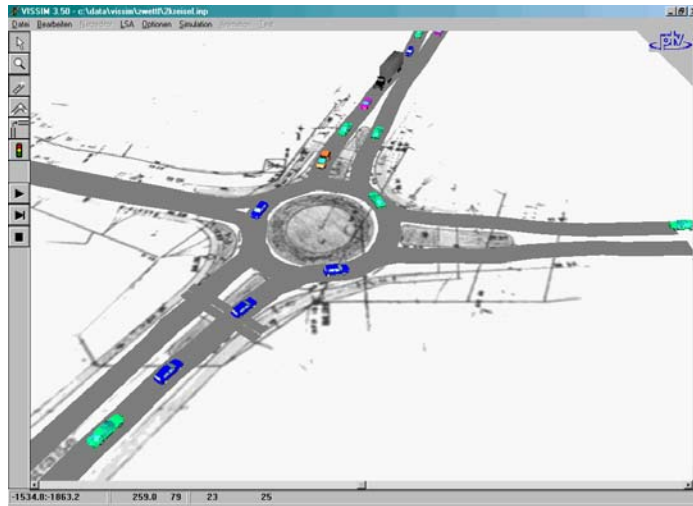
Figure 4.6 3D Traffic Simulation of a Roundabout

Wilbur Smith's decision to develop and use visualization products was driven by the increasing need for public participation during the design process. By using visualization techniques that rely more on realistic presentations than symbolic representation, the firm believes that public meetings have provided both more useful feedbacks on the design and improved public relations.

c.) Connecticut Department of Transportation

The Connecticut Department of Transportation (ConnDOT) has been using transportation visualization techniques for the past several years. Currently, their visualization personals are located in the bridge design unit. As with Wilbur Smith, image composite is the most frequently used visualization technique. Animation is scarcely used for public presentation.

During the interview, the visualization personal emphasized that good site photography is one of the most important elements in a successful composite image. The digital base photograph used for the composite image needs to be chosen with special attention to the audience and to the project issues being addressed. The camera position and setting (focus length, etc) should be carefully chosen to cover the design layout, specific right of way impacts and general aesthetic issues all in a single photograph.

Three major softwares are used for their visualization process. Microstation is used to construct 2D drawings or 3D models of the terrain for the proposed project. If the project is related to roadway or bridge design, Inroad is used to construct the horizontal and vertical alignments. Finally, PhotoShop is used to edit and retouch the final composite image.

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During one recent project, the Route 1 intersection improvement at Cedar Street, road widening, retaining wall, new sidewalk and landscape were proposed to improve the traffic movement and the surrounding environment. A detailed 3D model of the proposed retaining wall and sidewalk was developed in Microstation. After the rendered 3D model was overlaid on the background photograph, Adobe PhotoShop software was used to edit and retouch the overlaid image to seamlessly match the synthetic 3D model to the existing background. Before and after images for this project are shown in Figure 4.7. ConnDOT reported the results of the product were very encouraging, with most of the responses from the public indicating a high approval rating for the visual images over the simple plan drawing. The ConnDOT staff felt that this kind of product provides a powerful tool for evaluating the proposed alternatives.

Figure 4.7 Before and After Result for ConnDOT Project (Source: ConnDOT)

4.3   Mail-in Surveys

The objective of the mail-in surveys was to obtain a broader and more complete picture of the current "state -of –the- art" of visualization techniques, technologies and trends at the DOTs in New England. These surveys were conducted to determine the extent to which the DOTs of the New England States are currently using visualization technology, the best examples of visualization techniques being used, the types of hardware and software being used, and the most commonly used visualization products.

The paper and pencil survey form used in our mail-in survey was adopted from a survey developed jointly by the North Carolina DOT (NCDOT) and the UNC Highway Safety Research Center (HSRC). NCDOT and HSRC conducted their survey in December 1998 and received completed responses from twenty-seven states and the District of Columbia. A copy of the survey form is included in Appendix A of this thesis. The reason we requested permission from NCDOT/HSRC to use their survey for our study was that we felt it would be useful to compare the current state of the art in New England to the results from this earlier national survey in 1998.

The survey was mailed to the state DOT representatives on our research committee. The committee members were asked to pass the survey on to visualization persons in their department. Surveys were sent to all six states but one did not respond.

4.3.1 Survey Results

The survey consists of a total of twenty-eight questions. There are three formats for survey questions: multiple response choices, open-ended format to allow for more detailed responses and rating scales (1~5), to obtain the extent of judgment. After the five surveys were returned, we summarized these surveys and combined the twenty-eight questions into fifteen categories of response.

A detailed summary of these fifteen issues is provided as follows:
1.) To what extent is visualization being used at the state DOT level?
>   All five states that responded reported that they use visualization in communicating design concepts and design alternatives to the general public. Vermont indicated that it did not feel the results justified the costs, since traditional presentation methods are fully adequate and they lacked in-house expertise in visualization.

2.) Are visualization capabilities provided through in-house resources or via outside contractors and/or consultants?
>   One state reported having in-house visualization capabilities; two states reported using both in-house and contractor resources; while two states reported relying on consultant/contractors for visualization support. New Hampshire, which reported that it relies solely on consultant/contractors for visualization support, noted that it is currently in the process of developing in-house capability with dedicated personnel.

3.) How many people are directly involved with visualization support?
>   The three states, which reported having in-house capabilities indicated that, the size of their visualization support personnel was in the range of 1-3 individuals. Connecticut reported there were no dedicated personnel involved with visualization support.

4.) What skill levels do the visualization support personnel have?
>   Of the three states having in-house visualization resources, one reported the highest level of technical skill is CAD Draftsman. The other two indicated 3D Database Modelers (3D Microstation, InRoads) was the highest skill level available.

