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**A REVIEW AND EVALUATION OF WEB-BASED METHODS FOR
VISUALIZING AUTOMOBILE TRAFFIC FLOW**

A Thesis

Presented to

The Faculty of the Department of Geography

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Greg Brost

December 2003

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ABSTRACT

A REVIEW AND EVALUATION OF WEB-BASED METHODS FOR VISUALIZING AUTOMOBILE TRAFFIC FLOW

by Greg Brost

Two of the fundamental goals of map design are to visualize geographic phenomena and present them in a way that is in synchronization with the requirements and sophistication level of the map user. Cartographers have required new techniques and tools as they tried to map, visualize, and present increasingly complex data. Dynamic cartography and Web mapping are techniques that emerged from the need to map these complex data.

Automobile traffic flow over an area is a geographic phenomena that can be visualized in a dynamic, Web-based cartographic form and is of interest to different types of map users with different requirements. A traditional, non-dynamic approach to mapping traffic flow data can be restrictive. The new, dynamic, and Web-based techniques require many of the rules of traditional cartography as well as new rules and new ways of evaluating the quality and usefulness of an animated map for each user type.

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CHAPTER ONE

INTRODUCTION

The traditional static map presents problems and limitations in the visualization of dynamic geographic phenomena. New cartographic techniques have become necessary to map and visualize complex information, processes, and geographic data that have, by static mapping methods, been difficult to display. Efforts to break free of the static limitations have resulted in the geographic technique known as dynamic cartography. Advances in technology and computing have fueled the static to dynamic mapping evolution. These technological advances have also provided software tools that can be seen as milestones in cartography. Along with these new software tools, Web mapping on the Internet has become one of the frontier areas in dynamic cartography.

Scientific and geographic visualization play a key role in understanding the meaning of maps and the capabilities, usefulness, and future of dynamic cartography. We can expand geographic visualization and scientific insight by using dynamic cartographic techniques and tools. These techniques allow for the expansion and exploration of the traditional two-dimensional map as well as the ability to view and display in the third dimension. Animation, interaction, and sound can be incorporated to further explain and analyze geographic data. Visualization and dynamic cartographic techniques can be incorporated into a Web map.

Automobile Traffic Flow

Traffic flow and rates through time over an area are data that can benefit from representation in an animated form. A static, two-dimensional map is limited in its ability to effectively show these phenomena and can be especially inadequate for showing temporal changes. The Internet and the World Wide Web are by nature dynamic and interactive; this thesis will examine Web-based cartographic techniques for analyzing, mapping, and visualizing automobile traffic flow.

Methodology

Dynamic maps can be subject to many of the same cartographic standards and graphic properties as static maps. For example, some of the fundamental properties for static maps are those of the graphic variables (Bertin, 1967/1983, chap. 2). In addition to the graphic variables, dynamic maps can also be subject to the properties represented by the dynamic variables (MacEachren, 1995, pp. 278-287). The Internet and Web mapping have their own limitations and challenges that must be taken into consideration when evaluating the effectiveness of a Web map. This thesis will evaluate different traffic mapping Web sites, techniques, and tools, against end user requirements. The evaluation methodology is discussed in detail in chapter 3.

Organization of the Thesis

Chapter Two provides a background and literature review and will include: visualization, dynamic cartography, traffic flow and traffic engineering, and research that

is similar to this thesis. Chapter Three covers the evaluation methodology. Chapter Four covers the methods for traffic flow visualization on the Web. It includes the techniques, data, tools, and user types. Chapter Five contains the individual site evaluations and user level evaluation discussion. Chapter Six describes the results, future research, and conclusions.

CHAPTER TWO

BACKGROUND AND LITERATURE REVIEW

The aim of this chapter is to provide background information on the concepts and technologies that Web-based traffic flow visualization draws from and builds upon.

Scientific Visualization

Visualization means to make visible or to form a mental image. Scientific visualization emerged as a distinct field in a 1987 report (McCormick, DeFanti, and Brown, 1987) sponsored by the United States National Science Foundation. The report identified the power and importance of Visualization in Scientific Computing (ViSC) and discussed key research opportunities. Computers were cited as necessary to process the vast amounts of scientific data available and assist in the visualization process by providing a means for the human visual system to process and understand geometric and spatial relationships in the data. Cartography was specifically mentioned as a geoscientific field that can use and benefit from scientific visualization techniques and offers valuable and worthwhile research opportunities.

Visualization in Cartography

Cartographers and cartographic researchers have taken an interest in the scientific visualization trend. The terms *geographic visualization* and *cartographic visualization* have emerged to describe scientific visualization applied to the fields of geography and

cartography. While the traditional use and meaning of visualization (making things visible) is nothing new in cartography, the use of computers for visualization is relatively recent. Scientific visualization techniques can provide cartography with new, powerful methods for mapping and exploring data that has by traditional means been difficult or impossible to do.

Cartographers can visualize by creating and using maps and have been doing so for centuries. Choropleth maps, topographic maps, and shaded relief terrain renderings can be categorized as graphic representations and visualizations of statistical or numerical data. However, these static maps are limited in their ability to show certain things. For example, if a cartographer wanted to display the same phenomena at a different scale, time or location, then another static map would have to be produced. This can take up more space on the map, add cost, add time, or result in a less effective representation of the data (Moellering, 1980).

MacEachren and Monmonier (1992) discuss visualization tools to help explore data and develop insights. These tools are usually computer programs that take raw numerical or statistical data and generate a graphic model to organize, consolidate, and view the information. This technique has become valuable and almost necessary to process the vast and complex data generated by, for example, earth observation satellites, or in combining multiple databases of related information into such things as three-dimensional air pollution models (Koussoulakou 1994, pp. 243-267). Furthermore, there is almost no other way to show these data except in graphic form. As it turns out, the conversion of data to graphic form and the ability to search visually for patterns and

anomalies is an effective way to learn and activate scientific insight (DiBiase, MacEachren, Krygier, and Reeves, 1992).

Visual Thinking and Visual Communication

Cartographic researcher DiBiase (1990) has built on the concept of scientific visualization and developed a graphic model to represent the ideas of visual thinking and visual communication (see Figure 1). The fundamental idea of the diagram is to show the relationships and research paths between the researcher and the public. According to DiBiase, the diagram idealizes the research process in four stages: “exploration of data to reveal pertinent questions, confirmation of apparent relationships in the data in light of a formal hypothesis, synthesis or generalization of findings, and presentation of the research at professional conferences and in scholarly publications.” The private realm is that of the researcher and the public realm includes the general public or the academic community to which the researcher is communicating or presenting the ideas or findings.

Figure 1. The research path and relationship between the researcher visualizing in the private realm and communication of the results to the public or academic community. (DiBiase, 1990). Copyright 1990 by David DiBiase. Reprinted with permission.

MacEachren (1994) extended the work of DiBiase (1990) and developed a three dimensional view of the concept (see Figure 2). The added dimension is map use. The researcher needs to explore, analyze, and interact with the data while the public usually requires consolidated information and minimal data interaction. For example, a cartographer studying temporal traffic flow may use computer tools to map, analyze, and visualize the traffic flow data. These software tools could include the ability to generate statistical data and to visualize the data using scatterplots, or other graphical means. A public form of the traffic flow data could be a map with summarized traffic flow counts with little or no ability to interact with the data or map. The public and private relationship and levels of map use are important later in the thesis when discussing the

user types for traffic flow visualization and the use of Web mapping as a visualization tool.

Figure 2. Cartography Cube. The depiction of visualization and communication combined with map use. The researcher requires a higher level of interaction with the data than the public does. (MacEachren, 1998). Copyright 1998 Alan M. MacEachren. Reprinted with permission.

Dynamic Cartography

Maps with moving objects, animated displays, or interactive elements are examples of dynamic cartography. Trends towards scientific visualization along with the

needs to visualize, process, communicate, and interact with large quantities of georeferenced temporal data have stimulated the growth of dynamic cartography. Computer graphic technology and multimedia capabilities enable the cartographer to visualize more effectively using dynamic maps. DiBiase et al. (1992) state that dynamic mapping offers at least three modes of expression that are not available in static displays. These modes are: animation (movement on a map), interaction (the ability of the map user to manipulate the map), and sonification (the use of sound with a map). Dynamic mapping techniques can use and combine these three modes of expression to expand and explore the traditional two-dimensional static map and offer increased analysis power. Statistical maps and maps showing change over time seem to benefit most from this type of representation. The next section will give an overview of the types and components of dynamic cartography.

Interaction

User interaction is an important feature and tool in dynamic cartography. Interaction may provide the greatest advantage over static maps by allowing map manipulation and an increase in the ability to analyze map information. A user interface with controls and interactive graphics can allow for the user to search for data they find interesting by navigating through a series of maps or manipulating data appearing on a map. It may be possible to produce a dynamic map customized to a user's knowledge level. The result would be varying levels of animation complexity or narration depending on a user profile at the beginning of the animation (Monmonier, 1992).

Scale changes can be incorporated into a dynamic map. Controls allowing for zooming can be provided with a level of generalization appropriate for each scale. This approach allows for a map to be generated or shown at a very detailed, localized level or a general, more regional level. A feature relating to generalization, is the ability to progress from simple to more complex representations of the data. The level of data complexity could remain constant through all scale changes, could change according to the scale, or could be adjusted by the viewer with each scale change.

Figure 3 shows screenshots taken from a QuickTime movie animation depicting the percent of cropland irrigated in Nebraska from 1954 to 1987. The actual animation shows every year in sequence from 1954 to 1987 and allows interactive controls to stop, pause, rewind, or move ahead or back. A static map lacks these controls and to show all the time periods would require over 30 maps or another, probably less effective representation of the data. The information could be presented with a single map showing percent change from the beginning year, 1954, to the ending year, 1987. The single map would depict a generalized change and not allow the viewer to see the individual year to year variations. A dynamic map allows the viewer to visually recognize patterns, cycles, and rates of change during the animation that may be difficult to see in a static representation.

Figure 3. Cropland irrigated in Nebraska (Peterson, 1996).

