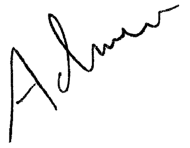
Technical Report UMTRI-99-30 November, 1999

The Development of Traffic-Information Web-Site-Design Guidelines

Christopher Nowakowski
John Lenneman
Mark Kojima
Paul Green

HUMAN FACTORS

UMTRI The University of Michigan Transportation Research Institute



Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-99-30		

4. Title and Subtitle The Development of Traffic-Information Web-Site-Design Guidelines	5. Report Date November, 1999 6. Performing Organization Code account 376102
7. Author(s) Christopher Nowakowski, John Lenneman, Mark Kojima, and Paul Green	8. Performing Organization Report No. UMTRI-99-30
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute (UMTRI) 2901 Baxter Rd, Ann Arbor, Michigan 48109-2150 USA	10. Work Unit no. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Matsushita Communication Industrial Co. Ltd. Information Systems Division 4-3-1, Tsunashima-Higashi, Kohoku-Ku, Yokohama 223-8639 Japan	13. Type of Report and Period Covered 1/99 - 11/99 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

At least 30 major cities and metropolitan areas in the U.S. have implemented real-time, traffic-information web sites to provide pretrip traffic information. Although general web-site-design guidelines are plentiful, no design guidelines were found specific to traffic-information web sites.

This project used 4 methods to create and evaluate traffic-information web sites: (1) user analysis, (2) heuristic evaluation, (3) the use of web-design guidelines, and (4) user testing. The knowledge gained from these 4 steps was then combined to form a set of traffic-information web-site-design guidelines. A total of 8 general principles (e.g., consistency, readability, etc.) and 33 specific guidelines in 4 categories (site organization, site navigation, real-time traffic-information presentation, and real-time map colors symbols, and design) were created.

The heuristic evaluation of 7 traffic-information web sites revealed problems involving violations of consistency, visibility (as to where the user was and where he could go next), and flexibility or efficiency of use. User testing revealed problems with unexpected feature implementations, confusing icons, legends or instructions, and feature or formats that were difficult to use or frustrating.

Although there were strengths and weaknesses in each method, guidelines use and user testing were found to be the most beneficial methods given the likely resources available in the traffic management center to develop a traffic-information web site.

17. Key Words	18. Distribution Statement
ITS, human factors, ergonomics, Intelligent Transportation Systems, traffic control center, Internet, web design, traffic management center	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classify. (of this report)	20. Security Classify. (of this page)	21. No. of pages	22. Price
(None)	(None)	106	

Form DOT F 1700 7 (8-72) Reproduction of completed page authorized

The Development of Traffic-Information Web-Site-Design Guidelines

UMTRI Technical Report 99-30
Christopher Nowakowski, John Lenneman, Mark Kojima, and Paul Green
University of Michigan
Ann Arbor, Michigan, USA

1 Issues

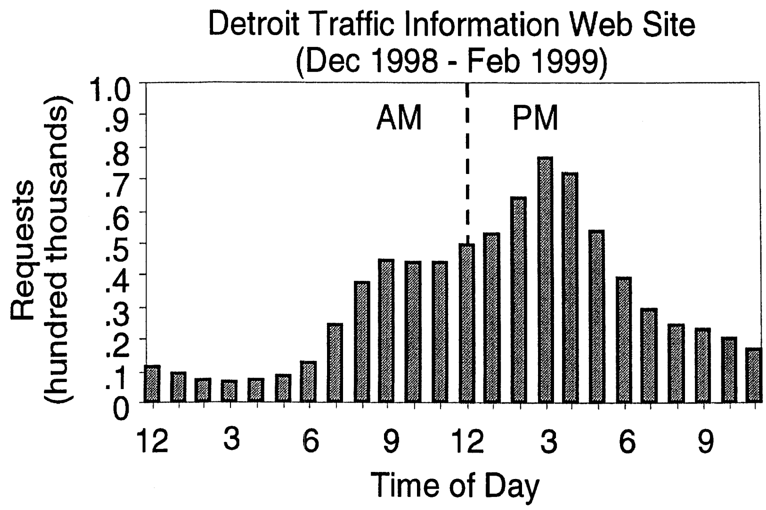
Approach	Questions
Current Users Analysis	Who are the current users of traffic-information web sites? When do users check traffic-information web sites? Which traffic-information web-site pages do they view?
Heuristic Evaluation	What kinds of problems were found in the heuristic evaluation? What were the advantages/disadvantages of this method?
Guidelines, Prototyping, and User Testing	What kinds of problems were found with user testing? What were the advantages/disadvantages of these methods?

2 Current Users Analysis

Who are the current users of traffic-information web sites?

1. Personal use through an ISP via dial-up, ISDN, or cable modem
2. Personal use by the employess of primarily white-collar companies in the city
3. Personal use by university faculty and students of "commuter" schools
4. Use by manufacturing companies to aid in routing trucks and parts
5. Use by companies providing on-site delivery or services
6. Use by third-party traffic-information providers

When do users check traffic information web sites?



Conclusions

1. Peak web-site usage occurs during the afternoon rush hours.
2. Traffic information web sites are not as effective at influencing morning rush hours.

Which traffic-information web-site pages do they view?

Chicago	Detroit	Requested
• Congestion overview map	• Congestion overview map	Most
• Travel-time overview (text based)	• Directory index and main menu	↑
• Detailed loop-detector speed and congestion estimates for specific freeway segments (text based)	• Links page (AAA traffic reports, AAA construction information, and various weather pages)	
• Construction information	• Detailed congestion maps of specific interchanges	
• Directory index and main menu	• MDOT construction information	↓
• Various area specific maps and more detailed loop-detector info		Least

3 Heuristic Evaluation

What kinds of problems were found in the heuristic evaluation?

- Visibility – Did the user know where he was and where he could go next?
- Consistency – Did features look, feel, and function similarly?
- Flexibility and efficiency – Were excessive steps needed to find the information?

Advantages

- A quick first-cut method to detect problems that may cause users to get "stuck"

Disadvantages

- Requires 3-5 human factors experts
- Experts are not "users" and can miss problems that cause users difficulty

4 The Use of Guidelines Alone vs. User Testing

What kinds of problems were found with user testing?

1. Instructions or features that were not noticed, not used, or caused confusion
   e.g., the menu bar provided did not contain useful links and, thus, wasn't used.
2. Confusing icons or legends
   e.g., grey colored roads were not defined in the legend and caused confusion.
3. Features did not function as the user expected
   e.g., a pull down menu with a seperate activation button caused problems even though the design was commonly found on the web.
4. Features or formats caused frustration
   e.g., the travel times table caused problems for Detroit users.

Advantages

- Guidelines provided a good design start
- The majority of problems were quickly found during user testing with 3-5 real users on a limited prototype without real-time data

Disadvantages

- The use of guidelines alone did not guarantee a usable web site
- User testing required that real users, including novices, be recruited from outside the TMC.
- Novice users got "stuck" easily

PREFACE

This report represents the third and final report written by the University of Michigan Transportation Research Institute (UMTRI) to assist Matsushita Communication Industrial Co., Ltd. in designing easy-to-use traffic management centers (TMCs). The focus of this project was originally on the development of human-factors guidelines for those centers. Mark Kojima served as the project liaison from Panasonic and was a visiting engineer at UMTRI for a portion of the project.

In the first phase of the project, the literature on human factors and TMCs was reviewed (Nowakowski, Green, and Kojima, 1999). The review highlighted the value of the first edition (Kelly, 1995) of the Georgia Tech human-factors guidelines. The second edition (Georgia Tech Research Institute, 1998) has recently been released. UMTRI has not compared the two editions to determine the differences.

In the second phase of the project (Kojima, Nowakowski, and Green, 1999), two local TMCs were examined in detail: (1) the Michigan Department of Transportation (MDOT) control center for the freeways in the Detroit area and (2) a center operated by Oakland County just north of Detroit. These examinations provided a basis for understanding the practical problems of TMC design.

In combination, these 2 studies highlighted the need to expand and enhance the human-factors literature on the use of internet web sites as a means of disseminating traffic information. Although there were numerous guidelines for web design, none were specific to traffic data. Accordingly, this third report has focused on the design of usable traffic-information web sites.

TABLE OF CONTENTS

INTRODUCTION

Overview

The number of vehicles and the number of vehicle miles driven in the United States have more than doubled in the past 25 years, but the miles of roads have only increased by about 5 percent for the same time period (Office of Highway Information Management, 1995). As more and more cities have begun to experience traffic congestion problems, the United States federal government passed 2 acts (the Intermodal Surface Transportation Efficiency Act, 1991, and the Transportation Equity Act for the 21st Century, 1998) to provide funding for state and local governments to monitor and manage traffic.

Although much effort and funding has gone into installing the monitoring equipment and building traffic management centers (TMCs), the centers themselves have few direct controls over traffic. Largely, their ability to manage traffic is dependent upon how well and how quickly they can disseminate traffic information to drivers in the hope that the drivers will utilize that information and avoid congestion.

Traditionally, traffic information has been disseminated to the public through commercial radio and TV, variable message signs (VMSs) installed along the roads, and through highway advisory radio (HAR), a low-powered broadcast dedicated to local traffic information. (HAR areas are usually denoted by freeway signs that might read something like "Tune to 890 AM for Traffic Information.") These information dissemination mechanisms can be classified into 2 categories: 1) pretrip and 2) enroute. A well-rounded information-dissemination strategy will include a combination of both pretrip and enroute information sources. One new, but promising, pretrip information source is Internet web sites.

According to the Oak Ridge National Laboratory Intelligent Transportation Infrastructure Deployment web site (http://itsdeployment.ed.ornl.gov), at least 70 major cities engage in freeway traffic management. At least 30 of these cities have web sites that provide drivers with real-time traffic information.

In general, traffic-information web sites offer the potential to provide a relatively low cost and reliable mechanism for information dissemination. However, the web sites can also have a number of problems which can cause users (1) to become frustrated with the site, (2) to receive misleading or insufficient traffic information, (3) to lose faith in the credibility of the web site's information, and (4) to eventually abandon web sites as a means of obtaining traffic information. This report addresses numerous issues that need to be considered to create a well-designed, reliable, traffic-information web site.

Issues

Designers face many crucial decisions when developing a traffic-information web site. For example, designers must choose between text or map displays as the method for relaying traffic information. Currently, existing web sites vary considerably in format. Some web sites opt for text displays to provide speed information while others use color coding and icons on a real-time map. In addition, designers may need to decide whether camera photos, message signs, incident reports, and construction reports should be included on the web site.

Failure to understand how certain decisions can affect the overall usability can ultimately lead to the creation of a poorly designed web site. For example, one web site provided the users with information about the time it would take to travel a road under the current traffic conditions. The time was presented as minutes in a black or white box (depending on the direction of travel) next to the road (Figure 1). However, the travel times being displayed lacked context. There was no way to determine the start point and end point for the given travel time. Thus, the 37-minute travel time shown could have been for a 15-mile section or for a 40-mile section of the road. Adjacent travel times may be additive, or they may cover overlapping areas.

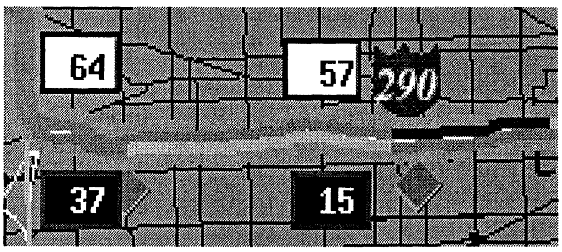


Figure 1. Times to travel along I-290 outside Chicago.

The preceding example was just one of a number of problems found that detract from the overall usability of a traffic-information web site. The goal of this study was to develop a set of guidelines for the creation of easy-to-use traffic-information web sites. The guidelines were based on the following sources:

- An analysis of the current users of traffic-information web sites
- A brief review of previous web-related research and guidelines
- A heuristic evaluation of 7 current traffic-information web sites
- Usability testing of a traffic-information web site based on the initial guidelines

The authors strongly believe that guidelines should emerge from real design (Green, Levison, Paelke, and Serafin, 1993), and they should not simply be a superset of the conclusions and recommendations found in the current literature. The classical superset approach often results in a guideline set that is too large to use and does not address the most important design issues.

Therefore, to provide a design context, a hypothetical traffic-information web site was developed for Detroit. As part of that effort, 4 background issues were addressed and summarized in this report.

1. What are the characteristics of traffic-information web-site users?
2. Who are the providers of traffic-information web sites?
3. What features are currently provided on traffic-information web sites?
4. What are the common usability problems in current traffic-information web sites?

TRAFFIC-INFORMATION WEB-SITE USAGE

Who are the users of the Internet?

Recent estimates are that by the end of 1998, there were 147,800,000 Internet users world wide, and 52 percent (77 million) of those users resided in the U.S. (as cited in the May, 1999, edition of the Internet Index, http://www.openmarket.com/intindex/). According to Georgia Tech's Graphic, Visualization, and Usability Center's (GVU) 10th WWW User Survey (Rossignac, Pitkow, Rogers, Aggarwal, Sutton, and Malholtra, 1998), at least 92 percent of the Internet users are over the age of 21, and there are twice as many males as females currently on the Internet. The bulk of the Internet users reside in urban or suburban locations (86.2 percent), and at least 51 percent reported having a household income between $20,000 and $75,000 per year weighted more heavily towards the high end (compared with the median U.S. household income of $37,005 according to the 1997 U.S. Census Bureau statistics available on the web at http://www.census.gov).