5.. Where have these individuals been recruited and can state DOT' salary scales retain individuals with visualization skills?

Of the three states with in-house visualization support capabilities, all three indicated that dedicated visualization personnel had been recruited from within the DOT itself. Two DOTs believed that current salary scales within their DOT were sufficient to retain these individuals. One DOT stated current DOT salary scales were not sufficient to retain qualified individuals.

6.) Where are visualization support units located organizationally within states?

Connecticut stated having no separate visualization unit: the visualization personnel are located in Bridge Design Unit. New Hampshire indicated that the visualization support unit was within the service bureau and administration support. Vermont has no visualization unit and their visualization has been performed from CAD support unit. Maine indicated that the visualization unit was located in the Program Services and Survey Section. The results illustrated that organizationally; visualization lacks a consistent home, as was the case in the previous survey by NCDOT and HSRC.

7.) What are the hardware and software resources currently being used by state DOTs?

All DOTs reported using Personal Computer (at the Pentium level) operating in Windows NT environment. Large memory (e.g. 256 Mb Ram) is commonplace. All report visualization capabilities are based on Microstation CAD platform. Adobe PhotoShop is used as a core capability for most of these states. It is used extensively in the development of the composite image products. EaglePoint and InRoads are also used to construct 3D model for roadway design.

8.) Are visualization support capabilities mostly for public involvement or for design?

All states reported that more than 60 percent of visualization applications were for the purpose of public involvement. Of these, three reported more than 90 percent. Vermont DOT and New Hampshire DOT reported that 100 percent of their visualization work is performed in direct support of the public involvement process. In other words, these DOTs are not routinely using visualization for design.

9.) What is the most important factor influencing the decision to use visualization?

The importance level of each factor was on a scale from 1 to 5 where "1" represented "never a factor" and "5" represented "always a factor". The factor, which obtained the highest rating (5), was "the department desire to communicate more effectively with the public" and the "controversial nature of the project." Next in importance 4) was "the belief that visualization will increase the likelihood of public consensus." Of intermediate importance (3) was "the belief that visualization benefits outweigh the costs/" Factors reported as 'almost never' (2) being a factor were 1) the belief that in the long run project costs will be less if visualization is used, and 2) the belief that in the long run visualization improves the 'quality' of the final product.

10.) What is the perceived ability of state DOTs using visualization to deal with scope of services, methods and treatments available, and cost?

On a scale from 1 to 10 where '1' represented "No Confidence" and '10' represented "Extremely Confident", these states reported an intermediate level of confidence in these areas. New Hampshire reported four; Connecticut reported seven; Vermont and Maine reported eight and Rhode Island nine.

11.) What types of visualization applications are the most frequently used and which is the least frequently used?

> All five state DOTs reported that their application of visualization was limited to photo composites for the most part. No state DOTs made regular use of animation in their public presentations. Regarding animation, two state DOTs reported that they had no "official position" on the use of animation, although two other state DOTs reported they anticipated an increase in the use of animation for future projects. Four state DOTs questioned whether the benefit of animation is worth the time and labor involved to do it, although two state DOTs believed that animation can be effective in conveying operational concepts.

12.) What form of visualization products is most often used?

> Large, wall-mounted display boards continue to be the most frequently used format for presentation. Projection using laptop and LCD-type projector is the second most frequently used format. Rhode Island reported using videotape presentation methods 10 percent of all the visualization products. New Hampshire reported using CD-ROM as a presentation method 10 percent of the time. Connecticut was the only state reported using Internet web page as a presentation method.

13.) To what extent are DOTs able to integrate CAD, 3D/4D models, GIS data in producing visualization products?

> The answer to this question from the DOTs varied. Maine and Rhode Island reported being able to achieve effective integration of different spatial data sources with little difficulty. Vermont indicated moderate difficulty while Connecticut reported great difficulty in integrating different data to produce visualization products. New Hampshire responded that they had no capability to integrate spatial data.

14.) Does DOT utilize visualization in evaluation of environmental impacts?

> All state DOTs utilized visualization in evaluation of environmental impacts. GIS (e.g. Arcview, ArcInfo) continues to be used as a major tool to relate different spatial data.

15.) Does DOT have a 'vision' to ultimately integrate visualization into design process?

> No state DOTs gave any indication of a "plan" or "vision" for how the visualization might be integrated into the overall DOT design process, except from the standpoint of its present use for public involvement.

4.3.2 Summary

Our survey and the previous survey conducted by Hughes [22] suggested that the status of visualization has not changed much during the three-year period between these two surveys. The two surveys have two major common findings. First, image composites that are presented in traditional wall-mounted 'board' type displays continue to dominate in visualization presentation. Although animation is considered to be important, it is not widely used. Second, with respect to the use of visualization for public involvement and for design, most state DOTs perceive visualization as more of a tool for facilitating communication in the public involvement process. Visualization is still not fully integrated into design process to provide design guidance.

Comparing our results with the Hughes' surveys mentioned above, there are several differences. The first difference is the in-house capabilities. The in-house capabilities of New England DOTs are in the range of 1-3 individuals. From the Hughes' survey, half of the DOTs who reported having in-house capabilities indicated the visualization support group are 1-3 individuals and the other half indicated 3-5 individuals. This indicates that the New England DOTs have less in-house capabilities than the average of those in the previous survey. This may be due to the relatively small size of the New England DOTs.

The second difference is in the use of video as a visualization product. In Hughs' survey, the use of video as a means of presenting the products of visualization was reported to be the second most often used format. Conversely, in our survey, projection using laptop and LCD-type projector is the second most frequently used format. We believe that the advancement of computer and electronic technology is the reason for this change.