Three Dimensional

Three-dimensional (3-D) maps are useful for showing volumetric data as in meteorological applications or terrain representations. Because these maps are displayed on a computer with a flat screen, the term two-and-a-half dimensional is sometimes used. This type of dynamic cartography is usually identified with terrain fly-bys or fly-throughs which by themselves can be more interesting and entertaining to look at than informative. However, a 3-D representation can increase insight into the correlation of data with the terrain. For example, it is possible to have a 3-D terrain model rendered with color-coded polygons to represent slope or landslide hazards and allow the user to manipulate the view and the fly-by. In addition, different map themes can be generated to cover the surface of a model or terrain. This type of representation may be more effective and give greater insight than a static, shaded relief map or 2-D map with the same data. Although 3-D can offer a higher information carrying capacity by including the third dimension, there are some disadvantages. Scale varies continuously through an oblique view and

some features are hidden. Providing user interaction can control some of the disadvantages.

Sound

Sound can be used in both 2-D and 3-D maps to provide narration, to cue the viewer into an important event, or to point out anomalies in the data. For example, narration could be used to alert the viewer to watch a certain point during the cropland animation (see Figure 3) or explain the terrain during a 3-D animation. Sound can be used to express data quality or uncertainty by dragging or clicking the mouse across a map and producing a different sound as the data varied (Kryger, 1995). This method can save the sharp image of the map by using sound as an invisible source of information. In a static map, graphics are used to represent data uncertainty and quality and at the extreme can become a blurred mess on the map. Sound can be annoying, a map viewer can escape chaotic movement on a map by not looking at it, but escape from sound is more difficult. Novice map viewers may appreciate some sounds or narration while experienced map users may be irritated.

Dynamic Variables

Many of the core principles of creating static maps can be applied to dynamic mapping. The traditional graphic variables of the static map can be expanded with dynamic variables. The graphic variables: hue, orientation, pattern arrangement, saturation, shape, size, texture, and value can still be used in a dynamic map. The dynamic variables as defined by MacEachren (1995) are:

Display Date: The time at which some display change is initiated

Duration: The length of time between two identifiable states

Order: The sequence of frames or scenes

Rate of change: The difference in magnitude of change/unit time for each
of a sequence of frames or scenes

Frequency: The number of identifiable states per unit time

Synchronization: The temporal correspondence of two or more time series

History and Evolution

Dynamic mapping is a recent development in cartography. While the use of computers is a relatively recent addition, dynamic mapping has been around longer than most would suspect. The era of cinema introduced the potential of dynamic mapping. For example, it became possible to take a motion picture of a landscape by flying over and around it, or a movie camera could be rotated around a physical model of the landscape rather than the actual terrain. In the early 1960's cartographers began writing about and describing the possibilities and benefits of cartographic animations. This was before computers had the ability and power to create them and hand drawn animations were the suggested technique. By the late 1960's, computers began to be viewed as a tool for creating dynamic maps and around the early to mid 1970's there were for example, city growth animations or models, made by combining individual scenes or frames created on computer then played back in a series on film. Most of the early animations didn't use enough scenes or a fast enough frame rate, which created an animation with

abrupt transitions similar to satellite weather animations used in the modern television news broadcasts. The 1980's saw the beginnings of 3-D vector animations and eventually with the increase in computer power the transformation was made to raster 3-D modeling. The early 3-D animations were called fixed-sequence because they displayed a predetermined sequence of images or graphics with minimal user control or interaction. This approach was less expensive than real-time interaction which was a very expensive, developing technology. A technique called stored image used a pseudo real-time approach in creating user controlled 3-D animations. This method used a vast database of views and was jerky, slow, and limited by the availability of stored images.

Currently, high-powered workstations and desktop models have made a big impact on dynamic cartography. The transition has been made from film and video in the 1970's and 1980's to personal computers and transferring an animation to film or video in order to show it is no longer necessary; the computer can create and display the animation on its own. In addition, tools available for creating dynamic maps range from programming languages, to multimedia packages and software designed specifically for scientific visualization. Computing power has made it possible to manipulate terrain models in real-time, meaning when a rotation or adjustment is needed it happens instantly compared to the earlier years when it would take hours or longer. With the ability to display an animation on screen, user interfaces were created to allow the user to manipulate the map and animation.

Web Mapping

The Internet and World Wide Web (WWW or Web) have become the newest platforms for dynamic cartography and geographic visualization. Interactive Web-based maps build on the hypermedia and hypermap concepts as discussed in Kraak and Van Driel (1997). Kraak and Van Driel define a hypermap as "...georeferenced multimedia systems that can structure individual multimedia components with respect to each other and to the map." The Web provides an accessible way to distribute and link maps and data and implement hypermaps. The Internet is growing and increasing in popularity and the occurrence and use of maps on the Web is becoming a regular sight and activity for users. Some of the popular activities are to find an address, location, or get driving directions (see Figure 4). The information is usually presented along with a static map with some minimal controls such as the ability to zoom or pan.

Figure 4. MapQuest is a popular Web-based location and direction tool.

Interactive controls exist to zoom, pan, re-center, or change location. (MapQuest, 2002)

Most of the Geographic Information System (GIS) vendors are now offering Web mapping products (McKee, 2001). Web maps, tools, and presentation methods can generally be grouped into the following:

Static maps: Maps with no interaction. These include paper maps that have been scanned and published as a graphic on a Web page.

Image maps: Maps with hotspots that when clicked link to another page, other information, or cause an action.

Java: A computer program written in the Java language and embedded in a Web page as an applet or accessed by a Web page from a server. These tools and maps are perhaps the most powerful. Interaction, controls, sound, etc., can be built into the application and Java provides the programming means to accomplish it.

Plugins: Add-on software tools for the browser. Plugins allow different and sometimes proprietary files and applications to be executed within the browser. Shockwave and Flash are examples.

Web mapping system: Software tools produced specifically for displaying maps and providing map interaction on the Web.

Note that while some maps may appear as a static graphic, the map may also be undergoing updates at regular or user defined intervals. These map updates occur on the server and are pushed to the client (browser) or are pulled from the server via a refresh on the client Web page. Java Server Pages (JSP) and Active Server Pages (ASP) are technologies that are often used in this type of periodic map updating. Keeping maps up to date has been a problem in traditional cartography. With Web mapping and the accompanying technology, that problem has been somewhat alleviated.

Web mapping and the associated tools are distinct from the traditional GIS and desktop mapping products (Limp, 2001). A key difference is the level of expertise needed to develop the Web maps and work with the Web-based tools and technology.

Web maps can also allow easier access to geospatial data. Geospatial data is increasingly becoming available through the Internet and organizations such as the United States Geological Survey (USGS) or Departments of Transportation (DoT) have data

available online. This data can be accessed through the Internet, processed, and served up for visualization purposes on the client. Traffic data is a good example. Current traffic counts and conditions can be accessed then displayed in a Web map form. Figure 5 shows the general relationship between data being accessed through the Internet then processed by a server and delivered through the Internet to the client.

Figure 5. Generalized relationship between data, the Internet, and client-server

The Internet is interactive and multimedia and provides a means to deliver dynamic cartography. Currently, most Web maps offer visualization at the public level with minimal interaction and limited tools to explore the data. Private level Web map visualization does exist and as Web mapping technology continues to advance, users of Web maps will have even more powerful tools to explore and interact with geospatial datasets and make use of modern cartographic visualization techniques.

Traffic Engineering and Traffic Flow

Traffic Engineering is a broad subject. It fundamentally consists of five areas of study. The study areas defined by Homburger and Kell (1963, I-1) are:

1. Studies of traffic characteristics
2. Traffic operations
3. Transportation planning
4. Geometric design
5. Administration

Of the five areas of study, traffic characteristics is the one most associated with traffic volumes and flow. The other four areas all include some aspect of traffic flow and control, but traffic characteristics is the study area that seems to focus on the traffic flow element of traffic engineering.

Homburger and Kell (1963, I-1) describe and define studies of traffic characteristics and state that “traffic studies must be conducted to obtain data on transportation and traffic trends for entire regions, and on traffic conditions at specific locations.” In addition, the following fields are covered by the studies:

1. Vehicular and human factors
2. Traffic volumes, speeds, delay
3. Traffic stream flow and capacity of streets and intersections
4. Travel patterns, trip generation factors, origins and destinations
5. Parking and terminal factors
6. Mass transit systems

7. Accidents

Many tools and technologies have emerged through the years to enable transportation engineers to help do their jobs. The incentive to create new and smarter tools was stimulated by congress in 1991 when they invoked the Intelligent Transportation Systems (ITS) initiative. The aim was to encourage development of Advanced Traffic Management Systems (ATMS) to help manage and improve the existing transportation system. Computer simulation has been a vital tool in traditional traffic engineering. Transportation GIS technology is one of the more recent computer technology additions and includes Web-based tools for visualizing traffic flow.

The traffic data counts and collection methods that are necessary to study traffic characteristics can range from manual, human-based counts to a variety of road-embedded and non-road-embedded sensors. Much of the current sensor technology has been developed under the ITS initiative. Road-embedded sensors include: pneumatic hoses (road tube), pressure, magnetic, radar, sonic, copper loop, and infra-red sensors. Non-road-embedded sensors include: Closed Circuit Television Cameras (CCTV) and in-car transponder tag signals. The captured data can often be transmitted from the sensor using modems or fiber optic cables to a traffic management center or the location of the data storage facility or processing center. The data can then be stored in a database or other formats. Other formats include raw text or tab or comma delimited text. Traffic data counts serve as the fundamental base and fuel for traffic flow mapping tools and visualization.

Existing and Similar Research

While traffic maps have become more common on the Web, research into Web-based strategies for visualizing traffic flow is not common. Research does exist on Web mapping but research specifically dedicated to automobile traffic Web maps is limited. Emmer (2001) offers an examination of the advantages and current means of distributing traffic information on the Web and points out that the main advantage is the ability to access real-time traffic data free of charge from any time or place that has Internet access. Emmer classifies traffic information sites into two categories: “sites offering routing facilities, and sites offering information on traffic conditions.” The routing sites can offer information on: travel times, route descriptions, quickest routes, and distances. The sites with traffic condition information are primarily concerned with traffic density and incidents. Speed, volume, and congestion are examples of the data provided. Emmer also provides suggestions for improving current traffic sites. One of the main suggestions is to better consider the user perspective. Emmer offers the following questions to consider for traffic map design and use:

1. What kind of information is desired?
2. Where does the user want to receive the information?
3. When does the user want to receive the information?
4. How should the information be presented?