A second important set of questions about the basic users of the Internet address how users access the Internet and how long they have been using the Internet. Over 78 percent of the Internet users have daily access from their home, while only 4.6 percent have no access from home. Conversely, 57.3 percent have daily access to the Internet through work, while 31.5 percent have no access from work. Over 87 percent have been on the Internet for over 1 year with 79.7 percent reporting that they were very comfortable with their Internet skills.

Who are the users of traffic-information web sites?

To identify these users, the server statistics from 2 traffic-information web sites were examined. The server statistics for the Gary-Chicago-Milwaukee Corridor traffic-information web site (http://www.ai.eecs.uic.edu/GCM) were publicly available from http://www.ai.eecs.uic.edu/GCM//stats/Statistics.html. The summary period analyzed was from November 1, 1995 to March 15, 1999. The server statistics provided the IP (internet protocol) number of the requesting computer and the number of requests received from that number during the 3.5-year period. Since the analysis period stretches for several years, the distribution of requests per month or even per year for any given IP number is unknown. It is also possible that IP numbers may have changed owners given the long duration of the analysis period.

The server statistics for the Michigan ITS: Detroit Freeway Conditions traffic-information web site (http://www.mdot.state.mi.us/mits/) were obtained from the Michigan Department of Transportation (MDOT) courtesy of Chuck Baird in MDOT's Information Services Department. The information provided consisted of summary reports for December 1998, January 1999, and February 1999, created using the WebTrends software. Although the statistics provided covered the entire MDOT web site, the real-time traffic information typically accounted for 49 percent of the monthly page hits, and 6 of the top 10 most requested pages.

Due to the sheer number of IP numbers with low request rates, an exhaustive list of requests was not attempted. Instead, a random selection of IP numbers with more than 1000 requests each was investigated using the UNIX "nslookup" command to find the IP number's domain. Once a domain name or owner was found, the company or organization type, location, and probable uses for the traffic-information web site were noted. The web-site usage generally fit into one of the following 6 categories:

1) *Personal use through an ISP via modem, ISDN, or cable modem.*

   AOL, Compuserv, Media One, and other local and nationwide ISPs (Internet service providers) were responsible for large numbers of hits and user sessions. Although IP numbers from ISPs were categorized as personal use (a single individual using the web site to plan his or her trip or commute), it may be misleading since smaller businesses often use these ISPs (and IP numbers) for their main Internet access.

2) *Use by the employees of primarily white-collar companies located within the city.*

   As an example, large numbers of hits in Chicago came from financial companies located in downtown (such as Arthur-Anderson), large engineering companies (Lucent Technologies, Motorola, Siemens), and large government employers such as Fermilab. The employees of these companies likely used the web site to plan personal trips or commutes.

3) *Use by university faculty and students.*

   Several blocks of IP numbers frequently accessing the Chicago traffic web pages came from the universities located in downtown Chicago (DePaul, Northwestern, Illinois Institute of Technology, and University of Illinois - Chicago). While some educational use may have been for academic or research reasons, portions may also be attributed to personal use by faculty and students for commuting purposes.

4) *Use by manufacturing companies to aid in routing trucks and parts.*

   Although this use cannot be confirmed, a high number of web-site requests came from manufacturing companies (Ford, Motorola, Johnson Controls). Since manufacturing companies would typically employ large numbers of blue-collar workers who would not have access to computers during their work shift, the traffic-information web-site usage may not be entirely from the employees planning their commutes home.

   However, current practices utilizing just-in-time manufacturing require that parts be delivered as they are needed in the manufacturing process to eliminate costly on-site storage of parts. It is more likely that the these companies are using the web sites to aid in the routing of trucks and parts for their operations.

5) *Use by companies providing on-site delivery or services.*

   Several companies (Sears, A1-Computing, Dominant Systems) found to frequently check the traffic-information web sites were in the business of making on-site deliveries or providing on-site services (such as computer repair). In this case, dispatchers or repair technicians may be using the site to check traffic conditions to plan their routes.

6) Use by third-party traffic-information providers.

A large number of hits on the Chicago traffic-information web site came from a third-party traffic-information provider, Transmart Technologies (http://www.trafficonline.com). It provides free personalized traffic information via their own software and web site. Similarly, in Detroit, Metro Networks (http://www.metronetworks.com), a third-party traffic-information provider, was one of the largest single users of the web site.

When do users check a traffic-information web site?

Given that the peak traffic hours would typically be during the morning and afternoon commutes, it would be expected that the number of web-site requests would increase during or prior to those times. The Gary-Chicago-Milwaukee Corridor traffic-information web site provided a summary of the number of requests received per hour (Figure 2). As expected, the number of web-site requests increased and almost doubled during the afternoon commuting hours between 3 p.m. and 7 p.m. However, only a slight increase in the number of web-site requests was seen during the morning commuting hours between 7 a.m. and 9 a.m.

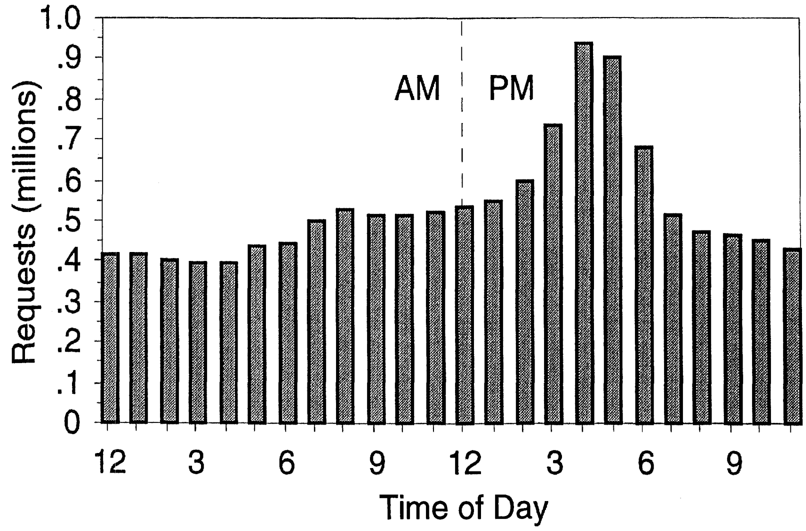


Figure 2. Chicago traffic-information web-site requests by time of day.

A similar trend was found for the Michigan ITS: Detroit Freeway Conditions traffic-information web site (see Figure 3). During the afternoon commuting hours, the number of web-site visits increased dramatically. However, only slight increases were seen during the morning commuting hours. The low use of the traffic-information web site in the mornings could be due to access or convenience. Some users may only have access through work since they do not have home Internet access. However, even if a user has home access, it may be inconvenient to start their computer, log onto the Internet, and download the page (given the typically slower home connections) before leaving for their daily commute. One option would be to provide other media (e.g., a traffic information TV channel) which might be more effective at reaching commuters in the morning hours.

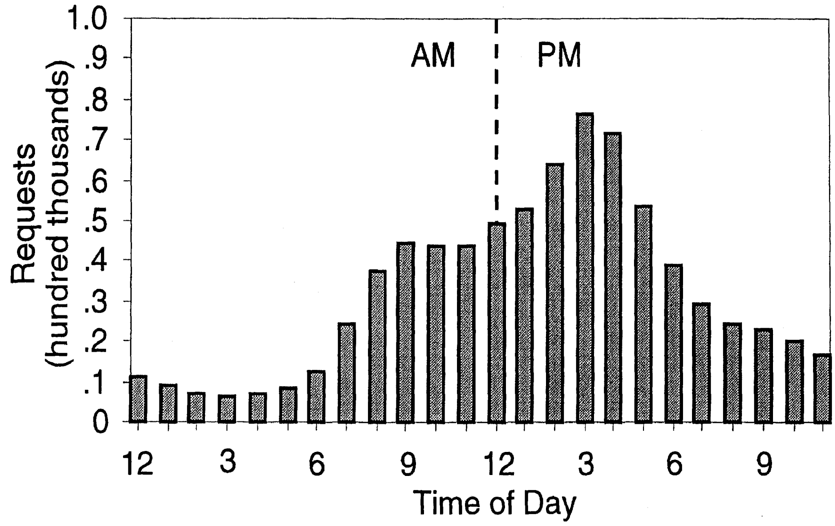


Figure 3. Detroit traffic-information web-site requests by time of day.

What information do users typically request?

According to Nielsen (1997a), the relationship between the number of requests for a site (or page within a site) and the rank order of the site (or page within the site) by number of requests will follow a Zipf distribution. The Zipf distribution is characterized by a curve that hugs the axes when plotted on a linear scale, indicating that a few pages in the site have extremely high request rates, while the bulk of pages in the site have a very low request rate. When plotted on a double logarithmic scale, the Zipf distribution forms a straight line.

When the distribution of page requests was plotted for the Chicago traffic-information web site (Figure 4), the results followed the expected Zipf distribution. The only departure from the expected distribution occurred with the top 10 pages. This particular site contained about 10 highly viewed pages (each with a similar number of requests), whereas the Zipf distribution would predict only one or two pages at the top.

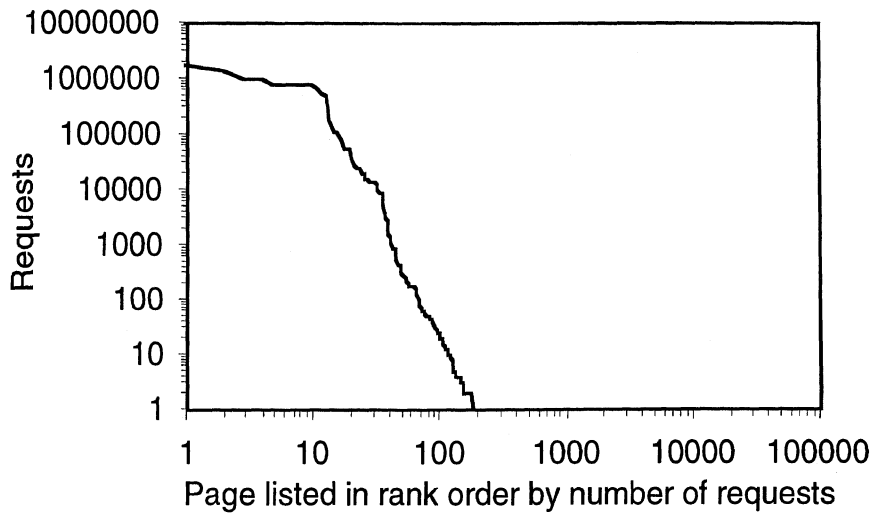


Figure 4. Distribution of requests for the pages on the Chicago web site.

The most requested page for both the Gary-Chicago-Milwaukee Corridor and the Michigan ITS: Detroit Freeway Conditions traffic-information web sites was the city's freeway and congestion overview map. The Detroit traffic-information web site provided an overview map with colored roads to represent the state of congestion and symbols to represent incidents and construction. The Chicago traffic-information web site provided a similar overview map with the addition of travel time information for major freeway segments. Furthermore, the analysis of the Detroit traffic-information web-site visit statistics showed that the congestion overview map was also the most frequent site entry page and the most frequent single page accessed (when the site visitor accessed only a single page). Table 1 lists the most frequently accessed pages for both the Chicago and the Detroit traffic-information web sites.

Table 1. Most frequently accessed web-site pages.

Requested	Chicago	Detroit
Most	• Congestion overview map	• Congestion overview map
	• Travel time overview (text based)	• Directory index and main menu
	• Detailed loop detector speed and congestion estimates for specific freeway segments (text based)	• Links page (AAA traffic Reports, AAA construction information, and various weather pages)
	• Construction information	• Detailed congestion maps of specific interchanges
	• Directory index and main menu	• MDOT construction information
Least	• Various area specific maps and more detailed loop detector info	

The most noticeable observation from the web-site usage data was that the directory index or main menu page was often skipped over, and the congestion overview map was the central focus of the site for many users. The next most requested page was the text-based overview of the freeway travel times followed by the text-based speed and congestion summaries for various heavily traveled freeway segments. This would suggest that users do prefer and use travel time information despite the recommendations found in the literature against the posting of disputable data such as travel time estimates (Dudek, Huchingson, Stockton, Kopa, Richards, and Mast, 1978).

Construction and weather information also rank fairly high in the number of requests received, suggesting a need to provide, at the least, quick and clear links to this information. However, the 2 sites examined did not contain several common features found on other sites. For example, real-time video feeds were not available on either the Chicago or the Detroit site, so the acceptance or use of this features is still unknown. Furthermore, as the technologies and interfaces change, so may the site content and usage patterns.

TRAFFIC-INFORMATION ENVIRONMENT

A good understanding of the relationship between all of the elements of the traffic-information environment is essential to the development of a traffic-information web site. Each provider in each city may have different access to the real-time traffic information sources, which constrains the design of the final web site. Understanding the relationships between organizations that collect and distribute the traffic data can often explain why certain design decisions were made. For example, the decision of whether or not to provide real-time camera images will be constrained by the video equipment used and the connections provided from the TMC to the ISP. Ultimately however, the constraints of any traffic-information web site will be dependent upon the infrastructure which is monitoring the roads.