The final difference is the skill level of visualization personnel. New England DOTs reported a higher level of skill than was reported in the previous survey. Three out of five New England DOTs indicated having 3D Database Modelers while only 6 out of 27 states reported having 3D Database Modelers in the Hughes' survey. This may again be due to the fact that our survey was conducted three years later. Computer graphic technology has developed so fast that the cost has dramatically decreased for 3D software and they are easier to use than ever before.

Chapter 5

DETAILS OF TECHNOLOGY AND PRODUCTS

There is currently no standard approach for characterizing visualization technologies. In 1996, Landphair [8] suggested the following five categories of visualization technology: electronic photography, video, image composite, video overlay and animation. More recently, Keiron Bailey suggested categorizing visualization technology according to model type. The three classes of models he considered were 2D model, 3D model and virtual reality model [26]. In addition to the list of technology above, geographic information system and traffic simulation have attracted much attention for visualization in transportation [3, 24].

Therefore, based on the literature and our understanding of current trends, we have identified the following seven major categories of the visualization techniques that are currently used in the transportation industry: artist concept and rendering, image composite, video overlay, computer animation, video, geographic information system and traffic simulation. Virtual reality is not included in our list, because Landphair reported that although this technology is evolving rapidly, there is no evidence of effective implementation other than in areas of flight simulation and pilot training.

In this chapter, we will present a detailed description of each technique and the related visualization products that can be used in the public involvement process. Then, a comparison of these techniques in terms of cost, development time, visual realism and software requirements will be provided.

5.1   Artist's Concept and Rendering

5.1.1   Overview

Artist's concept and rendering is a specialized technique that is used to illustrate design concepts. It can be produced manually or through computer software. Manually produced artist's concept and rendering is a traditional technique which is produced using pen and ink, charcoal, watercolors and sometimes oil paint to sketch, draw or paint design concepts.

A modern extension of this concept is the use of the computer to generate an artist's concept. Computer generated artist's concept and rendering are produced by painting new elements on a background image of the existing context of the project. The background images can be converted from photographs by using scanners. They can also be imported by image capture board as a single frame from standard video. Image capture board converts the analog video frame to the digital image that is used in the computer paint software.

5.1.2   Procedure and Products

The procedure to produce traditional manual products for artist's concept and rendering are pretty straightforward, using pen and color for a professional with adequate training and skill. However, the production of a traditional artist's concept does require the skill of a highly trained artist. Figure 5.1 shows an example of an artist's concept bird's eye view of a new construction. The bird's eye view provides a vision of the proposed design. Figure 5.2 shows an example of manual artist's concept of a mixed- use street design.

Figure 5.1 Artist's Concept Bird's Eye View (Source: New York DOT)

Figure 5.2 Artist's Concept of Specific Design (Source: New York DOT)

2D computer-based artist's concept and rendering are created by using image-painting and editing software (such as PhotoShop, CorelDraw).   This computer-graphics technology is pixel-based [14]. The draftsman can see, and modify, individual pixels and

so has a high degree of control over fine details. Computer-based artist's concept and rendering is similar in concept to the traditional manual renderings with the added benefit in some cases of utilizing real photography as a background for realism. In addition, it provides great freedom of experimentation because images can be made quickly and modified endlessly.

Image painting and editing software both have an interface that provides a palette of artist's tools that range from freehand line drawing to air-brush painting and texturing. In addition to that, image-editing software provides features such as color manipulation and image processing. For example, image processing consists of a diverse set of tools that include sharpening and blurring, brightness and contrast control, hue control, and others. The combination of scanning and image painting and editing technologies makes it very easy to modify base images and to create near-photographic quality images [2]. Figure 5.3 shows an example of a proposed sidewalk design that is produced by using image painting and editing software. The top image is the background image that was used in the artist's concept.

Artist's concept and rendering can be also generated using commercial computer software, based on a 3D model. Figure 5.4 is an example of computer rendering of new interchange construction based on a 3D model. The process for making these 3-D artist's concepts are similar to the process for 3D animation. The difference is that in a 3D artist's concept, only a single still frame of the animation is used. Editing and retouching can be performed after the 3D rendering is finished.

Figure 5.3 2D Artist's Concept (Source: Earth Tech. INC.)

Figure 5.4 3D Artist's Concept (Source: Earth Tech. INC.)

5.1.3 Software Requirement

Software requirement for producing visualization products will be reviewed separately for each product. The major source of information that we have used is a survey conducted by Rizzo from Maine DOT in 2000. He collected software usage information for visualization from fifty state DOTs and many industrial companies. We supplemented the information from Rizzo's survey with a review of web sites on visualization design from selected states.

The most frequently used 2D image painting and editing software for computer-based artist's concept and rendering in DOTs is PhotoShop (Adobe®). Although CorelDraw® is not as ubiquitous as Adobe PhotoShop, it was also reported in use in some DOTs including North Dakota's.

5.1.4 Benefits and Limitations

The result of artist's concept and rendering can be very effective in communicating design concepts to the public. However, it is important to recognize that the manipulated images typically used for rendering are not based on geometrically accurate elements and the resulting image may not truly reflect the actual outcome [6]. This might not be a disadvantage at the initial design stage. Because of the fuzziness of the artist's concept, people who observe them are likely paying more attention to the design concept that is important for the initial design stage. Too much design detail and high accuracy of the design would distract people and may cause misunderstanding; people think it is a finished product, rather than a product that is subject to review.

5.2   Image Composite /Photomontage

5.2.1   Overview

An image composite (or photomontage) is one of the most common and powerful forms of visualization technology. All five New England states reported using image composite extensively in public involvement. It combines two images that have the same viewing location, as defined by coordinates and perspective parameters. Composite static images most frequently involve using photographic or video based images for which the camera location and settings (focal length etc.) are already known [2]. These images are then overlaid with a 3D computer image to generate a composite image.