These questions can feed back into the public and private visualization needs of traffic map users and will serve as part of the methodology framework in this thesis. As indicated in the visualization section of this thesis, different types of maps are needed

based on the level of visualization desired. These questions will be incorporated into the evaluation methodology.

The design of traffic Web maps is identified as another area needing improvement. Emmer (2001) points out that symbolization is frequently poor and improper use of the graphic variables often exists when displaying ordinal data such as traffic. While these improvements and recommendations are not purely Web specific, it is important to note that fundamental cartographic standards should still be applied to Web maps.

Research on Internet based Transportation GIS and system architecture can be found in Nambisan, Jensen, Puterski, Miller, and Park (1999). The paper offers technical information on implementing Web interfaces to a transportation GIS and developing the system infrastructure. Ran, Chang, and Chen (1999) also offer information on system architecture for Web-based transportation GIS. Alam, Melchiorre, and Clayton (1999) discuss the development of Intranet and Internet applications for dynamic presentation of a cross-jurisdictional transportation database.

Weather maps are one of the closest (to traffic) Web-based examples of visualization. While weather is a different phenomena from traffic, these two types of data share some characteristics and issues when mapping and visualizing them on the Web. They each are constantly changing, real-time phenomena and information presented on a map or otherwise must be updated to be of use to the public visualizer.

CHAPTER THREE

METHODOLOGY

Requirements for Public and Private Visualization

Requirements for public and private visualization of Web-based traffic flow maps will incorporate and build on the *what*, *where*, *when*, and *how* questions from Emmer (2001). User type is the driving element for the requirements.

What kind of traffic flow information is desired? The question depends on the type of user. A user requiring public level visualization will probably have a different traffic flow map than a user requiring private level visualization. The lists of requirements are based on how the existing literature defines the typical needs of public and private visualizers. In general, the public visualizer requires less map tools, controls, and features than the private visualizer. The minimal attributes for a traffic Web map for public level visualization include the following:

1. Web-based
2. Map available
3. Current traffic volume or congestion conditions (can include incidents and construction)
4. Zoom
5. Pan
6. Change location

Zoom, pan, and change location can be considered optional minimum requirements for the public level visualizer but are worth including as some other controls that may be necessary if the scale of the map is insufficient for visualizing the traffic data.

Private level visualizers require more advanced features. The features include those needed and optional for public visualizers and are extended by the following:

1. Sound
2. Three Dimensional
3. Symbolization manipulation
4. Graphic and dynamic variable manipulation
5. Traffic data in chart, table, or plot form
6. Temporal manipulation with the ability to go back and forward in time to view changes
7. Ability to interface with auxiliary traffic data: traffic cameras or video, Changeable Message Signs, highway patrol or first hand accounts, incident listings, construction listings
8. Search
9. Query
10. Select and Identify
11. Popup message windows
12. Icons for CMS, and Cameras

Public visualizers are primarily commuters and others interested in some basic traffic information. Private visualizers include: traffic engineers, researchers, or anyone else interested in advanced traffic map use and traffic data analysis.

Where does the user want to receive the information? Commuters would most likely be accessing the traffic conditions from work or home. A computer with Internet access is required. Traffic maps and information could also be transmitted to a handheld device or an Internet connected car navigation system. Advanced users such as traffic engineers, researchers, or people requiring more interaction would be accessing and interacting with the traffic maps from a home, office, or school.

When does the user want to receive the information? Traffic information is most useful to most people when it is current and real time. Public visualizers are usually not interested in any information that is not current. Private level visualizers want current information but can wait for historical or future data projections to be processed or calculated. Five minutes will be used as the maximum acceptable update interval for a public visualizer.

How will the information be presented? Before the data gets presented on a map, there are processes and tools that make it happen. These tools, technologies and presentation methods were introduced in chapter 2 and include: static maps, image maps, Java applets, Java servlets, plugins, and Web mapping systems. The data needs to be processed and displayed on a map with the necessary controls. Each of the techniques have their strengths and weaknesses which lead them to be more appropriate for either public or private level visualization. Cartographic concerns exist for the map and

interface. One of the main elements is the symbolization of the traffic data. While the quality of the Web map graphics is important, this thesis will not include graphics quality as part of the evaluation criteria as it could easily be the subject of another thesis.

To summarize, the fundamental requirements and differences between the visualizer is interaction with the traffic map and traffic data. The private level visualizer needs more map interaction and tools for exploring the data than the public visualizer.

Acquisition of Sites and Tools

Existing traffic flow Web sites and technologies were accumulated using a few techniques. One technique involved a Web search using a variety of search engines. Key words for the search used combinations of the following words: automobile, traffic, animation, real-time, map, GIS, visualization, flow, and Web. Examples of the search key word combinations include: real-time traffic, real-time traffic GIS, live traffic, traffic report, traffic map, automobile traffic, traffic animation, traffic GIS, traffic visualization, traffic flow, and Web traffic. Another method was reviewing literature on traffic flow and transportation related research and articles with a Web focus. The literature occasionally provided links to traffic Web sites or to experimental or more advanced Web-based traffic flow visualization tools. The experimental and advanced tools were usually located at research institutes, software development companies, academic institutions, or government transportation organizations. A spreadsheet table was created listing the sites and attributes and provided an efficient way to gather a list of traffic sites

and organize their associated information. The information or attributes were listed under the following column headings:

1. URL - The Internet address of the Web site
2. Logical Name - The name of the Web site
3. Traffic Symbolization Type - How the traffic volumes are graphically symbolized
4. Other Symbolization Type - Graphical symbols for associated data (i.e. incidents, construction)
5. Technology - The tools and presentation technology (i.e. static map, image map)
6. Controls - Available map controls (i.e. zoom, pan, find)
7. Other Features - Features such as links to Highway patrol incident reports
8. Public/Private - Categorization as Public and/or Private visualization
9. Update Interval - How often the map is updated with new data and if it is automatic or not
10. Data Source - Where the traffic data comes from
11. Comments - Some general comments and notes for the Web site

The table did not contain a complete list of all available traffic Web sites; it contained sites with a variety of technology types and approaches. Many available sites were not included because they were too similar in their approach to sites already listed in the table. The table provided the core information for chapter 4 where sites representative

of each type of technology will be presented as well as the symbology, tools, controls, and features available with the map.

Symbology, Tools, Controls, and Features

Elements of a traffic Web map have been organized into categories. These elements aid in visualizing the traffic data and include symbology, tools, controls, and features and also make up the what requirements. Symbology includes methods for showing traffic speeds and traffic incidents. Tools include: find, query, and select and identify. Controls include: zoom and pan. Features include: popups, charts, tables, changeable message signs, camera views, and historical data. The different map elements and their approaches will be presented in chapter 4.

Technology Types

Technology types are categorized into: static image, image map, Java applet, Java servlet, plugins, and Web mapping systems and make up the how requirements.

Examples of each technology type will be presented.

Evaluation Structure

Existing traffic flow Web maps and technologies will be compared based on their capability to visually communicate at the public and private level. The symbology, tools, controls, features, and technology types will be evaluated on their ability to meet the requirements for visualization as discussed in the first part of this chapter. The evaluation result will identify the Web site implementations that effectively communicate traffic

flow data for the public and private visualizer based on the defined criteria. The recommendations will include some areas of improvement and ideas for future research.

A matrix listing the symbology, controls and tools, and other properties associated with each Web site will be used to indicate how each site satisfies the what requirements. Another table will be used to show how each site satisfies the when and how requirements. The when requirement is the update interval and the how requirement is the technology type. Each Web site will be individually evaluated and discussed with a focus on how it satisfies the public and private visualization requirements and what it's strengths and weaknesses are. A strengths and weaknesses summary table will be included in the discussion for each of the evaluated sites. The evaluation, discussion, and summarization format is partially based on the one used in Boxill and Yu (2000).

CHAPTER FOUR

REVIEW OF THE CURRENT STATE OF WEB-BASED AUTOMOBILE TRAFFIC FLOW VISUALIZATION

Symbology, Tools, Controls, and Features

Methods for representing traffic conditions may be the most important part of a traffic map. Most maps use colored segments or colored points with the color indicating the speed or congestion level or congestion range.

Colored Segments

Colored segments can be used to represent traffic data for each side of the road. Segment delimiters are usually determined by the sensor locations. Figure 6 shows two common examples of colored road segments.

Figure 6. Examples of colored road segments to represent traffic state (Puget Sound Traffic Conditions WSDOT, 2002) on left; (Georgia Navigator, 2002) on right.

Colored Points

Colored points are used to indicate the traffic conditions at the sensors and mark the sensor location. Figure 7 shows an example of colored points. In this particular example, green is for 0-30 MPH, yellow for 31-45 MPH, red for 46-70 MPH, and gray for no data.

Figure 7. Colored points to represent sensor location and traffic conditions (District 8 Congestion Information - California DOT, 2002).

Proportional Circles

Proportional circles can be used to show changing traffic volumes through time. The circles contract and expand as the traffic volume data changes. Figure 8 is an example of proportional circles.

Figure 8. Proportional circles used to show traffic volume changes through time (Brost, 2003).

Color Scheme

Traffic condition symbology is colored according to traffic speeds or congestion levels. One of two methods is usually used. One method uses three to six colors for ranges of speed or congestion level while another method uses a graded color range to represent speed. Figure 9 shows examples of these methods using the speed or congestion level part of a traffic map legend. The graphic on the left shows a hierarchy of colors for speed. The middle left graphic shows three colors for three ranges of speed while the middle right graphic shows five colors for five speed ranges. The right graphic

shows four colors for four levels of congestion. Red is most often used for low speeds or high congestion while green is used for higher speeds or low congestion.

Figure 9. Portions of map legends showing possible methods for relating traffic speed ranges or congestion (Georgia Navigator, 2002) on left; (Los Angeles City Traffic Conditions, 2002) on middle left; (Houston Real-Time Traffic Map, 2002) on middle right; (Gary-Chicago-Milwaukee Corridor, 2002) on right.