In addition, understanding the relationship between the elements within the traffic-information environment can identify other potential sources for traffic-information data. While a majority of the traffic data may be obtained directly from the traffic management center, there are other sources of traffic data web-site designers can use (such as links to third-party organizations that provide independent traffic and incident reports).

Figure 5 illustrates the flow of data from the road infrastructure to drivers. The arrows represent the flow of traffic information. The traffic data can be collected from a number of core information sources, such as cameras, speed detectors, or even from the reports of the drivers themselves.

Data is primarily gathered by the local departments of transportation (DOTs) at their TMCs. The DOTs would have been responsible for placements of cameras, speed detectors, and variable message signs. Helicopter reports are also common in many metropolitan areas, but these reports are exclusive to particular radio and television stations. Thus, the information gained through helicopter monitoring will reach both the drivers and the TMC through the radio or television at the same time unless partnerships were established between the stations and the TMC. These partnerships may also work in reverse, where the TMC provides the local media with information to be passed along to the drivers.

The Internet providers typically gather their information from the local DOT. Information may also be exchanged between different Internet providers. Many different partnerships could exist here. The DOT may write its own web pages and only use the Internet provider to maintain the connection to the Internet, or in some cases, the Internet providers will write and maintain the web site while receiving only the real-time data from the TMC.

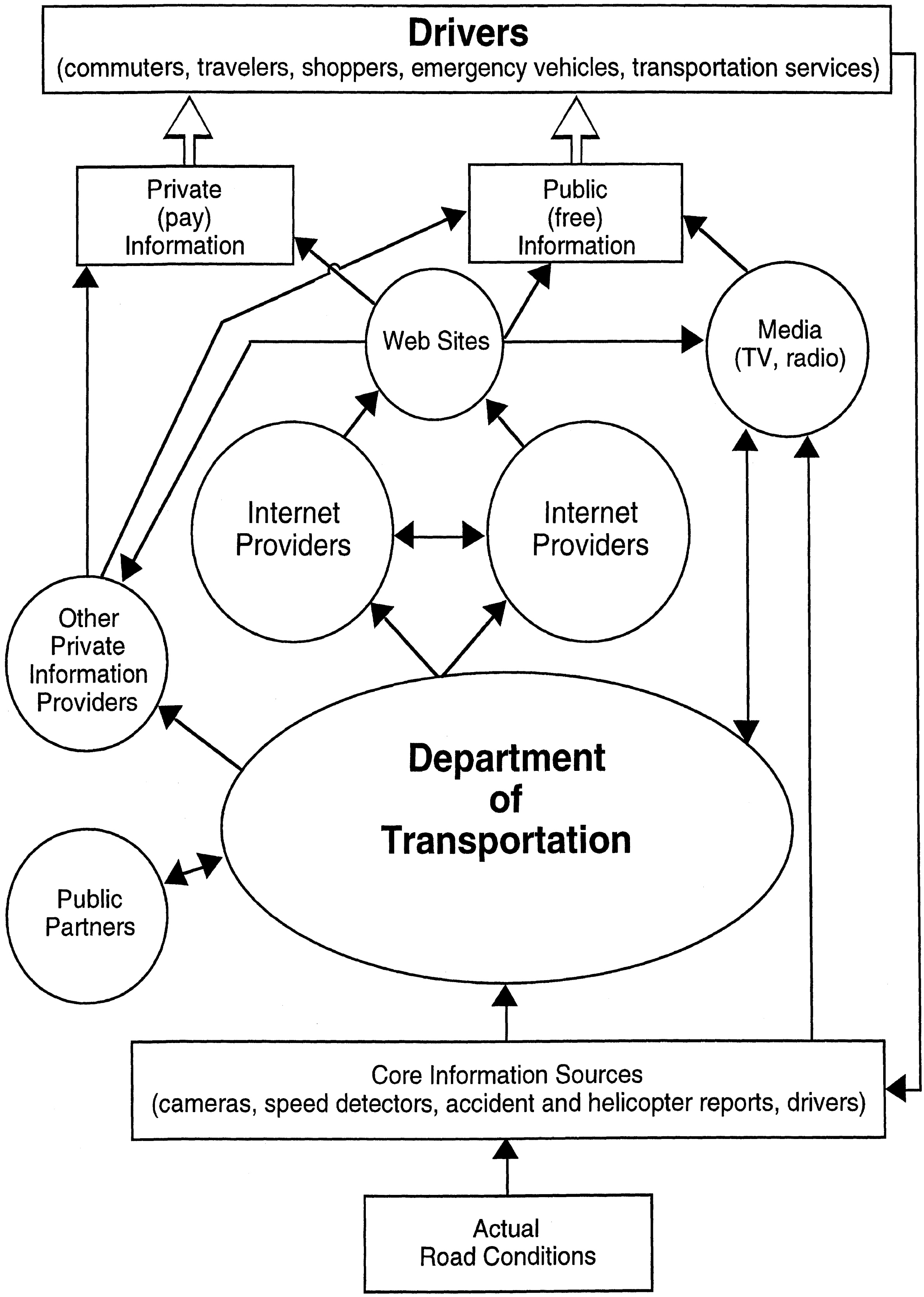


Figure 5. Flow of information through the traffic-information environment.

Third-party information providers (e.g. specialized web sites, pager services, in-vehicle information systems, etc.) may also become involved either in direct partnership with the TMC or by using the free information provided by the TMC for their own purposes. Thus, the information can be given to the drivers in two ways. First, some information is publicly available (through web sites, television, radio, and other media). Second, some services may be available for a fee. These information providers may provide basic or customizable services to customers through E-mail, special applications, pagers, or in-vehicle systems. These services may eventually include route specific information that can be relayed to the driver whenever and wherever the driver needs the information.

Finally, drivers themselves may act as an information source. Since drivers are often encouraged to use mobile phones to report accidents, with the right partnerships, this information could be passed along to the TMC. Drivers can also personally contact other drivers (through mobile phones or CB radios) or media sources to relay important traffic information. In a similar manner, drivers may also act as a source of feedback. Errors in traffic information can be relayed back to the local DOT and media via driver reports. However, the perception of errors in the traffic information provided to drivers seriously undermines the drivers' trust in that system of information delivery.

WEB-SITE FEATURE REVIEW

A total of 39 U.S. traffic-information web sites were investigated to determine the most common features and formats currently available. Extensive web searches by the investigators revealed that 17 of the 50 states have traffic-information web sites for some portion of the state. Of these states, California had the most web sites (9) providing traffic information for four metropolitan areas (Los Angeles, San Diego, San Francisco, and Sacramento). With the exception of Texas and Washington every other state had traffic web sites for only one major metropolitan area. However, multiple traffic-information web sites were common for many cites. For example, five traffic-information web sites were found for the Minneapolis/St. Paul metropolitan area. The sites were generally sponsored by different providers, and they often contained varying amounts of information and different formatting.

A list of the traffic-information web sites reviewed and their URLs can be found in Appendix A. It is possible that not all U.S. web sites were found and reviewed. However, it is important to note that web sites that were not found by the investigators are also unlikely to be found by other users through normal search engines.

One major provider of traffic-information web sites was the SmartRoute Systems Corporation. Eleven of the 39 web sites found were maintained by SmartRoute (Figure 6). It is important to note that many of the web sites maintained by SmartRoute were formatted differently. For example, the Los Angeles web site used to be owned and operated by Maxwell Technologies, and it had recently switched to control by SmartRoute, yet the formatting remained similar to the old Maxwell site.

Figure 6. SmartRoute Systems home page.

A second major provider of traffic-information web sites was Etak, which currently provided traffic information for 18 metropolitan areas (see Figure 7 and Table 2). Etak was also working (at the time of this report) on developing web sites for 7 more metropolitan areas with plans for 36 more metropolitan areas in the future.

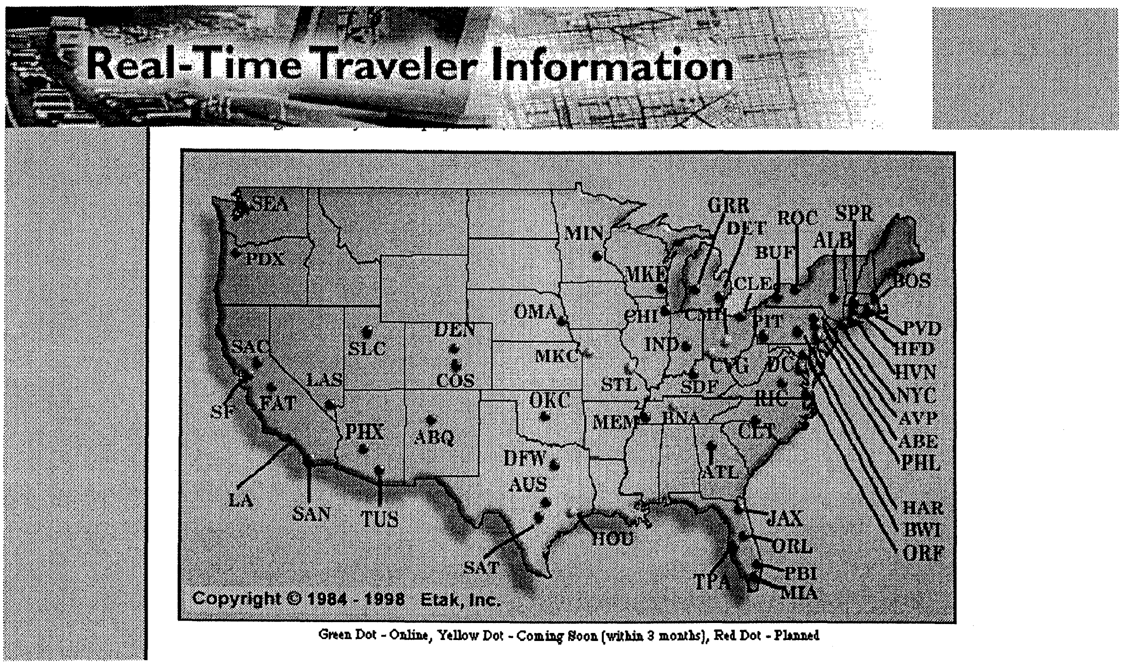


Figure 7. A map display of the cities with current and future Etak web sites.

Table 2. Current and future Etak web sites (excluding long term plans).

Cities currently with live, real-time traffic information:	
Atlanta	Los Angeles
Baltimore	Minneapolis
Boston	New York
Chicago	Phoenix
Dallas	Sacramento
Denver	San Diego
Detroit	San Francisco
Indianapolis	Seattle
Las Vegas	Washington D.C.
Cities which plan to have traffic information within the next 3 months:	
Cincinnati	Kansas City
Columbus	Nashville
Dayton	St. Louis
Houston	

Unlike SmartRoute Systems, Etak had a consistent format for all of its web sites. However, the amount of information on the SmartRoute Systems web pages was much greater than the amount of information that could be found on any of the Etak web sites. However, the purpose of this document was not to compare the quality of SmartRoute and Etak web sites specifically, nor to review all of the different ITS technologies available. Rather, the purpose was to address the issue of displaying ITS and traffic information on a web site in general.

A number of features considered potentially important to a useful web site are listed in Table 3. This list summarizes most of features available on current traffic-information web sites. To provide an indication of the variety of implementations and problems associated with the implementation of a traffic-information web site, 7 web sites were selected for a detailed examination using the heuristic evaluation method described in the next section. The Etak web sites were immediately dropped from consideration for further analysis because very few of the features discussed in Table 3 were found on their web sites.

Table 3. Features commonly found on a traffic-information web site.

Feature	Comments
Road Construction	Construction projects throughout the area were displayed on the web site.
Real-Time Map	Information was either displayed to the user in text form or on a real-time map.
Camera Images	Camera snapshots were used to provide users with a visual image of current traffic conditions.
Incidents	Information about accidents or other incidents on the roads was provided to the user.
Closures	Exit and/or freeway closures can were displayed or listed.
Travel Time	The estimated time to travel between two points was provided to users either in a general form or for a users specific interests.
Speed or Congestion	The speeds or estimated congestion levels for highway segments was presented to the user.
Variable Message Signs	The current messages for each variable message sign were accessible to the users.
Parking	Parking information was displayed on the web site.
Route Builders	Some sites provided door-to-door driving directions. In the future, these sites may incorporate the real-time data into the directions.
Customization	Some sites provided customized traffic information specific to the users route each time the user logged on or via E-mail.

HEURISTIC EVALUATION

Test Plan

The usability of each of the 7 traffic-information web sites listed in Table 4 was evaluated using the heuristic evaluation method as described in Molich and Nielsen (1990), Nielsen and Molich (1990), and Nielsen (1994a and 1994b). In summary, the heuristic evaluation method uses expert evaluators to examine the site with regard to 10 usability heuristics provided by Nielsen. (See Appendix B for a list of the heuristics and an explanation of each heuristic.)

Table 4. Listing of the 7 traffic-information web sites chosen for analysis.