The important point is that this 3D image is designed to be geometrically and dimensionally accurate. In other words, this technique is object-based, rather than pixel-based as in artist's concept and rendering. With an object-based system, the computer is used to represent the 3-D geometry of objects and to simulate light and other phenomena. The emphasis for image composites is on geometrically accurate representation, rather than on getting a conceptual view, as in computer-generated artist's concept and rendering.

5.2.2   Procedure and Products

A composite image begins with a digital image scanned from photographic or video background with known geometric location and camera setting. Then a 3D model is generated for the new transportation elements, in which the perspective of the 3D model matches the coordinates of the camera location from which the digital image is used. The new transportation elements might be a new bridge, addition of new lanes, landscape development or similar elements. Once the perspective of the wireframe of the 3D model matches that of the digitized photograph, the 3D model can then be rendered by computer software that includes accurate lighting, colors and textures (such as grass, concrete, wood etc.). These two images, base image and computer generated image are then overlaid together into a single 2D raster image. Finally, this image is retouched and adjusted through 2D image edit software to blend the 3D model more naturally into the background image.

The final product is a very accurate representation of the proposed change with a background of the actual photograph showing existing conditions. Figure 5.5 is an example of using 3D model and rendering for a proposed roadway improvement. The photograph to the left shows the existing conditions. The image to the right is a composite image that combines the left photograph and a computer generated roadway based on 3D model.

The production of a composite image is more time- intensive than an artist's concept, since image composite requires building accurate 3D model [2]. On the other hand, if several different images of a site are required, developing 3D models for the composite

images can actually be faster than an artist concept. This is because the 3D computer model only has to be constructed once. The same model can be used again and again to generate the composite image for each of the selected views of the study site. The high realism and accuracy make image composite the most desirable method for many transportation visualization presentations.

Figure 5.5 Image Composite using 3D Model (Source: NCDOT)

5.2.3   Software Requirement

The software for producing image composite can be divided into three categories. The first category is the CAD system software that is used for drafting and modeling. The two commonly used software for this purpose include Microstation and AutoCAD. These two softwares provide the drafting platform; Rizzo's survey shows that most DOTs reported that their visualization designs are based on Microstation; only four states reported using AutoCAD for design. Our survey shows that all five New England DOTs that responded use Microstation.

The second software category is the civil design software add-on to the CAD system. This software performs roadway design, earthwork computation, surveying and digital terrain modeling. The most frequently used software in this category is InRoads, Geopak (Bentley®), Eagle Point and Caice. Among these four, Geopak appeared to be the most popular. Recently, VDOT became the 20th state DOT to adopt GEOPAK software [38]. In fact, VDOT has conducted formal evaluations of available civil software offerings over many months. It feels that GEOPAK's capabilities for handling bridge design and geotechnical evaluation were critical to its selection. MXRoad (Infrasoft®) was reported to be used in the Maine DOT, New Hampshire DOT and Indiana DOT. Michigan and Virginia DOT reported the use of Igrds (AASHTO), but Michigan is preparing to upgrade to Caice.

The third category of software is that used for final editing and retouching. As with artist's concept, PhotoShop (Adobe®) is the predominant software used for this purpose. But some states also uses CorelDraw.

5.2.4 Benefits and Limitations

An image composite is more accurate than an artist's concept because it represents geometrically correct features of the new construction. Although the process of construction is more complex than a computer generated artist's concept, it is still inexpensive and not very time- consuming compared to other more advanced technologies. Despite the advantages of composite images, it has some limitations. The major drawback is its static nature. A composite image, working alone, gives only a single view that may bias opinion concerning other important elements of the transportation infrastructure [13]. In general, the best way to view a proposed transportation modification is to travel on it. Some specific impacts of the transportation such as parking, building frontage, signage and sight distance can't be fully presented through the composite image. Furthermore, because any public meeting is composed of many individuals with specific concerns and questions, a few selected composite images are unlikely to fully address all of their concerns.

5.3   Video Overlay

5.3.1 Overview

The video overlay technique is closely related to composite image. Like a composite image, a video overlay uses a background image and a foreground image (from a model) to place a new project within an existing context. The foreground image is generated in a similar manner as for a composite image in that a model must be developed. The major difference is in the background image. Instead of a static still image, a video sequence is used to provide the background in a video overlay.

5.3.2 Procedure and Products

There are two ways to produce video overlay: digitizing the video sequence or using specialized graphics boards [12]. In the first method, the video sequence with the background context is digitized as a series of still frames. Then a digital composting process can be used to overlay the foreground image frame by frame. Care must be taken in this process to register the foreground image in exactly the same location since any misalignment will cause the foreground image to seem to vibrate when the sequence is played back [2].

The second method is based on displaying the video sequence while simultaneously displaying a foreground image, by using specialized graphic boards and recording both to a video tape recorder. The advantage of this second method is the speed and ease of production with minimal resources. A disadvantage of the second method is that

individual frames cannot be retouched after recording due to its analog format. Figure 5.6 is an example of three sequent frames of a video overlay.

Figure 5.6 Frames of Video Overlay (Source: NCDOT)

5.3.3   Software Requirement

The software to produce video overlay will be discussed in 5.4.3 in conjunction with the discussion of the software for video editing and production since, video overlay and video technology share the same software resources.

5.3.4   Benefits and Limitations

Video overlay adds realism through real-time moving vehicles and other elements in the background image. However, in video overlay, the view is generally limited to a single viewpoint in which the camera remains stationary with a fixed view and focal length. Because the overlaying of the foreground image over the video sequence is difficult to align, any change in the perspective of the background image due to change in the camera settings necessarily would cause a change in the perspective of the synthetic image. Although these changes can be smoothly matched by the synthetic camera, frame-by-frame, variations in the speed of the zoom or pan of the camera makes the matching of these parameters very difficult [3].