Incidents and Construction

Traffic speeds and congestion are often affected by incidents and construction. Incidents are usually accidents and are commonly represented on the map using icons. Construction is represented with icons for construction points or colored or iconized segments for construction over a road segment. Figure 10 demonstrates some of the symbols used for showing incidents and construction. The left graphic shows icons that appear on the map for active and cleared freeway incidents. The middle graphic shows icons for incidents, construction, and closures. The right graphic shows symbology for point construction and construction that is moving or occurring over a section of road.

Figure 10. Portions of traffic map legends showing symbolization for incidents and construction (Houston Real-Time Traffic Map, 2002) on left; (Minneapolis / St. Paul Real Time Traffic Conditions, 2002) middle; (Gary-Chicago-Milwaukee Corridor, 2002) on right.

Popups

Popup windows contain information on a selected road point, segment or map icon. A user can click on the map and a separate window will spawn with information on traffic speed or congestion, incident information, or construction information. Camera views also frequently appear in popups. One of two methods is usually used: a separate browser window containing the information or a custom (usually Java based) window that appears with, and perceptually in front of the map. Figure 11 demonstrates the two methods. The graphic on the left is a separate browser window spawned when clicking on an incident icon on the map. The graphic on the right shows Java generated popups

containing information on traffic speeds (left box) and the text from a Changeable Message Sign (CMS) on the right box.

Figure 11. Popup windows for traffic information (Traffic.com, 2002) on left; (District 8 Congestion Information - California DOT, 2002) on right.

Charts

Charts can be used to plot and show current speeds and speeds throughout the day. The charts are usually accessed by clicking on a road on the map or from a list of roads associated with the map or area. Figure 12 shows a speed chart where real-time data is plotted throughout the day. Historical data is also plotted on the chart.

Figure 12. Real-time speed chart with historical speed data also plotted (Houston Real-Time Traffic Map, 2002).

Tables

Tables or lists are frequently used to itemize speeds and incidents. They are usually linked with the map and are available by clicking on a map or on a text listing near the map. Figure 13 shows data for freeway segments and also provides an icon that is colored to correspond to traffic speed. The icon helps the table viewer to more easily comprehend the speed data. Figure 14 shows a table of traffic incidents with the time, location, and incident type. These tables in combination with the traffic map can assist the map user in better understanding the speed and incident data by providing more detailed information than the map itself is capable of.

I-45 North Detailed Data						
Freeway Southbound						
From	To	Date/Time	Distance	Travel Time(m:ss)	Speed(mph)	
Hardy Toll Road	FM 1960	10/07/00	5.40	5:02	64	
FM 1960	Aldine Bender	10/12/00	7.00	6:00	70	
Aldine Bender	Shepherd	10/12/00	3.00	3:22	64	
Shepherd	Crosstimbers	10/12/00	4.00	4:02	55	
Crosstimbers	Outman	10/14/00	2.00	2:13	64	
Outman	Allen Parkway	10/08/00	2.30	3:38	24	
Freeway Northbound						
From	To	Date/Time	Distance	Travel Time(m:ss)	Speed(mph)	
Allen Parkway	Outman	10/14/00	2.30	2:36	63	
Outman	Crosstimbers	10/15/00	2.50	3:14	48	
Crosstimbers	Shepherd	10/11/00	4.00	4:51	50	
Shepherd	Aldine Bender	10/12/00	3.00	3:39	50	
Aldine Bender	FM 1960	10/10/00	7.00	6:06	60	
FM 1960	Hardy Toll Road	10/11/00	5.40	7:22	45	

Figure 13. Tables of data for sections of a freeway (Houston Real-Time Traffic Map, 2002).

Orange County Communications Center				
Number of Incidents: 10		Last Updated on: 10/10/2002 4:24:58 PM		
0000 3:00PM	10000	NE 80000 NATELLA AV	0000	Westminster
0001 3:00PM	10000	LIVE OAK CANYON RD AT PROUD CANYON RD	0001	Capistrano
0002 3:00PM	10000	NE 8000 AT 8000	0002	Capistrano
0003 3:00PM	10000	NE 8000 E 17TH ST	0003	Capistrano
0004 3:00PM	10000	NE 8000 LA FAZ RD	0004	Capistrano
0005 3:00PM	10000	EL CAMINO REAL AT RED HILL RD	0005	Capistrano
0006 3:00PM	10000	NE 8000 AND CAMPUS DR	0006	Capistrano
0007 3:00PM	10000	NE 8000 AT 8000	0007	Capistrano
0008 3:00PM	10000	NE 8000 AT 8000	0008	Capistrano
0009 3:00PM	10000	ORANGE COUNTY COMMUNICATIONS CENTER	0009	Orange County Comm Center

Figure 14. Listing of incidents with links to specific information (California Highway Patrol Traffic Incident Information Page, 2002).

Changeable Message Signs

Changeable Message Signs are physical, electronic signs along the roads and alert drivers to incidents and other congestion or traffic speed related information. CMS

locations can appear on a traffic map as icons and can be clicked on to view the current message. The message and information usually appear in a popup, as a graphic, or in text on the Web page near the map. Figure 15 shows typical CMS map icons (top), a graphic with the information (middle), and text displaying the message (bottom).

Figure 15. Icons and messages for Changeable Message Signs (CHART On The Web, 2002) on top and bottom; (TransGuide: Current Conditions Map, 2002) middle.

Camera Views

Camera views are a photographic means to view current traffic conditions.

Physical camera locations are usually shown as icons on the traffic map or in a text listing (see Figure 16).

Figure 16. Text listing of traffic cameras with the selected view appearing on the right. The listing appears on a Web page separate from the traffic map. (TransGuide: Current Conditions Map, 2002).

An active camera icon can be selected on the map which generates a separate browser window (see Figure 17), a separate browser page (see Figure 16) with the camera view, or in a frame next to the map and in the same browser window (see Figure 18).

Figure 17. A camera view browser window (District 8 Congestion Information - California DOT, 2002).

Figure 18. The selected camera view in a browser frame next to the map and on the same page (Puget Sound Traffic Conditions WSDOT, 2002).

The images are usually a still shot from a video camera that continuously views or records traffic or can be streaming video images that show nearly live motion traffic action. The cameras can be useful in combination with the other methods to visualize the current traffic speeds and conditions by providing a way for the map user to relate the graphical and tabular traffic information to the traffic conditions shown in the camera views.

Historical Data

Historical data can be made available in graphic or tabular form and can be plotted on charts as in Figure 12. Historical averages can also be presented in a graphical

form much like the real-time maps available during each day. An animated sequence of the historical data can allow the viewer to visually extract speed or congestion patterns as the colors representing speed on the map change as the time, speeds, and congestion level change (see Figure 19).

Figure 19. Portions of an animated sequence of historical traffic speed data (Houston Real-Time Traffic Map, 2002).

Additionally, the historical data can be available in tabular form (see Figure 20) or in an archived map where the user can select the map view, date, and time. Insight into the historical data is most useful when visualizing in combination with a graphic.

Historical data and the associated charts, maps, and tables are usually accessed through a link on the page that contains the current traffic data and map. By clicking the link, the user is taken to a separate page that contains the options for viewing the historical data. Private level visualizers are often the users that are most interested in historical data; they seek trends and insight into the information with the help of graphics to view archived data.

Figure 20. Historical travel times and speed table (Houston Real-Time Traffic Map, 2002).

Figure 21 shows some common buttons that are used to access each map tool mode. The buttons often appear next to the map as shown in Figure 22. Once the tool is selected, the user can click on the map to invoke the tool process.

Zoom	Pan	Search	Query	Select and Identify

Figure 21. Buttons for map tool access (Gary-Chicago-Milwaukee Corridor, 2002) on left; (San Diego Regional Traffic Forecast, 2002) on middle left, middle, middle right, and right.

Zoom

Zooming is a useful way to navigate the map and is usually accomplished by one of two methods. Icons can be selected (see Figure 21) to enter a zoom in or a zoom out mode. The map can then be clicked at a point of the desired zoom. In some maps the mouse pointer is turned into a crosshair when in zoom mode. Another method for zooming involves creating a quadrangle by dragging the mouse pointer or crosshair while in zoom mode (see Figure 22). Zooming then occurs for the created quadrangle. This method is usually referred to as zooming to an area.

Figure 22. Zoom to an area or rectangle is accomplished by dragging a crosshair to mark an area to zoom to. Buttons on top of map allow access to different zoom and pan modes. (District 8 Congestion Information - California DOT, 2002).

Pan

Panning can be used to scroll around and navigate the map and, like zoom, is usually accomplished by one of two methods. Graphical links on or around the map can be available for each direction. These directions or links can be clicked on and the map view will change to show more in the selected direction. Another method for panning is

to select an icon to enter the pan mode then drag the mouse pointer or a hand graphic (see Figure 21) to move the map to view the desired region.

Much like a desktop GIS, tools exist for interacting with the underlying raw data that make up part of what is displayed on the screen in a traffic Web map. Find, query, select and identify are some of the tools that allow interaction with the traffic and map data.

Find

Map attribute data can be searched using a find dialog that is usually accessed through a link or icon near the traffic map. Data such as road names can be found then accessed on the map via a hyperlink in the search results. This feature allows the user to locate and go to a particular point without the need for zooming or panning around the map in an effort to find the feature visually. Figure 23 shows a find dialog.

Figure 23. Find interface (San Diego Regional Traffic Forecast, 2002).

Query

Query tools allow the user to build searches using logical operators, Boolean logic, and user defined datasets or map layers. Queries are advanced forms of a find and provide powerful methods to search for data that may be difficult to find visually. For example, a query can be generated to find and list results for traffic conditions of a certain

type. The result would allow the user to have a custom listing of data that is of interest to them and have the ability to be linked to the map data in the query result. Query dialogs can usually be accessed through an icon or link near the map. Figure 24 shows a query dialog.

Figure 24. Query interface (San Diego Regional Traffic Forecast, 2002).