Web site	Location	URL
Arizona Traiilmaster	Phoenix, AZ	http://www.azfms.com
GCM Corridor	Chicago, IL	http://www.ai.eecs.uic.edu/GCM
Georgia Navigator	Atlanta, GA	http://www.georgia-traveler.com
Los Angeles (SmartRoute)	Los Angeles, CA	http://www.smartraveler.com
Michigan DOT, MDOT	Detroit, MI	http://www.mdot.state.mi.us/mits
Sidewalk Twincities (Microsoft)	Minneapolis/ St. Paul, MN	http://www.trafficview.twincities.sidewalk3.com
Twincities, MN (SmartRoute)	Minneapolis/ St. Paul, MN	http://www.smartraveler.com

This collection of web sites was chosen to:

1. Encompass a broad range of important web-site features (see Table 5).
2. Compare multiple implementations of each feature.
3. Allow for the comparison of multiple sites for the same city.

Information concerning road construction, closures, and traffic speed was found on all of the web sites sampled as described in Table 5. This allowed for an extensive comparison of the methods used to present this information to the users. Information on incidents was found on three of the web sites sampled, and parking information was found on only one of the web sites sampled.

This sample of web sites also allowed for comparisons of the methods used to integrate ITS technologies into a web site. Three of the web sites chosen provided the user with camera snapshots of the roadway, and 3 of the web sites presented the user with information about the messages appearing on VMSs on the actual roadway. In addition, 4 of the web sites sampled provided the user with travel time between pairs of locations. One of the web sites providing travel time allowed the user to specify the beginning and end points of the route, whereas the other sites presented the travel times for a predetermined number of frequently traveled routes.

Table 5. Features found in the 7 traffic-information web sites chosen.

Feature	Georgia Navigator	Arizona Trailmaster	MDOT	MN Sidewalk	MN Smart Route	GCM	LA Smart Route
Road Construction	√	√	√	√	√	√	√
Snow Emergencies				√			
Traffic Condition (map)	√	√	√	√		√	√
Traffic Condition (text)	√				√		
Camera Use	√	√		√			
Incidents	√				√		√
Closures	√	√	√	√	√	√	√
Travel Time	√			√	√	√	
Speed	√	√	√	√	√	√	√
VMS	√	√	√				
Parking					√		
Route-builders				√			

In accordance with the recommendations in Nielsen (1994b), 3 independent evaluators were used to examine each site. Two of the evaluators were specifically educated and trained in human factors, while the third was an engineer with interest and some short professional training in human factors. All of the evaluators reported a high degree of familiarity with both computer and web usage. Each evaluator spent approximately 1 hour per site recording the usability problems found for himself.

The evaluators used various Power Macintosh computers with CPU speeds between 120 and 200 MHz. Two evaluators used 19-inch CRT monitors at a resolution of 1024x768, and one evaluator used a 12.1-inch active matrix LCD with a resolution of 800x600. All of the evaluators were connected to the Internet through a 10bT ethernet connection. The sites were tested using Netscape Communicator 4.5 for the Macintosh OS.

A usability problem was defined as a violation of any of the 10 heuristics or as a violation of any basic human factors principle. Upon the completion of the individual analyses, the evaluators met as a group to compile and organize a list of general problems found and to rate the severity of those problems. The severity of each problem was rated after considering the following criteria:

- Frequency - How often did the problem occur?
- Impact - How difficult was it for users to overcome the problem?
- Persistence - Was it a one-time problem, or did it continue to annoy the user?

Severity ratings were then given by group consensus using the following scale:

1. *Cosmetic problems* which will result in slight delays or annoyances
2. *Serious usability problems* which will significantly slow or frustrate users
3. *Catastrophic usability problems* which may prevent the user from completing a task

The heuristic evaluation generated a large list of usability problems and comments for the 7 sites. However, many times similar problems occurred on multiple sites, or many times, a single problem occurred multiple times in the same site. As a final step, the analysts' comments were combined to avoid duplicates and sorted into the following 4 categories based on the part of the web site addressed:

1. Overall screen design
2. Menu and navigation structure
3. Real-time information interaction
4. Real-time map colors, symbols, and design

Results

Overall Screen Design

Four usability problems that were noted on several sites (Table 6) were categorized as problems with the overall screen design. Of these 4 problems, 3 were classified as serious and 1 was classified as cosmetic. Several screen design problems were associated with the display of excess information. Borders, frames, menu bars, browser toolbars, and advertisements can all reduce available screen area. Cluttering the screen with excess information, links, graphics, animations, etc. can lead to difficulty in determining the site structure and distinguishing what options and links are available. As an example, the Atlanta traffic-information web site is shown in Figure 9. The actual link for real-time traffic information (the item "Georgia Traffic" roughly in the center of the screen) was overshadowed by the other items on the page.

Table 6. Overall screen design usability problems.

Problem Description	Severity Rating
1. *Excessive horizontal and vertical scrolling* was required which hid critical features such as legends, menu bars, and orientation overview maps.	Serious
2. *The menu frame was mismatched with the screen size* which caused some menu items to be hidden on smaller screens.	Serious
3. *Excessive page download times were required* (greater than 10 seconds according to Nielsen, 1993). The download times were also not balanced with the automatic reload cycle (e.g., a page with a 60+ second download time should not be reloaded every 90 seconds or the user has no chance to interact with the map before it disappears).	Serious
4. *Screen was cluttered* with too much excess information, graphics, or links. Too many flashy icons and graphics obscured the navigation structure of the site.	Cosmetic

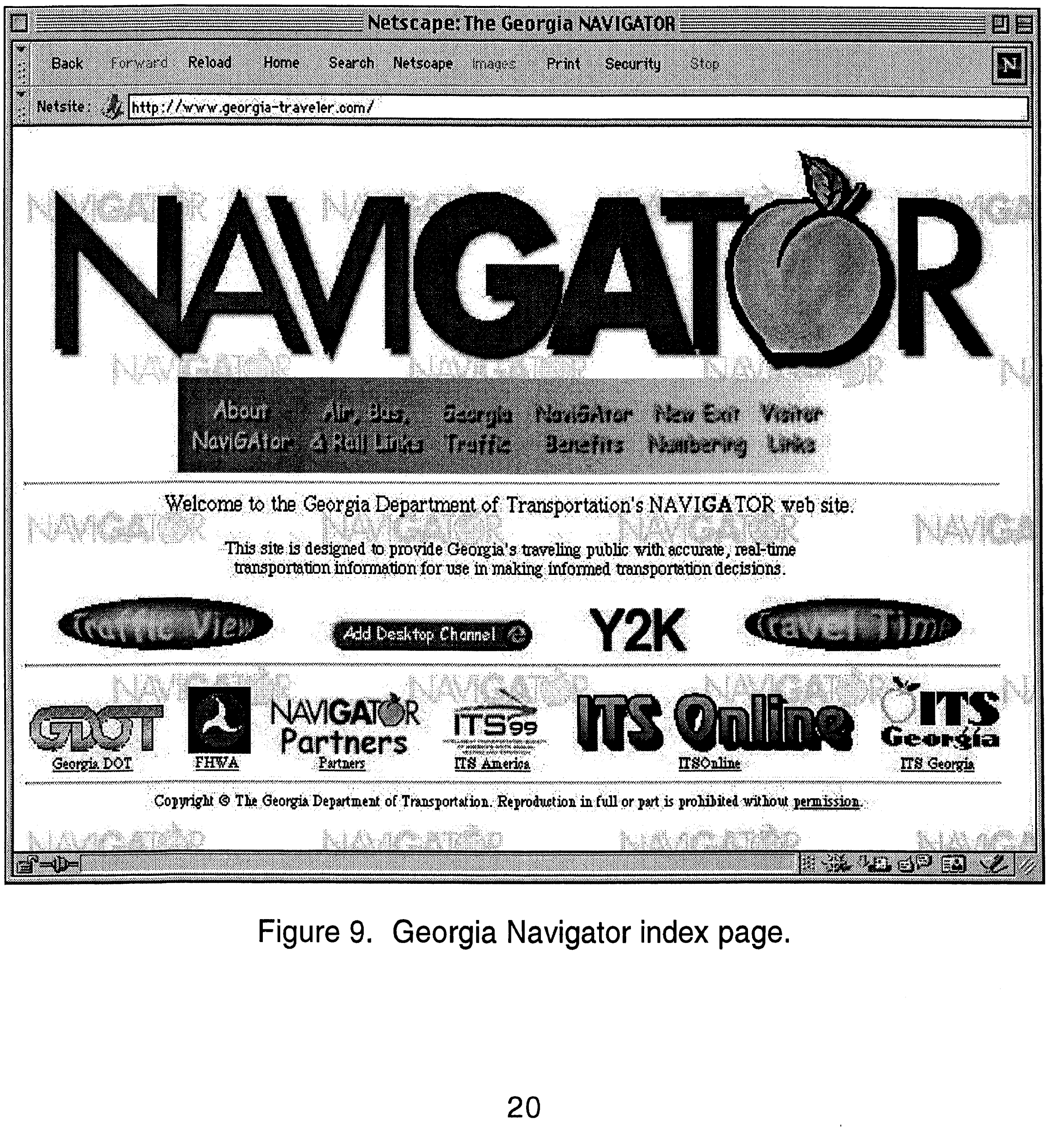


Figure 9. Georgia Navigator index page.

All of the pages were tested using screen resolutions of 800x600 and 1024x768. However, a substantial number of computer users and all WebTV users are still using a 640x480 screen. While the Detroit site and the Twin Cities Trafficview site were created with the 640x480 screen in mind, the Atlanta site and the Chicago site required horizontal and vertical scrolling even when viewed on larger screens. Early usability testing of web users indicated that only 10 percent of the users would scroll beyond the initial information visible on the screen (Nielsen, 1996). Although more recent testing has indicated a shift in the number of users who will scroll on a web page (Nielsen, 1997c), any critical feature not visible on the screen due to the required scrolling is at risk of not being discovered by the user. For example, the legend for the Atlanta maps was in the lower right corner of the map and required significant vertical and horizontal scrolling to find. The legend was thus not initially found by several of the analysts.

Similar screen-size issues were noted with the design of menu bars. The menus on the Atlanta site were designed for larger screens. When the site was viewed on a 640x480 screen, the frame containing the menu was too small to hold all of the menu items, causing the last two menu items to roll over onto the next line (effectively being hidden). Compounding the problem, since the menu frame was only designed to display one line of text, it was not large enough to display scroll bars correctly when the menu items spanned two lines.

Menu and Navigation Structure

Most of the serious and catastrophic usability problems were related to navigation, either navigation through the site's menus and hierarchy or navigation through the information provided on the site. The most important (and the most often violated) heuristic was the "visibility of the system status." According to this heuristic, each page needs to indicate both where the user is and what options are available (where the user can go). A summary of the usability problems dealing with the menu and navigation structure is contained in Table 7.

The first serious usability problem encountered with the design of menu bars (Table 7, Item 2) resulted from a lack of cues to indicate that a page structure was a menu bar and which items were actually links. Initially, the hypertext markup language used several cues to indicate that something was a link. Text was colored blue and underlined, and graphics were framed with a blue border to indicate a link. However, in current designs, text is often presented as part of a graphic and the borders around the graphics are often disabled for aesthetic purposes.

Table 7. Menu & navigation structure usability problems.

Problem Description	Severity Rating
1. *Buttons, links, and maps did not act as they appeared to.*	Catastrophic
2. *Menu bars and their links were not apparent.* Either the bar was not separated from the clutter of the page or the links on the menu bar were not obviously links.	Serious
3. *Site menu bar was used inconsistently* such that within a single site, the menu bar appeared on some pages, but not on others. Since a user can enter a site from any page (through bookmarks or search engines), orphaned pages should be avoided.	Serious
4. *The menu bar did not remain static.* The items added, deleted, or changed order on each page within a site.	Serious
5. *The menu bar is not detailed enough.* The current location indicated on the menu bar does not reflect the information that is actually being shown.	Serious
6. *Location was indicated by the item that disappeared from the menu.*	Cosmetic
7. *Inconsistent use of background colors* when menu bars appeared in separate frames.	Cosmetic
8. *Page titles did not support navigation.* Page titles were not used, or did not match links that brought the user there.	Cosmetic
9. *Page titles and headings were misleading* because they did not represent the information actually provided by the page.	Cosmetic

Without the hypertext-markup-language link-default cues, anything on the page could potentially be a link. As an example, the 4 text items across the bottom of the Detroit site (see Figure 10) were part of the site's menu structure. Given that the menu text was the same size, font, and color as the rest of the text on the page, users may then conclude that the text item "Real-Time Freeway Conditions" was also a link (even though it is not). The Detroit site did, however, offer a better menu-bar design with its top menu bar. The items Home, E-Mail, and Search were not only distinct in font and color from the rest of the text, but they appeared inside a button graphic, which further cues the user to the fact that this item was a link.

Figure 10 also illustrates 2 minor cosmetic usability problems and 1 catastrophic usability problem (Table 7, Items 1, 8, and 9, respectively). The cosmetic usability problems came from the fact that the page's title and heading were both inconsistent with the information actually shown on the page. Reading a title or page heading which states "Detroit Real-Time Freeway Conditions" would suggest that the real-time freeway conditions appeared on the page. In this case, the real-time conditions did not appear on this page. The map shown was a static snapshot and had no relation to the actual traffic conditions. Since the purpose of this page was as a menu or index, it should have been labeled as such.