5.4   Video

5.4.1   Overview

Video is the standard medium for recording motion and events of historical or temporal interest. This media is superior for demonstrating existing conditions and illustrating day-to-day conditions in a transportation corridor.

5.4.2   Procedure and Products

Analog format of video technology is available in VHS, SVHS, 8mm or similar commercial and professional grades of equipment. Current equipment provides ease of recording with automatic exposure and from 1 to 3 hours per tape.   The editing equipment is also available for editing and adding special effects for specific applications. Figure 5.7 is a single frame of the video to display the traffic situation on a freeway.

Figure 5.7 Single frame of Video (Source: ODOT)

Videos can also be converted and stored in a digital format. This is becoming more widely used with the advance in computer technology. Instead of bringing a video player and tapes for presentation, the digital video can be played by commercial video play software installed on a laptop computer. Digital video is produced by digitizing a video clip from a camcorder and converting it into a digital computer-readable file, such as movie or MPEG.

There are three key variables for digital video format: compression, frame rate and resolution. For compression, there are a variety of digital file compression methods that can reduce the storage space required by digital videos. There is typically a tradeoff between visual quality and file size. For frame rate, this involves a tradeoff between the smoothness of motion portrayed in a shot and the amount of space or memory available on the computer.   Frame rate is typically measured as frames per second (fps). Resolution describes the size of the image on the screen. It is measured as horizontal pixels times vertical pixels. Resolution involves a tradeoff between the amount of detail in a shot and the amount of space or memory available on the computer.

5.4.3   Software Requirement

Premiere (Adobe®) is the most frequently used video editing software used for video products (including video overlay and video). It provides features such as mixing audio,

adding title, applying effects and creating composite. It also provides a direct interface to import digital video files from camcorder that makes video editing fast and precise. As a result, there's no need to install additional hardware such as a video capture card.

5.4.4   Benefits and Limitations

The ability to record motion is the primary advantage of video. Video offers the advantage of flexibility and ease of use, but it is limited to recording existing events. The image quality, i.e. color and clarity of the image will vary widely with the quality of the equipment used. In addition, since it can only record existing conditions, it cannot be used to visualize the future.

5.5   Computer Animation

5.5.1   Overview

Animation is a sequence of images that when played at specific speeds (15 to 30 frames/second) will produce the illusion of motion. Different from video overlay, animation is a completely synthetic image, based on a mathematical modeling of all components in the scene. This would include transportation features, topography, and the surrounding context at varying levels of detail depending on the complexity of the 3D model. Based on the viewpoints and paths of interest, a "camera" can be positioned and moved along a specified path within the model. Three major products: walk-through, drive-through and fly-over are frequently used in animation.

5.5.2   Procedure and Products

This technology is the most demanding of computing and video resources, and it normally requires a three-step sequence to produce a series of images [6]. First a full 3D description of the study location must be constructed. This is usually done in a CAD system that has 3D capabilities (such as AutoCAD or Microstation). Next a set of instructions must be developed to guide the movement of the camera through the model. When this is completed, the information is transferred to a rendering module where the colors, surface materials, shadows, reflections, light sources and other effects are specified and the images are created. The level of detail in the final images is directly related to the complexity of the information in the 3D model and the sophistication of the effects specified in the rendering module.

Figure 5.8 is an animation frame showing the drive through for the proposed interchange project by using computer animation.
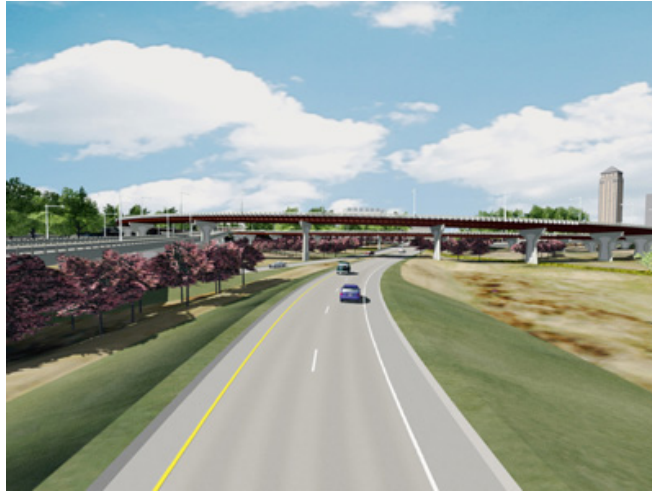
Figure 5.8 Single Frame of Computer Animation (Source: Earth Tech. INC.)

5.5.3   Software Requirement

Modelview (Intergraph), which is based on the Microstation platform, is used to view, manipulate, render, and animate 3D models in DOTs with 3D capabilities. It directly supports MicroStation and AutoCAD data formats, as well as any other design package that can output IGDS or .dwg files. Many firms and companies also choose 3D studio Max (based on the AutoCAD platform) for the same task as Modelview.

5.5.4   Benefits and Limitations

Computer animation is the best way to communicate the full scope, extent and detail of a transportation project [2]. No other technology can integrate the parts to the whole as effectively as animation. For example, complex issues such as operation of a multi-level interchange are most easily understood when traffic patterns are seen in relationship to the interchange in 3D space.

In addition, it is the most flexible means of viewing a proposed design in a 3D environment over time. It provides complete control of the camera and viewing conditions so that the designer can see a feature from any desired point of view for the proposed design.

However, developing the model database is very labor intensive, and any addition to the level of detail required in a scene results in near exponential increases in the time requirements for input and computing. In short, animation is the most expensive visualization option, requiring high-level equipment and a well-trained specialized visualization staff.