Select and Identify

Features and attributes on the traffic map can be selected to generate a listing of information for the selection. A user can click and select roads, areas, icons, etc., on the map. The selection is then processed by the map software and the resulting information is displayed as a list or a textual block of information for the selection. Select and identify allows the user to view information that may not be available visually on the map. For example, a traffic sensor location may be selected to view information related to the sensor. Data may include the sensor coordinates or operation status. Selection on the map can be done by point, line, or polygon to list information for all available attributes within the selected point, line, or area. Figure 25 shows a select dialog and Figure 26 shows an identify dialog.

Figure 25. Line or Polygon selection interface (San Diego Regional Traffic Forecast, 2002).

Roads									
Seq	NAME	AWT	SPEED	LANES	WAY	CLASS	WORKFLOW	ADOT	
1	RAMM	100PS	45	2	1	FREWAY CONNECTOR	NEW	4424	

Figure 26. Identification information (San Diego Regional Traffic Forecast, 2002).

Technology and Presentation Types

The following section examines the types of technology used to process and present the traffic data. These are Web technologies that are not unique to traffic Web maps but have been applied to traffic Web maps. The technology is a means to an end; it accesses, processes and presents the traffic data, makes it available to the end user, and provides the controls and features to interact with the map and data. While each type of technology can generally perform similar tasks, there are fundamental differences, advantages and disadvantages that are worth discussing and evaluating. Examples are given to help illustrate and explain the technology types.

Static Image

Static images are one of the most basic ways of displaying a traffic map. These maps have minimal or no interaction and provide traffic information and little else.

Figure 27 is a static map of the traffic conditions of the bridges of Puget Sound. Traffic maps of other sections of Puget Sound are available by selecting one of the tabs at the top of the map.

Figure 27. Puget Sound bridges traffic conditions (Puget Sound Traffic Conditions WSDOT, 2002).

Figure 28 shows an example of a static map that contains controls allowing for access to traffic information not visible on the map. A static map of San Diego area traffic is in the center frame. The left frame contains clickable icons and directions for

action. The action usually includes: zooming to the point, access to more information about the selected point, or re-centering the map to the selected point. The technology builds on what is used for static maps by using programs external to the HTML to mark the selectable map parts and process the request. Common Gateway Interface (CGI) and Active Server Pages (ASP) technologies are methods frequently used for implementing image maps. The HTML references the CGI or ASP program that then does the request processing and can deliver the result to the browser. The programming languages C++ and Perl are frequently used to create CGI and ASP programs. Figure 28 shows a traffic map using an image map implemented with ASP technology. Coordinates (249,356) appear in the status bar on the bottom of the browser window. The coordinates are the location of the hand cursor (near the airport) on the traffic map. Once the point coordinates are selected, the ASP program will process the request and return information about the particular point selected.

Figure 29. Image map using ASP technology (SmarTraveler South Florida Map, 2003).

Java Applet

Java applets are programs written in the Java programming language and are referenced from a Web page. An applet exists on the Web server and often has a graphic interface embedded in a Web page. Java is a powerful programming language and can

allow the developer to create a traffic map with custom controls and specialized interaction. Java is especially powerful because of its built-in capabilities to use Web technology and access databases. Part of Java's built-in capabilities includes programming libraries for manipulating graphics and the associated graphical interface elements. Private level visualizers are often the group that uses Java technology for developing Web-based traffic maps and the associated tools.

Figure 31 is a screenshot of a Java applet for the traffic conditions for Caltrans District 8 covering Riverside and San Bernardino Counties in Southern California. This map appears on a Web page along with some instructions for using the map and the legend (see Figure 30). Multiple interactive controls exist for navigating the map and choosing which map elements or layers to display. Much of the interface and map elements appear similar to the other types of technology.

How To Use	
Zoom <ul style="list-style-type: none"> Click on the "Zoom In/Out" button. Click on the area of the map that you would like to zoom in/out. Right-click on map to turn off "Zoom" mode. 	If the map does not display correctly, please check the following: <ol style="list-style-type: none"> 1) You may have an older browser which does not support JAVA. 2) The security settings on your browser are set too high - You can fix this problem by lowering your security settings or adding "www dot ca.gov" as a trusted site on your browser. 3) Your browser settings do not allow you to view JAVA Applets.
Pan <ul style="list-style-type: none"> Click on the "Pan" button. Click and drag to navigate the map. Right-click on map to turn off "Pan" mode. 	<p>This interactive map utilizes JAVA, and requires a browser that has a JAVA JIT compiler installed. This is usually a standard install with Netscape or IE. If your problems persist, you might consider downloading the newest version of your favorite browser that supports JAVA, and install or re-install the browser.</p>
Display Traffic Information <ul style="list-style-type: none"> Click on a VDS dot, CMS sign, or camera. Click again to close message box. OR click on the "Deselect All" button to close all open message boxes. 	Legend <p>Vehicle Detection System (VDS)</p> <ul style="list-style-type: none"> = 0-30 MPH = 31-45 MPH = 46-70 MPH = No Information <p>Changeable Message Sign (CMS)</p> <ul style="list-style-type: none"> = no message = message to read
Display Road Closure Information <ul style="list-style-type: none"> Click on State Route Shield or route number on the bottom of this web page to view closure information for that route. Closure information will open in a new window. Close the window to return to this page. 	
Customize Map <ul style="list-style-type: none"> Checkmark the boxes on the bottom of the map for the items you would like displayed on the map. 	<p>Traffic Cameras</p> <ul style="list-style-type: none"> = Traffic Camera

Figure 30. Instructions and legend for map in Figure 31 (District 8 Congestion Information - California DOT, 2002).

Figure 31. Java applet displaying traffic conditions and map controls for Caltrans District 8 covering Riverside and San Bernardino Counties in Southern California (District 8 Congestion Information - California DOT, 2002).

Java Servlet

Java servlets are similar to Java applets. The main difference is the Java program resides and runs on an application server. The images and data are controlled by JSP technology. This technology controls the communication between the browser/client and

Shockwave and Flash are two common plugin examples. Figure 8 shows a Shockwave traffic map with interactive controls for map data and features.

Web Mapping System - ArcIMS

Web mapping systems provide specific solutions for creating and implementing maps on the Internet. One such tool is ArcIMS from Environmental Systems Research Institute (ESRI). It was developed specifically to integrate GIS technology with the Web, publish maps, and provide tools to interact with the map. The software provides a framework for distributing GIS capabilities over the Internet and allows GIS processing power along with the ability to serve up the map. Multiple controls are available as well as the ability to turn layers on or off and set the active layer.

Figure 33 shows a map of traffic forecasts for the year 2010 in San Diego, California. The interface and map use ArcIMS technology. Tools such as find and query are available and are some of the controls that appear in the text panel of the map interface. The text panel is the white rectangular area near the bottom in Figure 33. Once a tool is selected in the toolbar, the associated tool and interface appears in the text panel. The map and controls are generated using HTML, JavaScript, and images.

CHAPTER FIVE

EVALUATION

What's available versus what's required

As discussed throughout this thesis, the public level visualizers have different needs than the private level visualizers. Different tools and technologies exist to accommodate those needs. This chapter will evaluate the satisfaction of user visualization requirements discussed in chapter 3 versus the symbology, tools, controls, features and technologies presented and discussed in chapter 4 and the traffic Web sites listed in Tables 1 and 2. Tables 1 and 2 are summary matrices that will be referenced for the evaluation, examination, and discussion. Table 1 represents the what requirements and Table 2 represents the how and when requirements. For the where requirement, each site, except where noted, is accessible via the Internet using a Web browser. Additional discussion of the where requirement will occur when applicable in the individual site evaluations and summaries.

SITE	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Speed Symbology																	
Colored Segments	X		X	X	X	X	X	X	X	X	X		X	X	X		
Colored Points		X															
Proportional Circles																	X
Other Symbology																	
Incidents	X				X	X	X	X	X				X	X	X		
Construction	X				X	X	X		X				X	X			
CMS Icon	X	X							X				X	X	X		
Camera Icon		X		X				X	X				X	X	X		

Controls and Tools																
Zoom		X			X				X	X	X			X	X	X
Pan		X			X				X		X		X	X		X
Change Location		X		X	X				X		X			X	X	X
Search																X
Query																X
Select and Identify																X
Temporal Manipulation				X				X								X X
Symbolization Manipulation																
Graphic and Dynamic Variable Manipulation																
Other Properties																
Popups		X			X			X	X					X	X	
Charts								X								
Speed Tables			X					X						X		X
Changeable Message Signs		X							X					X	X	
Camera Views	X	X	X	X			X	X	X			X		X	X	
Historical Data				X				X								X
Incident listing	X	X	X	X			X	X	X		X	X		X	X	
Sound																
Three Dimensional																

Table 1. Site summary matrix. Light gray indicates a public criteria. Dark gray indicates a private criteria. Speed symbology is for both public and private criteria.

Site Identifier	Site Name	Technology Type	Update Interval
A	Current Phoenix Freeway Conditions - Arizona DOT	Image Map	120 seconds
B	District 8 Congestion Information - California DOT	Java Applet	60 seconds
C	San Diego Area Traffic Report	Static Image	60 seconds
D	Puget Sound Traffic Conditions WSDOT	Image Map	180 seconds

E	Traffic.com	Static Image	120 seconds
F	Branson, Missouri Live Traffic Map	Static Image	360 seconds – manual
G	Minneapolis / St. Paul Real Time Traffic Conditions	Static Image	60 seconds
H	Houston Real-Time Traffic map	Image Map	180 seconds
I	Georgia Navigator	Image Map	300 seconds
J	Athens Real-Time Traffic Volume Map	Image Map	180 seconds
K	Los Angeles City Traffic Conditions	Image Map	120 seconds
L	SmarTraveler	Image Map	Unknown
M	Chicagoland Expressway Congestion Map	Image Map and Java Applet versions	5 to 10 minutes
N	Gary-Chicago-Milwaukee Corridor	Java Servlet	60 seconds
O	TransGuide: Current Conditions Map	Image Map	5 minutes
P	San Diego Regional Traffic Forecast	Web Mapping System (ArcIMS)	N/A
Q	Kandui Viz	Plugin (Shockwave)	N/A

Table 2. Site key and auxiliary information for Table 1.