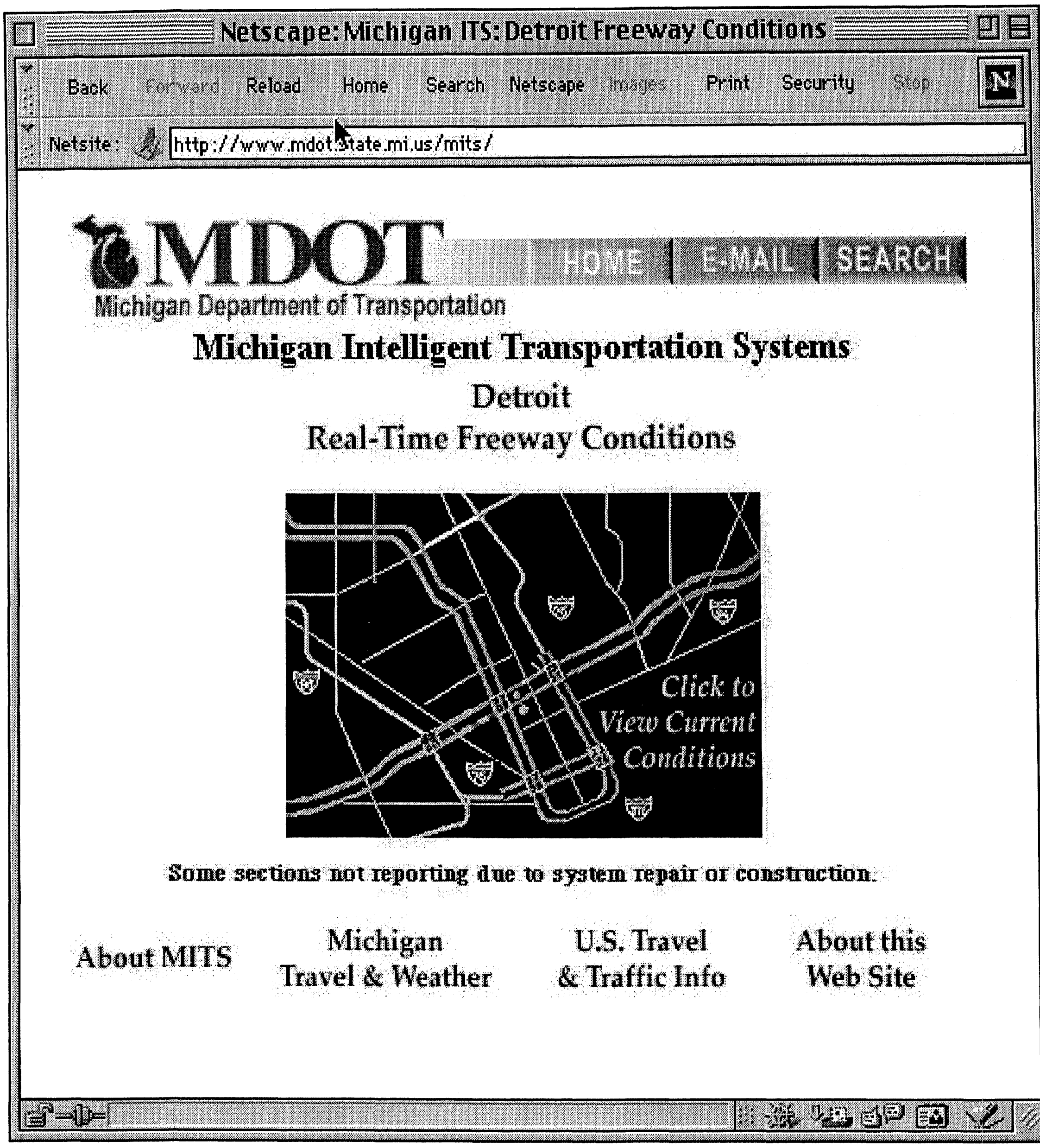


Figure 10. Michigan ITS's Detroit index page.

While misleading page titles and headings constituted only a minor usability problem, Figure 10 shows how smaller usability problems can compound. The small map graphic looked like it could be a real-time map, was labeled as a real-time map, but did not act like a real-time map. The misleading labeling of the index page could lead users to mistake the information presented on the graphic for the current conditions.

Another example of a catastrophic usability problem caused by page items not functioning as they were expected to was found on the Georgia Navigator site (see Figure 11). The instructions on the right show a large "Display Map" button; however, the button does not function. The button graphic on the right was merely meant to refer the user to the smaller "Display Map" button on the left. All of the evaluators initially missed the smaller "Display Map" button on the left, and instinctively tried to click the nonfunctional "Display Map" button on the right.

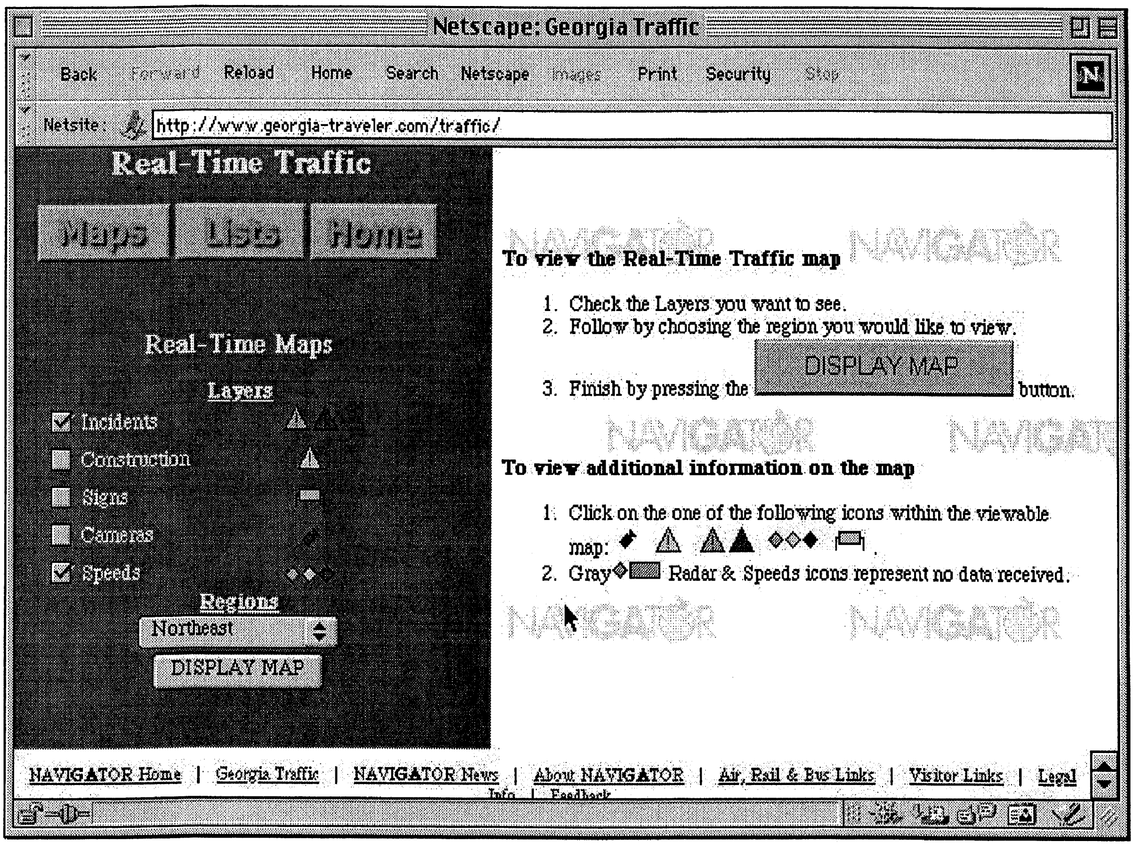


Figure 11. Georgia Navigator map display instructions.

Real-Time Information Interaction

All of the sites examined used some form of an interactive, graphic map to represent the freeway network. When properly implemented, the map provided both a summary of the current traffic conditions and an index of the other, detailed, real-time information available on the site. However, as mentioned earlier, the task of navigating through the information caused most of the serious and catastrophic usability problems (see Table 8 for a listing of usability problems found). Again, the "visibility of the system status" heuristic was noted most often as the source of the usability problems, and the biggest challenge for the interactive map designer was to provide an adequate preview of what would happen when the user clicked somewhere on the map.

Table 8. Real-time information access usability problems.

Problem Description	Severity Rating
1. *Clicking on the interactive map did not produce location relevant information.*	Catastrophic
2. *Lack of link preview.* When clicking on the map, the user did not know what information would appear, where it would appear, and what it would replace.	Serious
3. *Map contained false links.* Clicking on parts of the interactive map reloaded the map. If part of the map is not a link to new information, it should not be clickable.	Serious
4. *Lack of or bad use of the status window* to support interactive map functions. User did not know what would happen when the map was clicked because the exact cursor position was unknown.	Serious
5. *Map pan and zoom functions were poorly supported.* Multiple means to navigate the map (menus, preselected area definitions on a drop down list, overview location maps, zoom and pan controls, etc.) were needed to allow the users flexibility.	Serious
6. *Travel time information was not anchored* with the start point, end point, and distance to assist occasional travelers.	Serious
7. *Camera direction was determined by visual comparison* without taking factors such as zoom level and season into account (which can make the comparison difficult).	Serious
8. *Map Status (date and time) not easily found,* overwritten by the map labels, or lost in clutter.	Cosmetic
9. *Information labels should match throughout the site.* For example, the camera number and location on the image should match the headings, any listings or other references to the camera, and the status bar in the interactive map.	Cosmetic

Given that the nature of a map is a spatial representation, clicking at a location on the map should provide more information or detailed information specific to the location of the click (see Table 8, Item 1). If the user clicks on a camera icon, variable message sign, incident icon, etc., a list of available cameras, signs, incidents, etc. should not appear. This method of interaction violated both the "efficiency of use" and the "recognition rather than recall" heuristics for 2 reasons. First, the user already selected the location he or she wanted by clicking on the map. Second, once presented with a list of options, the user has to recall the location of the previous click to reselect the information from a list format. This poor interactive map implementation was common on the Los Angeles site, the Phoenix site, and the Chicago site, but even the Atlanta site, which spatially implemented cameras, variable message signs, incidents, and construction well, could still be improved upon.

Given that a click on the map will bring up location-specific information, the user was still confronted with the following 3 questions:

1. What information will appear when I click here?
2. Where will that information appear?
3. Will it replace anything critical at which I am looking?

To address the problem of providing feedback as to what the cursor was over, the elimination of the next two usability problems (Table 8, items 3 and 4) would provide a start. First, the Los Angeles site, the Detroit site, and both Minneapolis sites contained large map areas that were clickable, but did not link to anywhere. On these sites, when the user clicked on the map background (or slightly off the roadway, camera, or incident location), the map would reload, recenter itself, or default to a list of available options. Eliminating this clickable "dead space" and making only the items that provide location-specific information clickable would provide the users with feedback (through the browser cursor icon) when the cursor was over a valid link.

Second, the browser status-window tags should be used to indicate what the cursor is over and to preview what information will be displayed if that location is clicked. The default setting for the status window is to show the URL for the link that the mouse is over. The SmarTraveler Los Angeles and Minneapolis sites used the status bar to bombard the user with scrolling messages (see Figure 12). The Microsoft Minneapolis site used the status bar to show what javascript function was being executed. However, neither of these uses helped the user to determine the current status. The Phoenix site actually used the status bar to aid the user by displaying the URL, which would be linked to from the current mouse location (see Figure 13).

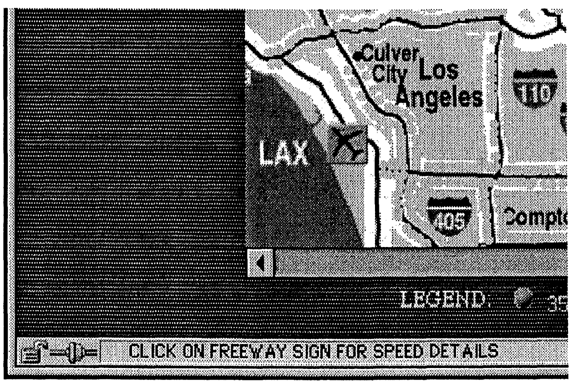


Figure 12. Status bar use on the SmarTraveler Los Angeles web site.

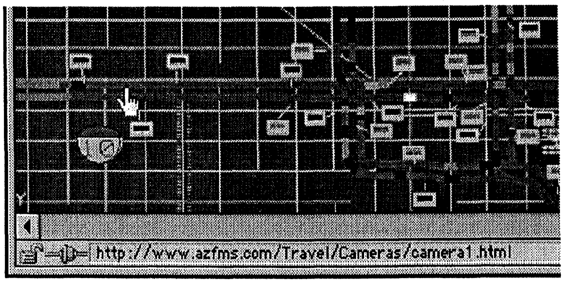


Figure 13. Status bar use on the Phoenix web site.

The Atlanta site went one step further and used the status window to simply indicate that the cursor was over camera 1 or VMS 1 (see Figure 14). However, even this could be improved upon. The status window could have been better utilized by providing information on the location of camera 1 (such as the intersection or cross street) or where the image would appear when camera 1 was clicked.