Computer animation has had limited implementation in the transportation industry. Of the firms that we surveyed, Sasaki Associates, Inc., a Landscape-Architecture firm, used animation frequently in large design project. Our mail-in surveys showed that none of the New England state's DOTs made regular use of animation in their public presentations. Many transportation professionals have also been slow in embracing this technique. Most firms and organizations do not have designated personnel with the necessary skills and training to be proficient at creating computer animation sequences.

5.6 GIS for Transportation

5.6.1 Overview

Geographic analysis is increasingly a key element in decision-making in the transportation industry. Application of this technique can be found in many aspects of transportation such as site selection, environmental impact and traffic analysis. GIS integrates two types of closely related databases: spatial (positional) and attribute (descriptive). The spatial database describes the distribution of things upon the surface of the earth (including transportation components). The attribute database contains information about the characteristics of the spatial features. The attribute database can include many different sources of information for analysis such as traffic counts, number of accidents or type of traffic signs. GIS provides a bridge allowing the visual display of the attribute information on the spatial maps.

Today, many transportation agencies use GIS for inventory and data presentation. Many studies have suggested the wider utility of GIS in the context of transportation forecasting and scenario analysis. GIS is more effective for visualization of large areas and attribute-related analysis, while CAD and traditional visualization are important for more detail design and ground level views [22]. Jan [9] pointed out that by using GIS technology, the pubic has a chance to experience the possible effects of the implementation of various transportation construction plans and thereby give their option on the best alternative. Player [22] also used GIS to visualize and analyze site data to expedite the site investigation for transportation projects.

5.6.2 Procedure and Products

2D data used in CAD and GIS are exchangeable and the technologies are becoming more and more similar [24]. A typical GIS layer can be overlaid on CAD roadway designs through a GIS-based software (such as ArcView). GIS layers for site properties and environmental features, when combined with CAD drawing, help to explain some critical questions such as relocation of property owners and wetland mitigation. Figure 5.9 is an example of using 2D model in GIS to analysis potential environmental impacts of a proposed rail corridor.
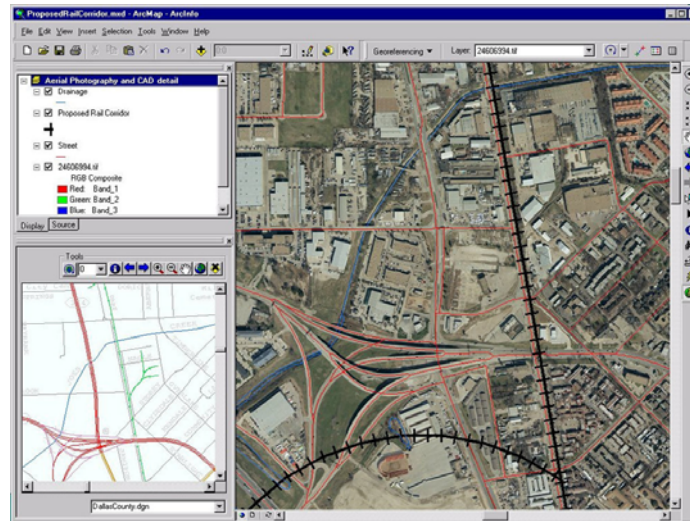
Figure 5.9 GIS using 2D model (Source: ESRI)

5.6.3   Software Requirement

Probably the most popular GIS softwares in use are ArcView and ARC/INFO (ESRI), especially in government organizations [34]. These are GIS analysis software for sharing and processing geographic data. ArcView is easier to use than ARC/INFO and is used to view ARC/INFO data and perform simple spatial analysis. MapInfo is a peer software to ARC/INFO and is used widely on desktop computers. It can share the data with ARC/INFO and vice versa. Maptitude and TransCAD are products of Caliper Cooperation. Maptitude is GIS software for general desktop mapping, while TransCAD is designed specifically for transportation applications.

5.6.4   Benefits and Limitations

Because of the spatial nature of most transportation data, transportation professionals have found GIS to be a powerful tool to construct and analyze transportation networks, to conduct impact assessment of transportation facilities, and to integrate transportation and land use planning.

However, the use of GIS in transportation requires expensive GIS software and extensive user training. Therefore the use of GIS in transportation is somewhat limited to a small number of transportation professionals who have the resources and expertise. Our survey shows that only two state DOTs in New England have the capability to integrate different spatial data source using GIS software.

5.7   Traffic Simulation

5.7.1   Overview

The effective presentation of traffic impacts to the public is an essential part of the approval process for proposed transportation changes. Many transportation agencies use the results of a transportation simulation program as a basic data source that is combined with corresponding visual aids to create technically effective and more appealing presentations.

Traffic simulation models are mainly used to investigate operational effects of the geometric design of the proposed project. They can be used to analyze route location, alternative planning and support decision- making process. However, traffic simulation requires extensive manual labor to input the different kinds of traffic data into simulation programs.

5.7.2   Procedure and Products

Traffic simulation can be implemented in either 2D or 3D models. Figure 5.10 shows an example of traffic simulation of the proposed roadway improvement based on 2D model. The background image is imported from a digital photograph. The proposed roadway improvement (including intersection design, number of lanes etc.) is overlaid on the background image. Traffic simulation can reflect the actual traffic volumes, traffic mixture (cars, trucks, buses, etc.), roadway geometry, and signal control plan used in the design.

Traffic simulation can also be implemented in 3-D as shown in Figure 5.11. In addition to features of 2-D traffic simulation, background detail such as sky, trees, building shadows, reflections, etc. can be added for life-like realism. 3-D traffic simulation can include not only views of traffic from any camera angle, but also aerial views and driver perspectives through the window of any vehicle.