Site A: Current Phoenix Freeway Conditions - Arizona DOT

Current Phoenix Freeway Conditions - Arizona DOT satisfies 3 of 6 of the minimum what requirements for public visualization. An update interval of 120 seconds satisfies the public when requirement. Private visualization what requirements are not satisfied because only 3 of 17 requirements are met. No outstanding strengths exist for the site. The main weakness is the lack of a zoom feature. The small scale of the map makes it difficult to determine which streets are being shown and it's especially problematic for complex freeway interchanges. The ability to zoom in on the

intersections and interchanges would make it easier to visualize the traffic flow at those points.

Strengths	<ul style="list-style-type: none">• None
Weaknesses	<ul style="list-style-type: none">• No zoom

Table 3. Strengths and weaknesses for Current Phoenix Freeway Conditions - Arizona DOT.

Site B: District 8 Congestion Information - California DOT

District 8 Congestion Information - California DOT satisfies 4 of 6 of the public what requirements and 6 of 17 of the private what requirements. An update interval of 60 seconds satisfies the public when requirement. Strengths include the powerful zoom and pan features with the ability to easily zoom in or out and pan or zoom to a selected rectangle. Other strengths include the ability to have certain map features appear or not appear by selecting or deselecting a checkbox for a feature. Some of the features available to appear or not appear include: highways, CMS Icons, and secondary roads. The option to have features appear or not can assist the visualizer in focusing on the specific pieces of data that they are interested in. One weakness of the site is that it does not symbolize incident or construction information. But it does contain links to tables of incident and closure information.

Strengths	<ul style="list-style-type: none"> • Powerful zoom and pan tools • Features on or off via checkboxes
Weaknesses	<ul style="list-style-type: none"> • No symbolization for incidents or construction

Table 4. Strengths and weaknesses for District 8 Congestion Information – California DOT.

Site C: San Diego Area Traffic Report

San Diego Area Traffic Report is representative of the most basic type of traffic Web map. The site meets 1 out of 6 of the what requirements for public visualization and satisfies the public when requirement by having an update interval of 60 seconds. Three of 17 private what requirements are met. A strength is the ability to have a speed table in a frame next to the map in the same browser window allowing the map user to view the map and table at the same time. Weaknesses include a lack of detail due to a small scale map without the ability to zoom. Camera icons and the associated views are available but navigation to another map or page is required. No symbolization of incident or construction is available.

Strengths	<ul style="list-style-type: none"> • Can view speed table in a frame next to the map in the same browser window
Weaknesses	<ul style="list-style-type: none"> • No zoom • Camera icons and views are not accessible directly from the main traffic flow map page • No symbolization of incidents or construction

Table 5. Strengths and weaknesses for San Diego Area Traffic Report.

Site D: Puget Sound Traffic Conditions WSDOT

Puget Sound Traffic Conditions WSDOT meets 2 out of 6 of the minimum what public requirements and meets the public when requirement by having an update interval of 180 seconds. Five of 17 of the private what requirements are met. While it does not contain a zoom tool, options are available to link to maps with more detail of the selected area. A strength of the site is the inclusion of maps with historical traffic flow data with controls to move through time to view the data changes and thus satisfy the private when requirement. The site also allows expanded where capabilities by providing software for traffic data map access with a Palm device, a pocket or handheld PC (such as the Jornada and iPAQ), a Java-capable operating system or a stand-alone device such as TrafficGauge. There is no symbolization for incidents or construction but a link is available to an incident listing table.

Strengths	<ul style="list-style-type: none"> • Historical traffic maps • Temporal controls • Expanded where capabilities
Weaknesses	<ul style="list-style-type: none"> • No zoom • No symbolization of incidents or construction

Table 6. Strengths and weaknesses for Puget Sound Traffic Conditions WSDOT.

Site E: Traffic.com

Traffic.com provides traffic maps for a variety of cities. Data for some cities only include incidents and other alerts. Of the cities where traffic flow data is shown, 6 of 6 of the public what requirements are satisfied and an update interval of 120 seconds satisfies the when requirement. One of 17 of the private what requirements are met. The main strength is that all of the public requirements are satisfied. While a zoom feature does exist, it is limited to 1 level of zoom.

Strengths	<ul style="list-style-type: none"> • Meets all public level requirements
Weaknesses	<ul style="list-style-type: none"> • One level of zoom

Table 7. Strengths and weaknesses for Traffic.com.

Site F: Branson, Missouri Live Traffic Map

Branson, Missouri Live Traffic Map meets 3 of 6 of the public what requirements. While incident and construction icons do exist, no additional information about the incident or construction point is given other than the icon appearing on the map at a

location. The data refresh interval of 360 seconds is much longer than other sites and does not refresh in the browser automatically; the user needs to manually refresh the browser page. The update interval and the need to manually refresh the browser do not disqualify the site from meeting the public when requirement. No strengths exist for the site. None of the private requirements are met.

Strengths	<ul style="list-style-type: none"> • None
Weaknesses	<ul style="list-style-type: none"> • No zoom • No data associated with incident or construction points • Data refresh of 360 seconds with a necessary manual reload

Table 8. Strengths and weaknesses for Branson, Missouri Live Traffic Map.

Site G: Minneapolis / St. Paul Real Time Traffic Conditions

Minneapolis / St. Paul Real Time Traffic Conditions meets 3 of 6 public what requirements and satisfies the public when requirement by having an update interval of 60 seconds. Two of 17 private what requirements are met. A strength is the incident listing appearing in a frame next to the traffic map and in the same browser window. This allows for viewing of the incident information and the map at the same time. A separate map with camera locations and the camera images is available but it requires navigation away from the traffic flow map.

Strengths	<ul style="list-style-type: none"> • Incident list appears in frame next to map in same browser window
Weaknesses	<ul style="list-style-type: none"> • No zoom • Camera map and view access requires navigation away from the traffic map

Table 9. Strengths and weaknesses for Minneapolis / St. Paul Real Time Traffic Conditions.

Site H: Houston Real-Time Traffic Map

Houston Real-Time Traffic map satisfies 2 of 6 of the public what requirements and 8 of 17 private what requirements. An update interval of 180 seconds satisfies the public when requirement. Strengths include the ability to view historical data and maps with controls to move through time and view the data changes. The historical data and temporal controls satisfy the private when requirement. Other strengths include the availability of speed charts and tables. The only obvious weakness is the inability to zoom into the map.

Strengths	<ul style="list-style-type: none"> • Historical data maps with temporal controls • Speed charts and tables
Weaknesses	<ul style="list-style-type: none"> • No zoom

Table 10. Strengths and weaknesses for Houston Real-Time Traffic Map.

Site I: Georgia Navigator

Georgia Navigator meets all of the public what requirements and 6 of 17 private what requirements. An update interval of 300 seconds is longer than most other sites but still within the limits to satisfy the public when requirement. The site provides potentially expanded where abilities by the planned implementation of over 110 traveler information kiosks to be located at highway rest areas, government buildings, and transportation hubs around Georgia. The kiosks would include touch screen displays and up to the minute traffic conditions. Strengths of the site include the ability to turn off the sign and camera icons via checkboxes. The map can be also be automatically refreshed by selecting a checkbox and the settings can be saved via another checkbox. The one level of zoom is the only apparent weakness.

Strengths	<ul style="list-style-type: none">• Meets all requirements for public visualization• Checkboxes to turn off sign and camera icons• Checkbox to automatically refresh map• Checkbox to save map settings
Weaknesses	<ul style="list-style-type: none">• One level of zoom

Table 11. Strengths and weaknesses for Georgia Navigator.

Site J: Athens Real-Time Traffic Volume Map

Athens Real-Time Traffic Volume Map meets 2 of 6 public what requirements and none of the private what requirements. The zoom-like feature works by selecting one

of four sections of the city from a central map. The result is a more detailed view of the selected city region. An update interval of 180 seconds satisfies the public when requirement.

Strengths	<ul style="list-style-type: none"> • None
Weaknesses	<ul style="list-style-type: none"> • No incident or construction symbology

Table 12. Strengths and weaknesses for Athens Real-Time Traffic Volume Map.

Site K: Los Angeles City Traffic Conditions

Los Angeles City Traffic Conditions satisfies 4 of 6 of the public what requirements and an update interval of 120 seconds satisfies the when requirement. One of the 17 private what requirements are met. The map's strongest point is the inclusion of links to quickly view traffic maps of particular points of interest. In a frame to the left of the map are Quick Links to traffic maps of popular sections of the city such as Dodger Stadium. Weaknesses include the lack of incident or construction symbology.

Strengths	<ul style="list-style-type: none"> • Links to traffic maps of popular sections of the city
Weaknesses	<ul style="list-style-type: none"> • No incident or construction symbology

Table 13. Strengths and weaknesses for Los Angeles City Traffic Conditions.

Site L: SmarTraveler

SmarTraveler provides traffic data for a variety of cities. Clickable city maps are available which link to a text description or table of the traffic information. The maps are

only really useful for selecting a road for which traffic information is desired. No speed symbology is available on the map and none of the public what requirements are met. Two of the 17 private what requirements are met. The when requirement is also not met because it is unclear how often the traffic data is updated. Some cities have links to traffic camera views.

Strengths	<ul style="list-style-type: none"> • None
Weaknesses	<ul style="list-style-type: none"> • No speed symbology • Unknown traffic data update interval

Table 14. Strengths and weaknesses for SmarTraveler.

Site M: Chicagoland Expressway Congestion Map

Chicagoland Expressway Congestion Map meets 4 out of 6 of the public what requirements but is missing a necessary zoom feature. The small scale of the map limits the visualization capabilities by not allowing the necessary detail to be viewed. The map update interval of 5 to 10 minutes is longer than most sites but is still within a reasonable amount of time to satisfy the public when requirement. It is worthwhile to note that the traffic data is collected every 60 seconds but it takes 5 to 10 minutes for the map to be generated with the traffic data symbolization. The image map and Java applet versions of the site behave and look about the same. The only major difference is the Java version has checkboxes to turn off or on certain symbology such as construction or incidents. Two of 17 private what requirements are met.

Strengths	<ul style="list-style-type: none"> • None
Weaknesses	<ul style="list-style-type: none"> • No zoom

Table 15. Strengths and weaknesses for Chicagoland Expressway Congestion Map.