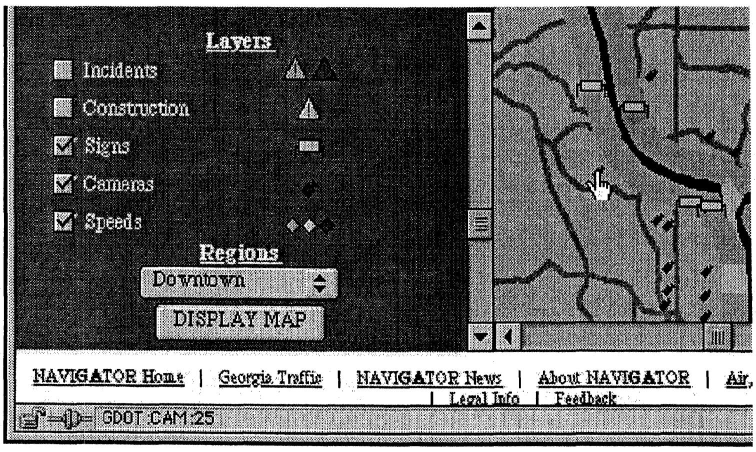


Figure 14. Status bar use on the Atlanta web site.

Two screen layouts that contained much potential for solving the remaining questions (where will the information appear and what will it replace) were used on the Atlanta site (see Figure 15) and on the Microsoft Minneapolis site. These sites provided both the map and an area for location specific information that appeared when a camera, variable message sign, or incident alert was clicked. Although this layout appeared to work well once the user became experienced with how the site worked, cues for new users were still lacking. Also, once location-specific information was selected, it replaced the legend and the map customization options.

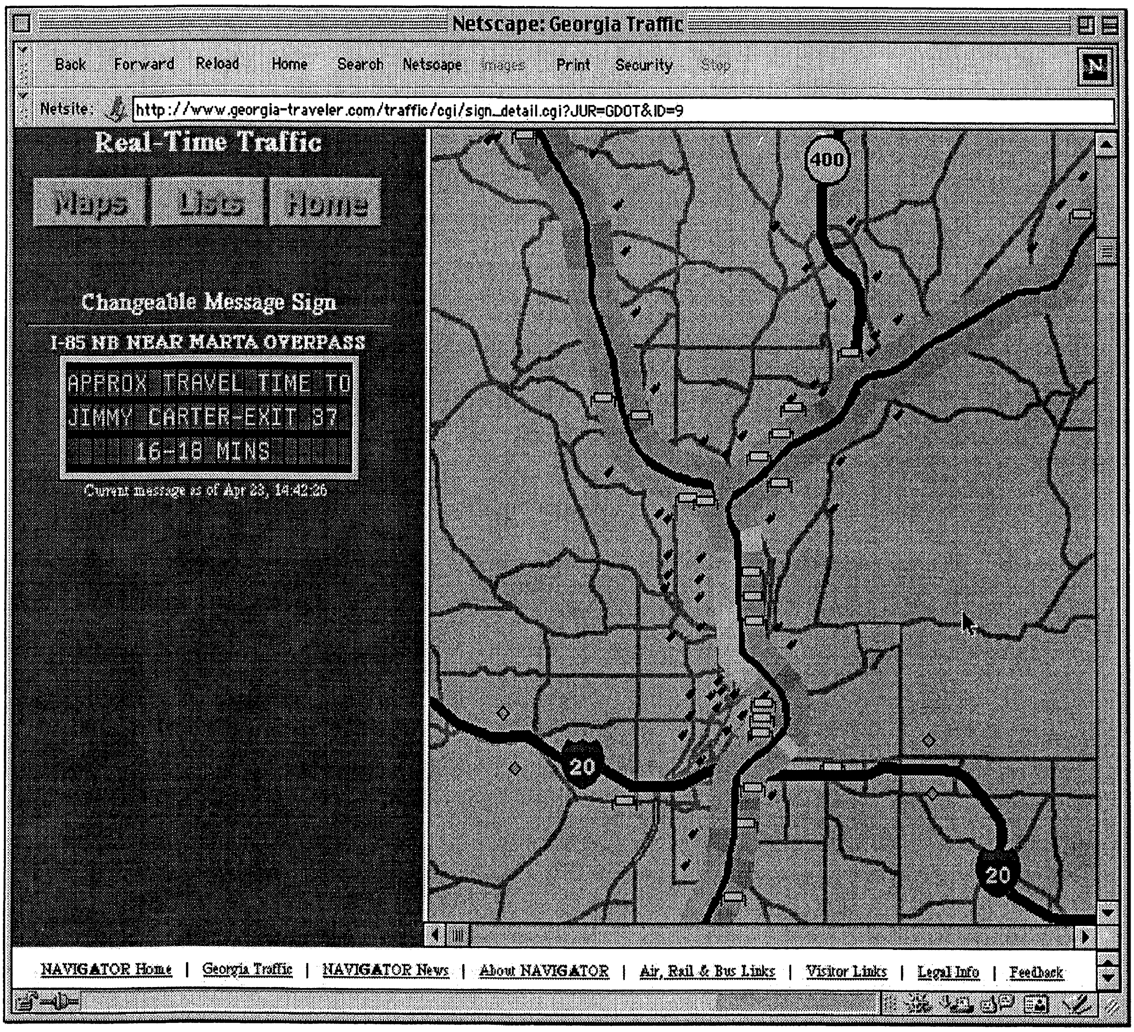


Figure 15. Georgia Navigator real-time map screen layout.

Real-Time Map Colors, Symbols, and Design

Most of the usability problems associated with the map design were cosmetic, and only a few problems posed a serious usability threat to a small number of users. A listing of these usability problems is found in Table 9. The first issue with the real-time map design concerned the overall readability. Most of the sites used greys, whites, or light colors for the map background; however, Phoenix used a bright blue background and Detroit used a black background. Using light road colors on a dark background generally reduces the readability. Excessive clutter can also reduce the map's readability. On several sites, the placement of information, incident, and construction symbols caused excessive clutter. Specifically, Chicago attempted to show construction with a start and an end symbol on the map. While this would not be a problem if only a little construction was occurring, the map quickly became cluttered with overlapping symbols attempting to define the boundaries of every construction project. (See Figure 16.)

Table 9. Real-time map design usability problems.

Problem Description	Severity Rating
1. *Low contrast* between the roads and the background color.	Serious
2. *Too much map clutter* between all of the symbols and colors.	Serious
3. *Arbitrary use of colors* to represent traffic data (both within a site and across sites). Too many levels of congestion used, or only a single color with varying shades used.	Serious
4. *Dependence upon a single characteristic (such as color) to distinguish incidents from construction.*	Serious
5. *Light colors on a dark background* generally reduces the readability. Dark color on a light background is preferred.	Cosmetic
6. *Lack of reference points* (airports, rivers, etc.) indicated on the real-time maps.	Cosmetic
7. *Overall map look departs from the roadway network* which is represented on paper maps for that particular area because major freeways without real-time data are not shown clearly.	Cosmetic
8. *Lack of use of interstate and state road symbols* to label the roads on the maps.	Cosmetic
9. *Arbitrary use of symbols* and colors to represent incidents, construction and closures across sites.	Cosmetic

One heuristic cited in evaluating the design of the real-time maps was the "match between the system and the real world" heuristic. The real-time map is a representation of the roadway system for a particular area. While the purpose of these real-time maps is not necessarily to provide all of the information to help drivers' navigate, the map should provide cues to allow users to match the real-time map to the real world. Most of the real-time maps were very simplistic. However, the SmartRoute Los Angeles and Minneapolis sites depicted several critical landmarks such as airports, rivers, oceans, etc., which enhanced the maps representation of the real world.

Similarly, another common departure from the real-world representation occurred because often the only roads shown were the ones with real-time data. Although the temptation was to conserve space by leaving roads without real-time data off the map (or to visually downplay their existence), major freeways serve as landmarks to most drivers and should be clearly included on the maps. A good example was seen on the Chicago map, which is also illustrated in Figure 16. The Chicago tollways, I-355, I-294, I-88, and I-90, did not display real-time traffic information because that service was not yet available. Although tollways are labeled and drawn in white, they are often difficult to find on the map since the size of the lines representing the tollways is not similar to the size of the lines representing the other freeways. This gives the real-time map a much different overall freeway look than drivers are used to seeing when looking at a paper map of the greater Chicago area.

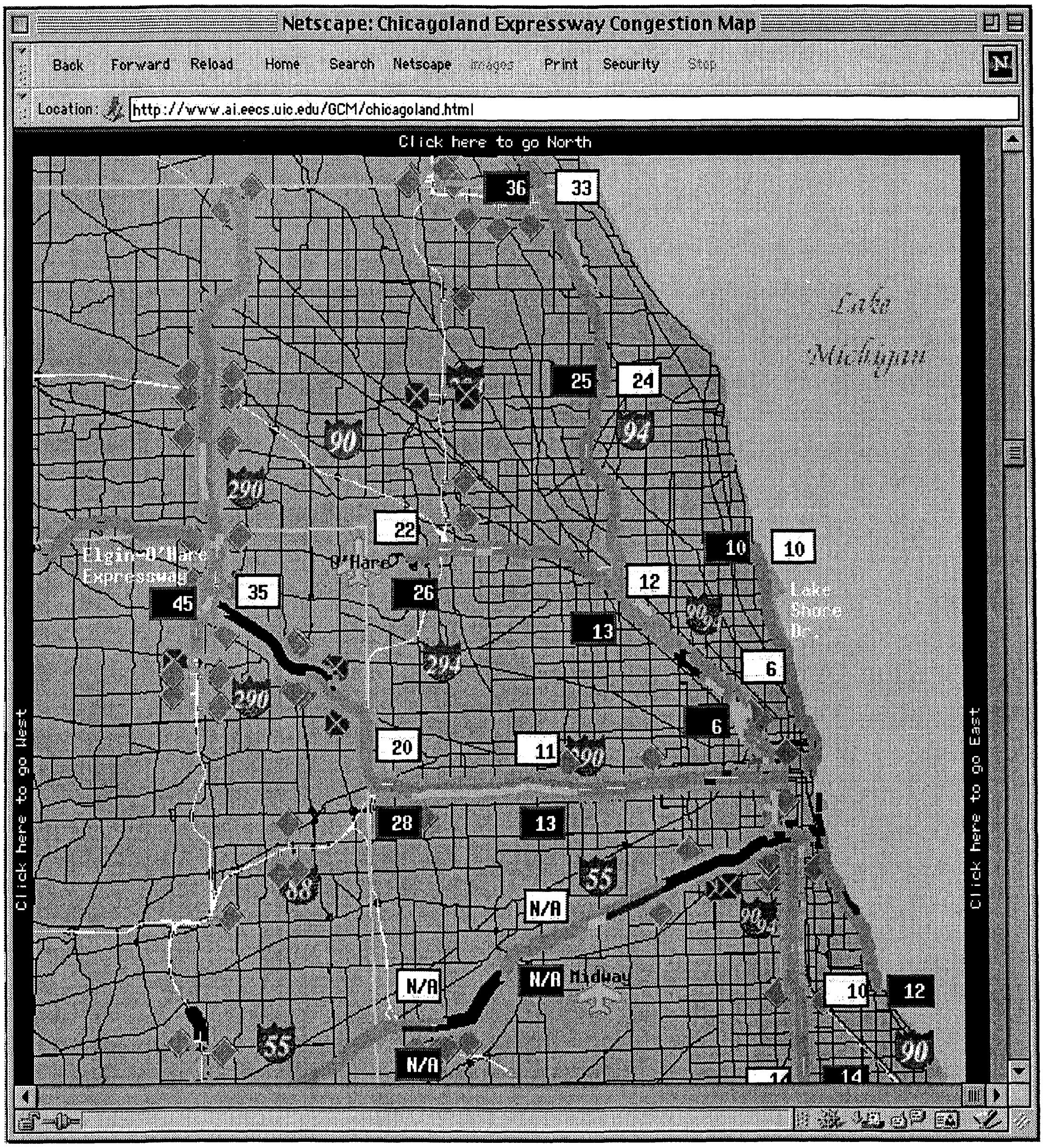


Figure 16. Chicago traffic-information real-time map.

Three usability problems with symbols and colors were noted (Table 9, items 3, 4, and 9) . First, color was generally used to represent speed or congestion. The number of colors used for real-time traffic conditions ranged from using 3 to 8 with one site, Phoenix, using up to 3 different shades of green to represent speeds in 5 mph increments above 50 mph. Since the literature suggests that drivers find such terms as "normal traffic" and "mild congestion" to be vague (Dudek, Huchingson, Stockton, Koppa, Richards, and Mast, 1978), the number of levels of traffic and thus the number of colors should be kept to a minimum.

The color usage should also be consistent in application and meaning throughout the site. In the case of Microsoft's TwinCities site, two different (but similar) color codings were used for the traffic and for the ramps (see Figure 17). Four levels of ramp meter flows were used: off, fast, moderate, and slow. However, only 3 levels of traffic congestion were used: wide open, heavy, and stop and go. The color red was used consistently for slow ramp meters and slow (stop and go) traffic, but on the other end of the scales, ramp meters used green and loop detectors used white to indicate free flowing conditions.