5.7.3   Software Requirement

There are four major traffic simulation software used in transportation agencies. They are CORSIM (CORridor SIMulation), VISSIM (VISual SIMulation), INTERGRATION and Synchro/SimTraffic. CORSIM is used to model arterials and freeways. They can be implemented for traffic impact analyses; roundabout analyses and interchanges justification studies. However, they do not include traffic optimization tool and 3D graphical output. VISSIM was developed in Germany and it has transit (light rail and bus) functionality and 3D graphical output. INTEGRATION was developed in Canada. It uses Origin-Destination (OD) Matrix to generate traffic. It has traffic signal

optimization tool and dynamic traffic assignment function. Synchro/Simtraffic is 2D traffic simulation software. It performs similar simulation as CORSIM for roadways and intersections. However, it provides simple and quick data entry Graphic User Interface (GUI). Signal phase, timing data can be input easily through man machine interface. In CORSIM, the simulation data (signal phase, timing) have to be typed in a text file and be imported into the software.

Figure 5.10 Traffic Simulation by Using 2D Model (Source: Trafficware)

Figure 5.11 Traffic Simulation by Using 3D Simulation (Source: KLD Associate, INC)

5.7.4 Benefits and Limitations

Traffic simulation technologies are especially useful at evaluating traffic operations and its impact on a proposed project. This steadily improving computer technology has become more powerful and accurate in recent years. The results of traffic simulation provide many valuable traffic characteristics (such as queue length, fuel and emission calculation etc.) for proposed projects that can be used as evaluation criteria for alternatives. Traffic simulation also provides optimization tool to optimize the traffic signal timing in a proposed traffic network.

The moving cars in 2-D traffic simulation are frequently modeled simply as a flat rectangular that is not very appealing to the public. In addition, some parameters (such as signal phase, intersection delays) are still difficult for the public to understand. For this reason, traffic simulation as a visualization tool is widely used in the design process and has limited success for public presentation.

5.8 Products Comparison

5.8.1 Overview

This section addresses the factors that contribute to the effectiveness of the visualization products discussed in the previous sections. These factors include visual realism, geometric accuracy, production effort, training and cost. The objective is to better understand these factors, and the results of comparison can be used as guidelines in selecting appropriate techniques for a given situation.

5.8.2 Characteristics of Visualization Technology

Table 5.1 gives a comparison of the important characteristics related to the visualization technologies. Visual realism indicates the effort that is required to give an image a photo-realistic appearance. It involves specification of material characteristics such as color, reflection and texture. Geometric accuracy is the ability of the technology to reproduce detail that is mathematically accurate for the proposed design. Production effort measures the length of time required to produce an image or sequence of images.

With still images, which include artist's concept and image composite, realism typically means photorealism. Artist's concept and rendering has relatively low on visual realism because the manipulated images of artist's concept and rendering are not based on geometrically accurate elements. This is important to remember when images are used for public presentations. Composite image performs well in areas of visual realism primarily because the high level of realism is retained for the background images. In composite images, only the new transportation elements must be modeled. More efforts

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can be expended in improving the realism of the new elements as opposed to every element in the drawing as for artist's concept.

Visualization Technique	Visual Realism	Geometric Accuracy	Production Effort	Cost Effectiveness	Output Format
Artist's Concept	Low-Med	Low	Moderate	High	Slide
Image Composite	High	Low-High	Moderate	High	Slide
Video Overlay	Med-High	Low-High	Moderate	High	Video
Video	Med-High	Low-High	Moderate	High	Video
Computer Animation	Low-Med	High	High	Low	Video
GIS	High	High	Moderate	Moderate	Slide
Traffic Simulation	Low-Med	Low-Med	Moderate	Moderate	Video

Table 5.1 Characteristics of Visualization Techniques

For video output products, video overlay and video do not perform well in the area of visual realism and geometric accuracy because of their limited resolution (720 x 486) of video format. Single images extracted from video frames do not translate well into other formats because of their low resolution. For example, image composite generally requires higher resolution of regular format of video overlay. Production time does not vary significantly from composite image for similarly sized projects.

Animation has the highest accuracy since it requires accurate camera positioning and created views that are based upon mathematically generated perspectives. It suffers primarily from the difficulty in achieving visual realism and in terms of production time. The definition of material characteristics in animation can be very time- consuming [2]. The time needed to spend on modeling and rendering make this technology inappropriate when short production times are required. However, animation performs very well in the area of flexibility since it can provide unlimited flexibility in camera placement and image format.

GIS provides high visual realism primarily because it uses the real background image of the proposed project. Due to the intrinsic feature of GIS, the geometric accuracy of typical GIS visualization products is also high. Production effort and cost- effectiveness is moderate.

2D traffic simulation, using CAD drawing or aerial photograph as background image, can reach a medium level of visual realism. The loss of realism compared to image composite is due to the synthetic moving vehicles and rudimentary modeling of geometric roadway features (such as intersection, median) that are typically generated by traffic simulation software. Visualization products based on 3D traffic simulation in

general perform even worse than 2D products. This is due to the relatively simple 3D modeling in the traffic simulation software compared to 3D animation software. However, the software has been improving steadily and it is more effective at presenting traffic patterns to the public than 2D software. The output of the traffic simulation is video and it has a moderate level cost effectiveness.

5.8.3 Training and Production Time

Table 5.2 indicates typical training times that might be needed for an individual to become productive using visualization technology. The numbers in the table are results of the combination of Landphair [13] and our experience. These times are estimated times because they can vary greatly depending on the experience and education background of an individual trainee. These training times are evaluated at three levels of proficiency: novice, intermediate and expert level. These values assume the trainee has a general familiarity with computer technology and transportation engineering. Workshops and short classes are available from many software vendors that can help keep these times at a minimum. Among visualization techniques, image composite and video are probably quickest to learn while computer animation requires the longest training time. Manual artist's concept and GIS require extensive training since they are two professions that require much theoretical knowledge. Other techniques, such as traffic simulation, video overlay and videos require an intermediate level of training. It is important to note that each technology requires extensive training to reach experienced skill level.