Site N: Gary-Chicago-Milwaukee Corridor

Gary-Chicago-Milwaukee Corridor satisfies all of the public what requirements and 7 of 17 of the private what requirements. An update interval of 60 seconds satisfies the public when requirement. A unique strength of the map is the ability for the user to set preferences of what sections of the map to view. A My Travel screen can be accessed which allows the saving of preferred road segments and the associated data. The next time the traffic map is accessed, the view will be set to the user preferred road or area. Map layer control is available by selecting or deselecting buttons to have map features or icons appear or not appear. One weakness of the site is the modal access to camera views, speed tables, CMS messages, and incident listings. To access and view these data, navigation away from the traffic map is required.

Strengths	<ul style="list-style-type: none"> • Meets all public requirements • Ability to save user preferences for roads or areas of interest
Weaknesses	<ul style="list-style-type: none"> • Modal access to camera views, speed tables, CMS messages, and incident listings

Table 16. Strengths and weaknesses for Gary-Chicago-Milwaukee Corridor.

Site O: TransGuide: Current Conditions Map

TransGuide: Current Conditions Map meets 4 of 6 of the public what requirements. A zoom feature is not specifically available but an option is available to view detailed portions of the traffic map. The detailed maps of sub areas provide an adequate level of zoom without the need of a zoom tool. A data update interval of 5 minutes satisfies the public when requirement. The main strength of the site is that CMS sign data, camera views, and information for a selected road segment or point show up next to the map in the same browser window. This allows the visualizer access to the selected information with the ability to view the map at the same time. Six of 17 of the private what requirements are met.

Strengths	<ul style="list-style-type: none">• Map data available in same view as traffic map
Weaknesses	<ul style="list-style-type: none">• None for the public visualizer

Table 17. Strengths and weaknesses for TransGuide: Current Conditions Map.

Site P: San Diego Regional Traffic Forecast

San Diego Regional Traffic Forecast as the name indicates, provides projected traffic volume information and also meets 5 of 17 of the private what requirements. Three of 6 public what requirements are met. The public when requirement is not met because real-time data is not available. The site strengths include the availability of tools to interact with the map and data. On or off control of multiple map layers is available via checkboxes. Layers include: freeways, local roads, traffic analysis zones, and

jurisdictions. The main weakness is the lack of speed symbolization. Use of the site is primarily for private visualization.

Strengths	<ul style="list-style-type: none">• Meets many private requirements not met in other sites• Map layer control
Weaknesses	<ul style="list-style-type: none">• No speed symbology

Table 18. Strengths and weaknesses for San Diego Regional Traffic Forecast.

Site Q: Kandui Viz

Kandui Viz is a Shockwave plugin and is primarily a prototype for implementing proportional circle speed symbolization with temporal control. Data point on or off control is also available via checkboxes. Potential strengths include the unique visualization opportunities of proportional circles combined with the ability to isolate data points and view the changes through time. The main weakness of the site is that it is in the experimental stage and not fully implemented or connected to an actual real-time traffic data collection system. One of 6 public what requirements are met and 2 of 17 private what requirements are met.

Strengths	<ul style="list-style-type: none"> • Proportional circle visualization alternative to colored segments or points • Data point on or off control
Weaknesses	<ul style="list-style-type: none"> • Experimental and not fully implemented or integrated with data collection system

Table 19. Strengths and weaknesses for Kandui Viz.

Public Level Evaluation

Public level requirements for traffic visualization are generally satisfied based on the results in Tables 1, 2, and in the subsequent evaluation and discussion of the individual sites.

Most of the evaluated sites and their associated technology types are capable of delivering the basic symbolization, controls and tools necessary for what the public visualizer receives and requires as listed and defined in chapter 3. Incident and construction symbology is frequently missing and thus limits the visualizer in correlating those phenomena with the traffic flow data on the map. The controls and tools identified as optional (zoom, pan, and change location) are frequently available for the sites that need them. But, there are sites that need a zoom and do not have it. The lack of a zoom restricts the investigation of complex freeway interchanges or other areas where the visualizer needs more detail.

Most automobile traffic Web sites are geared towards use with a personal computer browser. So the question of where the public user is receiving the information is primarily limited to places with an Internet connection and a computer with a display and a Web browser. Additionally, cellular phones, car navigation systems, and handheld devices may also include the ability to receive traffic information. Each site is available via a personal computer Web browser and in addition to the availability provided by kiosks, cell phones, handheld devices, and car navigation systems, the where requirement is satisfied for public visualizers.

Public visualizers need updated and current traffic information. As examined in the technologies and presentation section of chapter 3, updates can occur automatically or manually. The updates are usually at a satisfactory interval to allow the user access to reasonably current information. The update intervals range from about 1 to 5 minutes with the option of a manual refresh to update more frequently if new data is available. The when requirement for public visualizers is satisfied by being within the 5 minute maximum update interval.

The public visualizer is not usually concerned with how the traffic information gets to the map and Web browser but is concerned with the resulting implementation. As stated earlier, the technology is a means to an end and for the public visualizer that technology frequently satisfies the requirements for the evaluated sites. The available technology satisfies the how requirements for a public visualizer.

Private Level Evaluation

Private level requirements for traffic visualization are generally not satisfied based on the results in Tables 1, 2, and in the subsequent evaluation and discussion of the individual sites. While no single site meets all the requirements, some sites do meet the individual requirements.

Private level visualizers require what the public visualizer does plus more. Many of the what requirements for the private visualizer are lacking in currently available traffic Web maps. The ability to modify symbolization or to manipulate the graphic and dynamic variables does not exist in any of the evaluated traffic sites. The cartographer would need to create the symbolization and modify the variables during the initial map creation process and before the map is published or made available on a Web page. Once the map is displayed, the ability to change the symbols and variables will not exist. MapQuest, for example, does not provide traffic data but does provide Web-based maps that can be customized by the user. Map customization options include the ability to choose a map style that represents a color theme such as neutral or bright which can be applied to the map. Options also exist for changing map icons and labels. With the possible exception of ArcIMS, there are few Web-based mapping solutions analogous to a desktop GIS environment where map attributes and symbolization can be changed relatively easily then presented; and even in this case, the changes would need to occur before the map is presented on the Web page. Sound and 3-D are apparently not being used in Web traffic maps. While the usefulness of 3-D in a traffic visualization context can be questioned, it may be useful to show how terrain changes affect traffic flow. For

example, a 3-D animation may be useful to visualize the correlation of steep roads to an increase in traffic congestion. Sound may have some uses to help explain the data or key the private visualizer to important events. Traffic data in chart or plot form does exist. Chapter 4 discussed charts and tables and gave examples in Figures 12, 13 and 14. Time manipulation of historical or projected data somewhat exists. The animation of the historical data in Figure 19 and the projected data available in Figure 33 are examples. Granular time controls allowing for incremental adjustments are available for some of the sites that have historical data. The ability to search, query, select and identify data is not widely available in current traffic map sites. The lack of these controls and tools limits the private user's interaction and analysis of the map and traffic data. The what requirements are deficient in most areas for the private visualizer and the requirements are generally not satisfied.

Private visualizers include traffic engineers, researchers, and academics and have at least the same access to traffic Web sites as public visualizers. Private visualizers usually operate out of offices, schools, or research institutions that commonly have access to the Internet and computing facilities. Because of these resources, the where requirement is generally satisfied for the private level visualizer.

Private level visualizers require some information in real-time but can accept a delay in accessing or viewing historical or projected data. The sites with historical or projected data allow access to it via links to separate pages with that information and thus the access to the information is can be made easily available when it does exist. Some delay in presentation may occur when processing or calculating the data for historical or

future traffic data, but frequently this data has already been generated and made available. Delays can also occur when receiving data from the traffic sensors but the lag time is acceptable enough to still call it real-time data as discussed in the satisfaction of the when requirement for public level visualizers. Historical, present, and future traffic data is available for some sites and leads to a satisfaction of the when requirement for private level visualizers for those sites.

The private visualizer is interested in how the traffic information gets to the Web page. These users may be concerned with the entire process from data collection to data processing to map creation to final presentation. Each stage in the process can allow insight into the data and help provide a more complete understanding that can assist in visualization. The technology to process and present the data is also a concern for private visualizers. Of the technology types discussed in chapter 4, Java and ArcIMS type products and systems offer the most powerful means to interact and visualize the traffic data. ArcIMS and Web mapping systems offer GIS level interaction tools with a means to publish and present the data in a Web map with an interface for the tools. Java allows database access, built-in Web technology, and is a powerful programming language. Steiner, MacEachren, and Guo (2001) point out that one of the challenges is that developers and other users would need to master formal computer programming and even the best tools can impose a serious limitation on graphic design. Steiner, MacEachren, and Guo also note that designing in Flash has distinct advantages including less design time for prototyping and creating functional tools and visualization interfaces. As

indicated in the public how section, map design is important. The private visualizer has access to adequate tools to satisfy the how requirement.

CHAPTER SIX

RESULTS

This thesis evaluated existing Web-based approaches to traffic flow maps against the visualization needs of public and private level users. Components of each evaluated traffic flow Web site were itemized and categorized then compared against specific user requirements. The following is a summary of the evaluation results, ideas for future research, and conclusions.

Based on the evaluations in chapter 5, Traffic.com, Georgia Navigator, and Gary-Chicago-Milwaukee Corridor satisfy all public visualization requirements. No site satisfies all the private requirements, but some individual private requirements are met by some sites. For public visualizers, important attributes such as zoom, pan, change location, incident and construction symbolization are frequently missing from the evaluated sites resulting in the site being disqualified from satisfying the public requirements. The private level visualizer is missing many of the attributes necessary to meet their requirements. Specifically, sound, 3-D, symbolization and graphic and dynamic variable manipulation are not available. Search, query, select and identify existed only in the San Diego Regional Traffic Forecast site. The update intervals and site availability were satisfactory for most sites. Static map, image map, and Java servlet technologies are the three types that were used in the sites that met all public requirements. A mix of technology types were used for the sites satisfying individual private requirements.

Future Research

Research into tools and interfaces to allow more private level visualization is needed. The ability to change map symbols and graphic and dynamic variables at the presentation level would be useful. Map user profiles, as discussed in chapter 2, may be useful for determining a public or private user type that would then influence the interface and tools available to the traffic map user.