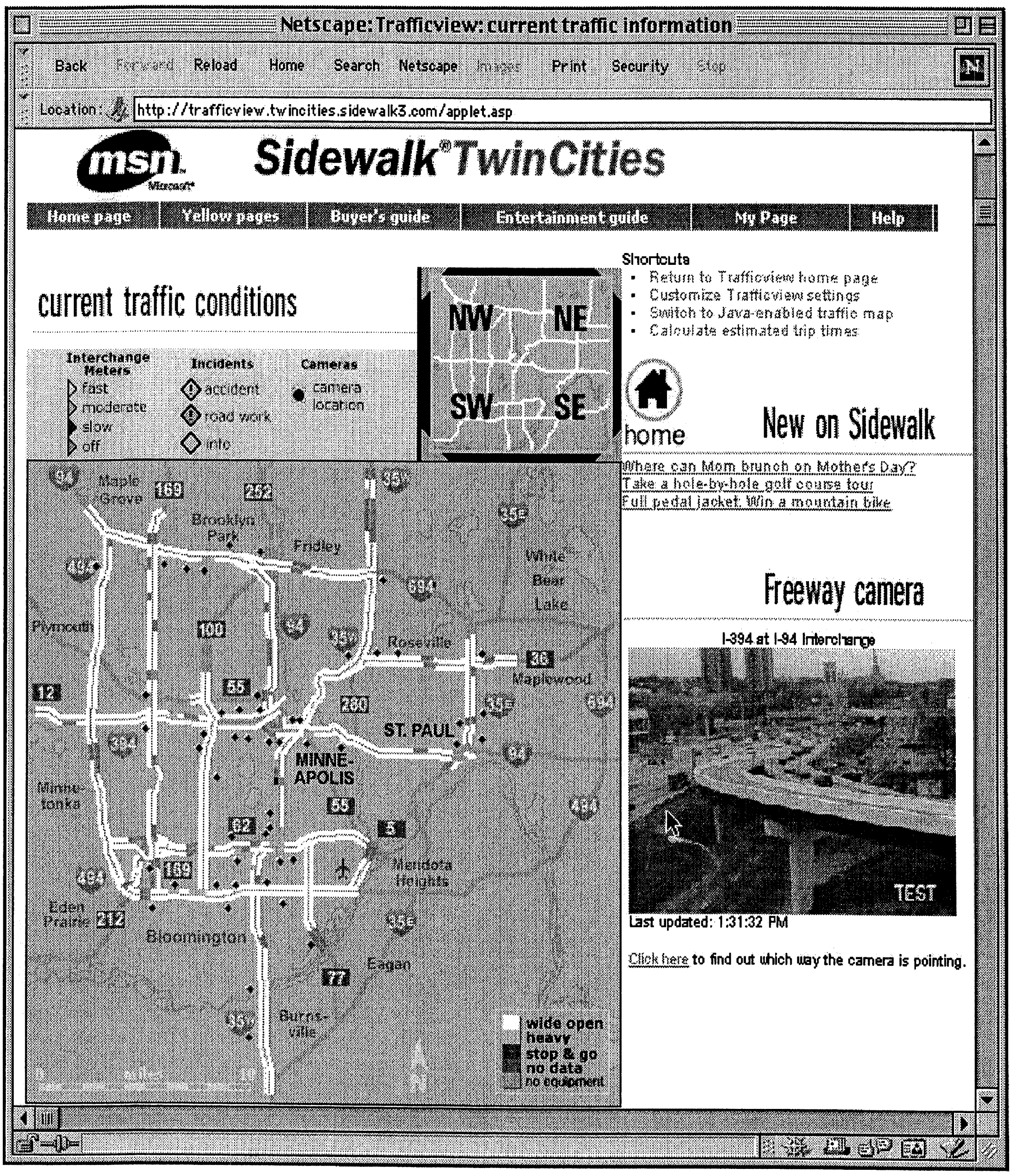


Figure 17. Microsoft's TwinCities traffic-information real-time map.

A second usability problem only occurred when transferring between sites. Although the color and symbol usage was generally consistent within a particular site, users who may frequent different cities encountered similar symbols and colors used differently between sites. For example, Minnesota represents accidents in yellow and construction in orange, while Atlanta represent construction in yellow and accidents in orange.

The final, symbol-related, usability problem was noted on the Atlanta site, where the same symbol was used for incidents and construction. Relying only upon a single dimension, such as color to distinguish incidents, construction, cameras, VMSs, etc. should be avoided, especially given that some users may not have color monitors.

USABILITY TESTS

Test Plan

Traffic-information Web-site Construction

The traffic-information web site constructed to test the usability design guidelines was based on the Michigan Department of Transportation's web site. The overall organization of MDOT's web site was not changed for the usability testing, but the navigational structures (e.g., menu bars, link labels, and methods of presenting the information) were modified to conform with the usability guidelines developed from the problems found in the heuristic evaluation performed earlier.

The focus of the usability test was on the design of the web pages that present real-time traffic information. From the MDOT Home Page, clicking on any link to real-time Detroit traffic information brought the user to the Michigan ITS: Detroit Travel Home Page. From this page, 2 forms of real-time traffic information were available: (1) text based travel-time estimates and (2) a map using color to represent real-time traffic speeds. Access to cameras, variable message signs, and incident and construction reports was available through the real-time map. (See Appendix C for screen shots of the tested web site.)

Since it would have required considerable effort to display real-time traffic information, and the purpose of the evaluation was to examine only the interface concepts, the specific traffic information shown during the experiment was artificial. A single, hypothetical traffic snapshot was created for the experiment. The traffic snapshot was based upon several drivers' experience and local traffic reports to determine where typical afternoon rush-hour back-ups occurred. Incident and construction locations were then added randomly to the freeway system. The traffic patterns caused by the proposed incidents were determined by watching traffic patterns near incidents on the Georgia Navigator and Twincities real-time traffic-information web sites.

Video images and messages for the VMSs were also added at the web site's proposed camera and VMS locations (which had no relation to real camera or VMS locations). Most of the camera images were taken from other real-time traffic-information web sites. The camera images used showed plausible traffic conditions and roads for the camera location (e.g., number of lanes, exit locations, and urban or rural backgrounds). Variable message sign messages were constructed according to the following priorities (listed from highest to lowest), which are similar to the practices of MDOT:

1. Drivers were warned of incidents, construction, or congestion on the current freeway within a few miles of the sign's position.
2. Drivers already in heavy congestion were informed where the congestion ended.
3. Drivers were warned of incidents, construction, or congestion on adjacent freeways when the VMS was near an interchange.
4. Drivers were given a courtesy message such as "Buckle Up for Safety."

Travel-time estimates were calculated by measuring the distance (in miles) between two points on the freeway and dividing the distance by the average freeway speeds. Freeway speeds were displayed using 3 colors: green, yellow, and red. The speeds for each color used to estimate the travel times are shown in Table 10. Urban areas used slightly lower speeds for each color than did suburban areas.

Table 10. Approximate speeds (mph) for each color used to estimate travel times.

Color	Speed Range	Urban Estimate	Suburban Estimate
Red	0-20	5-10	15-20
Yellow	25-45	25-30	35-45
Green	50-70	50-55	55-70

The site was designed and tested to specifically work with the Macintosh version of Netscape Communicator 4.5 (or Netscape Navigator 4.08) running on MacOS 8.6. The specific HTML code used in the experiment was not tested on other versions or browsers since the purpose of the experiment was to test the general web site interaction and not the code itself. To simulate some downloading delay, the prototyped web pages were not stored on the hard drive of the test participant's computer. Instead, the were stored on a second Macintosh computer and accessed via an AppleTalk connection over 10BaseT Ethernet. The download delay would roughly simulate a fast cable modem used by home users or a T1 connection used by many larger businesses.

Test Participants

Consistent with contemporary usability practice, 5 computer users, who were also licensed drivers living in southeastern Michigan, were asked to use a prototype of the Detroit-area traffic-information web site to plan a hypothetical trip. The average age of the users was 30, and all of the users reported annual driving to be between 10,000 and 25,000 miles. All of the users took trips in the Detroit suburban area with a frequency between a few times a week and a few times a month. Three of the users were men; 2 were women.

Based on computer and web experience, the 5 subjects fell into 2 categories: novices (2) and experts (3). The experts reported that they browsed the web daily, had been browsing the web for more than 3 years, and were very comfortable with using the web. The novices reported browsing the web only a few times a month, had only been browsing the web for 1 to 2 years, and were not very comfortable using the web. All of the test participants reported being most familiar with Windows. Four of the subjects selected Netscape as their preferred browser, and 1 selected AOL (America Online) as his preferred browser. Only 2 users had previously encountered a traffic-information web site, the MDOT MITS Detroit Travel web site.

Test Activities and Their Sequence

Each test participant began by completing a participant consent form (Appendix D) and a short biographical form (Appendix E). Appendix F contains the complete instructions given to each test participant by the experimenter.

The test participants were presented with a Macintosh 8100/100 AV with a 17-inch monitor, a standard 105-key Apple keyboard, and a standard 1-button Apple mouse. Test participants who were unfamiliar with the Macintosh operating system were given brief instructions on the locations of the menus and the basic interactions of the system. Test participants who were unfamiliar with the Netscape Navigator were given a brief demonstration of how it functioned using the Yahoo web site (http://www.yahoo.com) as an example.

Before the test participants arrived, the computer used to present the web site was preloaded with Netscape Navigator 4.08 and cleared of all bookmarks except for the standard list of bookmarks installed by Netscape followed by a single bookmark to the prototyped MDOT Home Page. This approximated a scenario where the test participant was given a web site and told that some useful information was on that site but were not told exactly where. Test participants were allowed to add bookmarks as the experiment progressed at their own discretion. The Netscape cache and link history was also cleared before the test participants arrived so that all of the links appeared in their default color. This prevented test participants from being influenced by the links that had already been visited by previous test participants.

When the test participants were comfortable that they were ready to begin, a video recording was started and they were given the first of 2 scenarios. The experimenter read the scenario to the test participant, and provided a printout for future reference. The test participants were then reminded that the traffic information was hypothetical and did not represent the current traffic conditions for Detroit roads. The test participants were also reminded that they were encouraged to "think aloud" as they interacted with the web site to solve the scenario. After completing the first scenario, the second scenario was read. Following the completion of both scenarios, a postexperiment interview was conducted.

After the interview, the test participants filled out a test participant payment form, were paid for their time, and were thanked for their participation.

Scenario 1 - Daily Commute Home

Scenario 1 assumed that the test participant was planning for a daily hypothetical commute home from Royal Oak, Michigan, to Belleville, Michigan. The information given to the test participant for this scenario is presented in Table 11, and the map provided to the test participants is shown in Figure 18. Since daily commuters are fairly familiar with their route home, this scenario provided test participants with information on their normal route home and how long the expected average commute time should be for that route. The actual travel time estimates for the various routes were not shown to the test participants (see Table 12).

After being read the scenario, test participants were asked to use the web site to plan their route home. They were asked to explain what route they would take home, to estimate how long the trip would take, and to mention anything noteworthy that might affect their drive home. No feedback was given to the test participants about the correctness of their answers.

Table 11. Scenario 1 information given to test participants.

Description	Available Information
Current Time	4:40 PM
Current Location	Royal Oak (Off I-696 several miles west of I-75)
Home	Belleville
Normal Route Home	I-696 West to I-275 South to I-94 West
Average Commute Time	40 minutes
Freeway Miles Traveled	35 miles

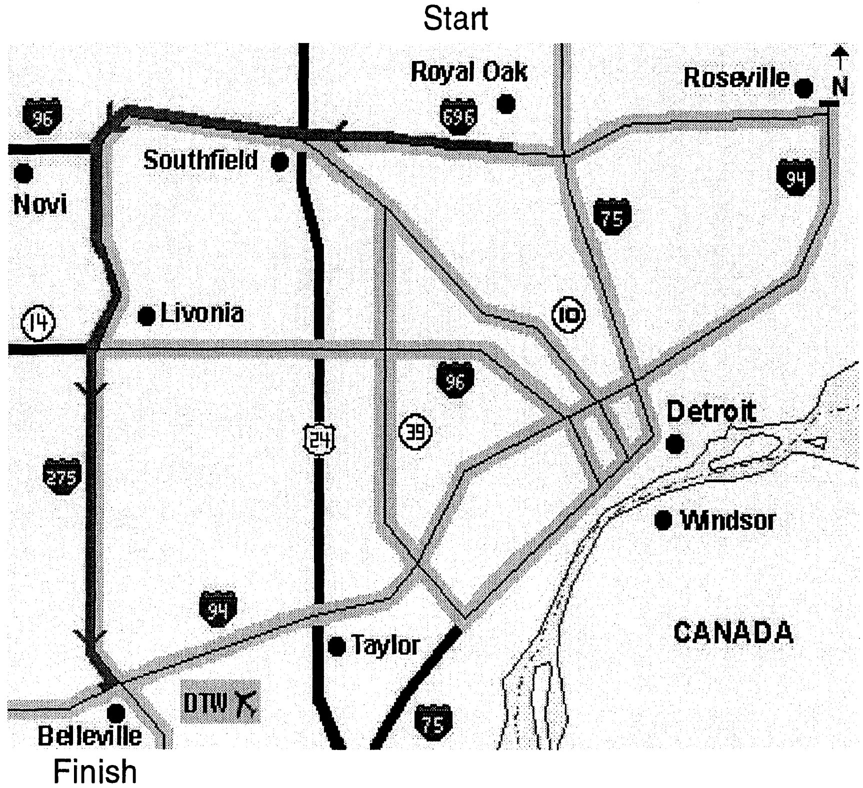


Figure 18. Scenario 1 normal route home map.