Table 5.3 shows typical develop time for visualization technologies. This table is a combination of the Larson's result [12], our survey results and our experiences. Visualization project is categorized into three levels: simple, intermediate and complex. For manual artist' concept, the develop time is based on a single image. Develop time for image composite is based on a project that includes constructing a 3D model and using this 3D model to generate several composite images from different perspectives.

The production time of video overlay does not vary significantly from image composite for similarly a sized project [12]. Video production includes recording time and video editing time. Video editing may require adding text, sound to the recorded video. Video production is less time- consuming than video overlay.
Development of a computer animation for a project is the most time- consuming of all the available techniques. Develop time includes 3D modeling and rendering. The highest levels of development time are associated with the use of high fidelity, real time 3-D simulation. Typically 3D modeling requires more than half of total develop time.

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Visualization Technique	Novice Level	Intermediate Level	Expert Level
Manual Artist's Concept	4 days	1 mo.	6 mo.
Image Composite	1 day	1 wk.	3 mo.
Video Overlay	5 hrs.	2 wks.	4 mo.
Computer Animation	1 mo.	6 mo.	1 yr.
Video	5 hrs.	2 wk.	4 mo.
GIS	2 wks.	1 mo.	6 mo.
Traffic Simulation	4 days	2 wks.	3 mo.

Table 5.2 Typical Training Time for Different Skill Levels

Visualization Technique	Simple	Intermediate	Complex
Manual Artist Concept (per image)	1 day	3 days	1 wk.
Image Composite	1 wks	3 wks	6 wks
Video Overlay	2 wks	4 wks	6 wks
Video	4 hours	1 day	1 wk.
Computer Animation	3 wks	6 wks	12 wks
GIS	1 wk.	4 wk.	8 wks
Traffic Simulation	1 wk.	4 wk.	8 wks

Table 5.3 Typical Develop Time for Visualization Technologies

5.8.4   Cost

Cost is also an important consideration when selecting visualization techniques. In the case of visualization technology, cost is often evaluated as a percentage of the overall development and construction cost of the overall project, the probable need for visualization techniques, and the period over which there will be a need for visualization products [5].

Relating visualization costs to the construction budget can provide a quick overview of project expenditures, but it is not a very reliable measure [5]. The cost of visualization has to be viewed in relation to the sensitivity and complexity of the project. Another

criterion for cost evaluation is the long-term value of the visualization products. This is particularly true when considering the cost of developing a 3-D model of a project corridor. TxDOT study [7] showed that transportation agencies prefer to use visualization products generated from a 3-D data set if it was already available. The problem is that the cost of developing the 3-D model was difficult to justify in relation to any single need [7].

According to labor and production materials, the artist's concept is usually the least expensive of all visualization products. The image composite, video overlay represents the middle ground of cost, with the computer animation representing the most expensive products. The cost of GIS and traffic simulation is based on the scale and complexity of the project. Within each of these techniques, different levels of detail affect the cost of the final product considerably. For this reason, it is seldom prudent to make a final decision based purely on generalized notion of cost [6].

Finally, while it is generally true that a 3-D model will cost more than a single image presentation [6], it is important to remember that once a 3-D model is developed an almost infinite number of still views and animations can be generated at a very low cost increment for each product. The 3D data set also has value even after the construction process is complete. In other words, the 3D model should not be rejected just based on the cost.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this project was look at ways to develop more coherent and effective approaches for presenting transportation projects to the public. Concurrent to the collection of the state-of-the-art practices of visualization, we researched theories dealing with the relationships between visual perception and visual stimuli. In this chapter, we will provide a summary of our research.

A detailed review of recent research on visual perception and visualization was conducted. We saw that effective visualization helps people utilize their innate visual perception capabilities to quickly grasp the important feature from images. We also addressed some major perception issues in visualization, such as how to improve image interactivity and how to use colors correctly. In order to make visualization presentation more effective, transportation professionals need to have knowledge of human perceptional systems and design visuals that maximize the use of the preconscious vision of the audience.

We categorized seven types of visualization techniques: artist's concept and rendering, image composite/photomontage, video overlay, video, animation, geographic information system and traffic simulation. Product examples related to each technique and procedures to produce them were illustrated. Required software for computer- based visualization techniques were evaluated. We also provided discussion on the benefits and limitations of each technique and compared all seven techniques in terms of cost, efficiency, training and production time requirements.

We conducted site visits to two industrial companies and one government agency: Sasaki Associates, Wilbur Smith Inc. and Connecticut DOT. We collected valuable information on what kind of visualization is most frequently used and the preferred visualization products related to different type of projects. We also analyzed project examples from all three sites.

In addition to field trips, we conducted mail-in surveys to the six New England DOTs and compared our survey results to a previous nationwide survey conducted in 1998. We addressed issues in visualization, such as what capabilities the DOTs have at their disposal, what kind of visualization products and media are most popular, what is the hardware and software resources that is being used.

The current trend suggests that image composite will continue to be the most popular visualization techniques used in both DOTs and consulting firms. Animation, which is the most effective visualization technique, is expected to be used more frequently as the cost and time of production are reduced. However, as is the case in other regions of the country, visualization techniques are mainly used in the public involvement process in the New England DOTs; they are rarely used in design and design development. Along with this factor, we found that there was a lack of dedicated visualization personnel in the

DOTs. These phenomena are expected to change as the Context Sensitive Design is propagated throughout the nation. As this occurs, we expect that visualization will be more frequently incorporated, not only in the public involvement stage, but also in all stages of design. Because transportation design and public involvement are parallel processes, DOTs will find that the usage of visualization in design will help transportation designers evaluate and refine their proposed design.

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