Combinations of technologies may provide for flexibility in development and the end solution. Studies could be conducted to determine an optimum technology combination for a specific visualization need. For example, Steiner, MacEachren, and Guo (2001) discuss the development and implementation of a geovisualization tool with a Flash front end interface that communicates via XML to Java servlets or Java servers which in turn can communicate with a database. This solution takes advantage of the development speed and graphical manipulation benefits of Flash while still using the powerful capabilities of Java including the ability to access a database.

While colored segments, colored points, and other icons do an adequate job of symbolizing traffic and events, Brewer (1998) offers some alternatives to these and other traditional symbolization methods. Line width can also be used to visualize volume as shown in Johnson and Nelson (1998). As mentioned in chapter 3, graphics quality in a Web-based traffic map implementation is worth researching. Graphics quality issues include: color guidelines, resolutions, icon sizes and placement, as well as any other general user interface guidelines.

Flow control of liquid, gasses, or computer network traffic can offer some unique perspectives on modeling traffic flow. These fields have produced models to simulate or visualize flows.

Conclusion

The evaluation results show that public level visualizers have available the symbology, tools, controls, features, and technologies to satisfy their traffic flow visualization needs. Three sites were identified as satisfying all public requirements. No one site fully satisfies all the requirements for private visualization. The private visualizer has adequate technology available, but all of the visualization requirements do not exist in a single implementation.

REFERENCES

- Alam, M., Melchiorre, and Clayton, A. (1999). Development of Intranet/Internet Applications for the Dynamic Presentation of a Cross-Jurisdictional Transportation Database. In H. Perkins (Ed.), *GIS Technologies for the Transportation Industry* (pp. 4-47 - 4-60). Park Ridge, US: The Urban and Regional Information Systems Association.
- Athens Real-Time Traffic Volume Map. (2003). Retrieved October 21, 2003, from <http://www.transport.ntua.gr/map/vcmap.html>
- Bertin, J. (1983). *Semiology of Graphics* (W. J. Berg, Trans.). Madison: The University of Wisconsin Press. (Original work published 1967).
- Boxill, S.A., and Yu, L. (2000). *An Evaluation of Traffic Simulation Models for Supporting ITS Development* (Report No. SWUTC/00/167602-1). Houston, Texas: Texas Southern University, Center for Transportation Training and Research.
- Branson, Missouri Live Traffic Map. (2003). Retrieved October 21, 2003, from <http://www.baimc.com/ssi.html>
- Brewer, C.A., and Campbell, A.J. (1998). Beyond Graduated Circles: Varied Point Symbols for Representing Quantitative Data on Maps. *Cartographic Perspectives*, 29, 6-25.
- Brost, G. (2003). *Kandui Viz* (Version 1.0) [Computer Software]. Santa Cruz, CA: Kandui.
- California Highway Patrol Traffic Incident Information Page. (2002). Retrieved October 19, 2002, from <http://cad.chp.ca.gov/>
- CHART On The Web. (2002). Retrieved October 20, 2002, from <http://www.chart.state.md.us/mapping/CHARTMap.asp>
- Chicagoland Expressway Congestion Map. (2003). Retrieved October 21, 2003, from <http://www.ai.uic.edu/GCM/CongestionMap.html>
- Current Phoenix Freeway Conditions-Arizona DOT. (2003). Retrieved October 21, 2003, from <http://www.azfms.com/Travel/freeway.html>

- DiBiase, D. (1990). Visualization in Earth Sciences. *Earth and Mineral Sciences, Bulletin of the College of Earth and Mineral Sciences, Pennsylvania State University*, 59(2), 13-18.
- DiBiase, D.W., MacEachren, A.M., Krygier, J.B., & Reeves, C. (1992). Animation and the Role of Map Design in Scientific Visualization. *Cartography and Geographic Information Systems*, 19(4), 201-214, 265-266.
- District 8 Congestion Information - California DOT. (2002). Retrieved October 15, 18, 2002, from <http://www.dot.ca.gov/dist8/tmc/webmap.htm>
- Emmer, N.N.M. (2001). Web Maps and Road Traffic. In M-J. Kraak and A. Brown (Eds.), *Web Cartography* (pp. 159-170). London, UK: Taylor & Francis.
- Feng, C., Wei, H., and Lee, J.L. (1999). WWW-GIS Strategies for Transportation Applications. In H. Perkins (Ed.), *GIS Technologies for the Transportation Industry* (pp. 4-1 - 4-10). Park Ridge, US: The Urban and Regional Information Systems Association.
- Gary-Chicago-Milwaukee Corridor. (2002). Retrieved October 15, 2002, from http://www.gcmtravel.com/gcm/maps_gary.jsp
- Georgia Navigator. (2002). Retrieved October 16, 2002, from <http://www.georgia-navigator.com/>
- Homburger, W.S., and Kell, J.H. (1963). *Fundamentals of Traffic Engineering*. Berkeley, California: Institute of Transportation Studies, University of California.
- Houston Real-Time Traffic Map. (2002). Retrieved October 16, 19, 2002, from <http://traffic.tamu.edu/incmap/incmap.asp>
- Johnson, H., and Nelson, E.S. (1998). Using Flow Maps to Visualize Time-Series Data: Comparing the Effectiveness of a Paper Map Series, a Computer Map Series, and Animation. *Cartographic Perspectives*, 30(Spring), 47-64.
- Koussoulakou, A. (1994). Spatial-Temporal Analysis of Urban Air Pollution. In A.M. MacEachren and D.R. Taylor (Eds.), *Visualization in Modern Cartography* (pp. 243-268). Oxford, UK: Pergamon.
- Kraak, M-J., and Van Driel, R. (1997). Principles of Hypermaps. *Computers and Geosciences*, 23(4), 457-464.

- Kryger, J.B. (1995). Sound and Geographic Visualization. In A.M. MacEachren and D.R. Taylor (Eds.), *Visualization in Modern Cartography* (pp.149-166). Oxford, UK: Pergamon.
- Los Angeles City Traffic Conditions. (2002). Retrieved October 18, 2002, from <http://trafficinfo.lacity.org/>
- Limp, F.W. (2001, February). User Needs Drive Web Mapping Product Selection. *GEOWorld 2001 Guide to Web Mapping*, 14, 8-14.
- MacEachren, A. M. (1995). *How Maps Work*. New York: The Guilford Press.
- MacEachren, A.M. (1994). Visualization in Modern Cartography: Setting the Agenda. In A.M. MacEachren & D.R.F. Taylor (Eds.), *Visualization in Modern Cartography* (pp. 1-11). New York, NY: Elsevier.
- MacEachren, A.M. (1998). *Visualization - Cartography for the 21st Century*. Retrieved June 8, 2003, from Pennsylvania State University, International Cartographic Association Commission on Visualization Web site: <http://www.geovista.psu.edu/sites/icavis/icavis/poland1.html>
- MacEachren, A.M., and Monmonier, M. (1992). Introduction. *Cartography and Geographic Information Systems*, 19(4), 197-200.
- MapQuest (2002). Retrieved September 12, 2002, from <http://www.mapquest.com>
- McCormick, B., DeFanti, T.A., and Brown, M.D. (1987). Visualization in Scientific Computing. *Computer Graphics*, 21(6).
- McKee, L. (2001, February). Geography Connects Cyberspace with the Real World. *GEOWorld 2001 Guide to Web Mapping*, 14, 2-6.
- Minneapolis / St. Paul Real Time Traffic Conditions. (2002). Retrieved October 18, 2002, from <http://www.dot.state.mn.us/tmc/trafficinfo/map/refreshmap.html>
- Moellering, H. (1980). The Real-Time Animation of Three-Dimensional Maps. *The American Cartographer*, 7(1), 67-75.
- Monmonier, M. (1992). Authoring Graphic Scripts: Experiences and Principles. *Cartography and Geographic Information Systems*, 19(4), 247-260, 272.
- Nambisan, S.S., Jensen, J.J., Puterski, R., Miller, T.D., and Park, C.H. (1999). Prototype Internet Applications for Transportation System Management. In H. Perkins

(Ed.), *GIS Technologies for the Transportation Industry* (pp. 4-11 - 4-26). Park Ridge, US: The Urban and Regional Information Systems Association.

Peterson, M.P. (1997). Retrieved April 8, 1997, from
<http://maps.unomaha.edu/books/IACart/book.html>

Puget Sound Traffic Conditions WSDOT. (2002). Retrieved October 10, 2002,
November 25, 2002, from <http://www.wsdot.wa.gov/PugetSoundTraffic/>

Ran, B., Chang, B.P., and Chen, J. (1999). Architecture Development for Web-Based GIS Applications in Transportation. In H. Perkins (Ed.), *GIS Technologies for the Transportation Industry* (pp. 4-27 - 4-45). Park Ridge, US: The Urban and Regional Information Systems Association.

San Diego Area Traffic Report. (2002). Retrieved October 10, 2002 from
<http://www.dot.ca.gov/dist11/d11tmc/sdmap/mapmain.html>

San Diego Regional Traffic Forecast. (2002). Retrieved October 15, 2002, from
<http://pele.sandag.org/trfic.html>

SmarTraveler South Florida Map. (2003). Retrieved January 8, 2003, from
[http://www.smartraveler.com/scripts/
miamidademap.asp?city=sfl&cityname=South+Florida](http://www.smartraveler.com/scripts/miamidademap.asp?city=sfl&cityname=South+Florida)

Steiner, E.B., MacEachren, A.M., and Guo, D. (2001). Developing and assessing light-weight data-driven exploratory geovisualization tools for the web. 20th International Cartographic Conference, Beijing, China, August 6-10, 2001. Retrieved August 4, 2002, from Pennsylvania State University, Department of Geography, GeoVISTA Center Web site
http://www.geovista.psu.edu/publications/Beijing01/SteinerICA01/flash_db2.htm

Traffic.com. (2002). Retrieved October 18, 2002, from <http://www.traffic.com>

TransGuide: Current Conditions Map. (2002). Retrieved October 19, 2002, from
<http://www.transguide.dot.state.tx.us/Traffic/ccmap.php>