Table 12. Travel time summaries for scenario 1.

Route	Segment	Distance (mi)	Time (min) & Notes
Normal	I-696 West	16	25
	I-696 West to I-275 South		Unknown (Detour Delay)
	I-275 South	7	Unknown (Construction)
	I-275 South to Destination	12	15 (Accident)
	Total Best Condition	35	52
	Total Worst Condition	35	74
Alternate 1	I-696 West to Telegraph	8	12
	M-10 East	3	3
	M-39 South	7	7
	I-96 West	12	15
	I-275 South to Destination	12	15 (Accident)
	Total	42	53
Alternate 2	I-696 West to Telegraph	8	12
	M-10 East	3	3
	M-39 South	14	20 (Construction)
	I-94 West to Destination	10	12 (Construction)
	Total	35	49
Alternate 3	I-696 East	2	3
	I-75 South	6	7
	I-94 West to M-10	2	15
	I-94 West to Destination	18	32
	Total	28	57

Scenario 2 - Run Errands During/After Work

Scenario 2 assumed that the test participant was planning to run an errand during or after work. The information given to the test participant for this scenario is presented in Table 13. Only the current time and location, along with a destination address were provided. Since the destination was assumed to be unfamiliar to the test participants, no normal route or expected travel time was given. The test participants were allowed to use other internet sites such as Yahoo Maps or Mapquest to locate the address. The actual travel-time estimates for the various routes were, again, not shown to the test participants (see Table 14).

Table 13. Scenario 2 information given to test participants.

Description	Available Information
Current Time	4:40 PM
Current Location	Ann Arbor
Destination	Woodward Ave & Highland St, Highland Park

Table 14. Travel time summaries for scenario 2.

Route	Segment	Distance (mi)	Time (min) & Notes
Route 1	M-14 East	14	12 (no data)
	I-96 East	20	31 (Accident)
	I-75 North to Davison Fwy	7	24
	Total	41	67
Route 2	I-94 East	16	14 (no data)
	I-94 East	16	21
	I-94 East	1	3
	I-75 North to Davison Fwy	3	6
	Total	36	44
Route 3	M-14 East	14	12 (no data)
	I-96 East	20	31 (Accident)
	I-75 North	1	2
	M-10 West to Davison Fwy	6	16
	Total	41	61
Route 4	I-94 East	16	14 (no data)
	I-94 East	16	21
	M-10 West to Davison Fwy	4	10
	Total	36	45

After being read the scenario, test participants were asked to use the web site to plan the freeway portion of their route to the destination. As before, they were asked to explain which freeways they would take, to estimate how long the trip would take, and to mention anything noteworthy that might affect their trip. No feedback was given to the test participants about the correctness of their answers, rather they were encouraged that all answers were correct.

Postexperiment Interview

The postexperiment interview began by asking the test participants to recall a recent trip they had taken and narrate a third scenario with the web site using their recent trip as the basis. Probing questions were used to help prompt the test participants along when they had difficulties. The probing questions used during the self-guided scenario were as follows:

1. Thinking back to a recent trip you've taken, how would this web site be useful?
2. What information on the web site would you have used?
3. Could you elaborate and show what you would check using the web site?
4. What other sources of traffic information did you recall consulting before the trip?
5. ...during the trip?
6. Did you specifically seek out traffic information before or during the trip?
7. What other kinds of information do you normally check before a trip?
8. ...during a trip?
9. Were there any problems or stumbling blocks you encountered with the site?
10. Do you have any further comments on how to improve the site?
11. Were there things you liked or did not like?

Results

The analysis of the usability tests produced a total 70 usability problems and 40 comments on how to improve the site. The usability problems were categorized by the page on which the problem occurred and the part of the page that caused the problem. Table 15 summarizes the problems encountered by the test participants.

Goal 1: Locate Real-Time Traffic Information

The first goal of the experiment was to locate the real-time traffic information on a mock MDOT web site. The 3 expert test participants were able to locate the information relatively quickly (within 4 or 5 mouse clicks), but neither of the 2 novices were able to locate the information without the help of the experimenter. Both of these participants began looking in the correct area under the heading "Roads and Travel." However, the novices quickly shifted from looking for real-time traffic information to looking for any links dealing with maps. Several of the experts commented that the page was too cluttered, and that the menu bar category names were too broad and vague to be useful. One test participant commented that, "Most people visiting this site are here for the traffic information. It should be a big button on the main page." (Although the participant was stating an opinion, he was correct in his assessment. As discussed earlier, the real-time traffic information receives 49 percent of the MDOT site traffic including 6 of the top 10 most requested pages.)

Goal 2: Plan the Route

Three participants began planning their routes with the real-time map, and 2 began planning their routes with the travel-time estimates. The participants who began planning their routes with the travel-time estimates eventually switched to the real-time map before deciding on a route. The real-time freeway-overview map contained only an overview of the freeways with coloring for various speeds. No icons (i.e., cameras, VMSs, incidents, or constructions) were shown. A total of 5 general problems were found with the Real-Time Overview Map page.

1. *The instructions were either not noticed or confusing.*

   An instructions frame was provided in the lower left corner of the page. The instructions read as follows: "Select a smaller map region (Downtown, North Suburbs, or West Suburbs) for access to cameras, message signs, and incident and construction reports. The experts simply neglected to read the instructions (even when they noticed them), but the novices always read the instructions once they found them. However, the instructions were confusing to the novices even when found since they did not specify how to select a smaller region or what an "icon" was. Both of the novices attempted to find further help and more detailed instructions by clicking on the menu bar item "About this Site."

Table 15. Summary of usability problems encountered.

Web Site Page	Page Structure	Subjects Affected	Problem Description
About this Site	Link label	2	Subject expected a detailed help page.
MDOT Home	Link layout	2	Too much clutter. Difficulty finding links to real-time data, and 1 subject focused only on the left column of links thus missing the desired link.
MDOT Home & MITS Home	Links labels & organization	5	Vague menu category names. The site organization never became apparent to the subjects. Difficulty locating real-time data for most subjects. No subjects found links to driving directions.
MITS Home	Menu bars	5	Site/Subsite structure not understood. Menu bars underutilized or ignored because the subjects did not know what they did, or the links did not appear important to the tasks at hand.
Overview map	Instructions	4	Experts did not notice or read the instructions provided. Novices attempted to read the instructions, but were only confused by them.
Overview map	Legend & real-time information presentation	5	Multiple problems with the legend and mappings between the legend icons and maps were encountered (e.g., construction was mistaken for variable message signs).
Overview map	Navigation map	3	Subjects were unable to understand how the navigation map worked.
Overview map	Pan/Zoom	5	The use of the pan and zoom functions caused subjects difficulty. Information which only appeared when the map was zoomed in was often not found. The suburb divisions used for the zoom levels were not natural.
Overview map	Pull-down menu	5	Experts were annoyed by the menu's implementation, novices were unable to use the menu without help.
Real-time maps	Icons/Reports	4	Most subjects did not realize that the camera/VMS/report icons were clickable.
Travel Times	Headings	3	Subjects were unsure about whether the travel time data was real-time.
Travel Times	Format	5	Tabular text format was difficult to use. Most gave up trying to use it.

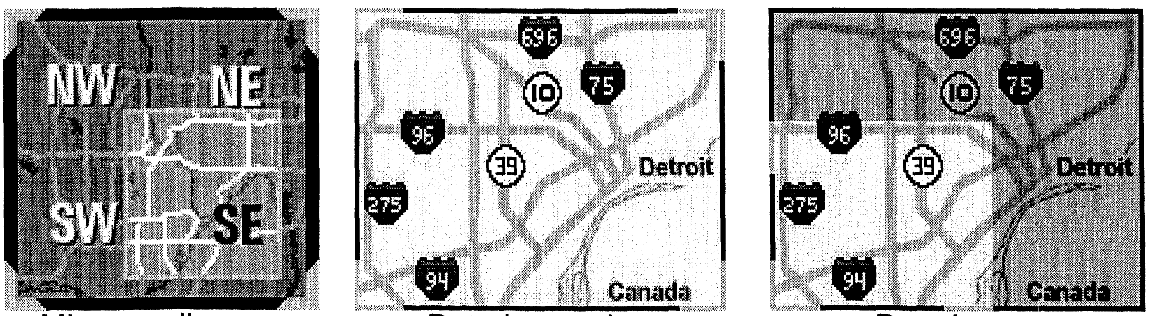
2. *Several problems occurred when translating between the map and legend.*

   There were two main causes of the problems encountered with the legend. First, the legend was incomplete. It defined red, yellow, and green as indicating the freeways speeds; however, some roads were grey (indicating that the equipment was not working, e.g., due to construction) and some were black (indicating that the roads were not monitored). One novice mistook the grey section of roads for VMSs since the VMS icon was also grey. Grey sections of road either caused frustration or were ignored. Most had difficulty grasping the concept of why some roads had data, and others did not. Even when the participants realized there was construction on the grey sections of road, they still did not understand why there was no speed information. One option mentioned was to color the road sections that were under construction orange and indicate it on the legend.

   The second cause for confusion occurred because cameras, VMSs, incidents, and construction were not shown on the overview map, even though the icons for these appeared on the legend. Most of the users commented that they would rather have all of this data on a single overview map, rather than having to "dig" for it by zooming in on smaller sections of the freeway system.

3. *The navigation map did not function as most expected it to.*

   Based on the navigation map found on the Minneapolis web site (see Figure 19), a similar navigation map was developed for the MDOT site. The Detroit overview navigation map (Figure 19) was located on the left side of the web page. Clicking on a location on the Detroit overview navigation map centered and zoomed the map in on one of three preset locations, such as the west suburbs (as shown in Figure 19). The novices, when presented with the Detroit overview navigation map, were mostly unable to figure out what to do with it. One novice simply commented, "That does nothing for me. I have no idea what it means." The second novice, eventually figured that he could click on the road signs, and that would change the map. However, this misunderstanding caused problems when the test participant wanted to zoom into the northern section of I-275, but clicked on the I-275 icon whose location centered the map on the southwest portion of the map.



Minneapolis map — Detroit overview — Detroit west

Figure 19. Illustrations of the navigation map and its origin.

The experts had less difficulty understanding the navigation map; however, their initial reaction to its functioning was one of surprise. One expert commented that the navigation map did not function similar to others he had seen. He expected to be able to pan and zoom freely, not to be limited to certain regions. The divisions or regions used in the prototype were also arbitrary and vague, unlike the Minneapolis navigation map, which was divided into named quadrants providing users a clue about how the map functioned.

4. *Users were confused about the extent of the overview map.*

   Four out of 5 of the test participants were confused about the extent of the map. When given a situation where information was needed for sections not on the overview map, most of the users attempted to pan the map (using various alternatives such as directly clicking on the map, clicking on the navigation map, or using the pull-down menus). After their attempts to pan the map, they tried to search the site for a different map to provide them with more information. Four of the users eventually gave up and concluded that the information was not available because those road sections were not monitored, but one of the novices completely failed to understand why some roads had real-time data (colors) while others did not.

   Allowing users to pan the map into sections that were not monitored might have cleared up some of these issues. The prototype basically ended the map at the extents of the monitored section, even though suburbs of Detroit existed beyond the monitored section of freeways. Had the experts been allowed to instinctively pan the map further, they most likely would have realized on their own that those sections were not monitored, alleviating some of the confusion and questions. The novices may also have benefited from a help page that explained why some roads were monitored and others were not.

5. *The implementation of the pull-down menu was confusing.*

   Since the navigation map caused considerable confusion, all of the test participants utilized the pull-down menu located above the navigation map which provided the same functionality. The pull-down menu was duplicated from several pull-down menus on other web sites. The user used the pull-down menu to select an option, then clicked on a second button under the menu labeled "Display Selection." Experts found this annoying, and novices were simply unable to make the pull-down menu work without experimenter intervention. The pull-down menu should have activated the selection immediately upon releasing the mouse (as is standard for most computer programs even though it is not standard on the web).

Goal 3: Estimate the Travel Time

The third goal of the experiment was to estimate the travel time for the chosen route. The only information regarding actual travel times for the prototype web site appeared on the Estimated Current Travel Times page. This page was arranged in tabular format by freeway. All of the test participants found this page extremely difficult to use. The travel-time page could be accessed either from the MITS subsite home page or from the pull-down menu on the real-time overview map page. Three main problems were encountered with the travel-time estimates page:

1. *The users were unsure of how the travel-time estimates were computed.*

   Several of the users questioned whether or not the travel-time estimates were real-time. The page heading "Current Travel Time Estimates" was not immediately taken as meaning "real-time" for several of the expert users. One of the novice users assumed that the travel times were based solely on distance and, thus, miscalculated the travel time by using a northbound estimate for a southbound trip, rationalizing that since he did not see the southbound estimate right away, the northbound would be the same.

2. *The users found it difficult to match the text tables to the map of their route.*

   All of the users commented that the travel-time estimates were useful information, but difficult to use in the table format. Some users had difficulty remembering the roads on their route, the direction of travel, and the approximate extents of travel on that road as they switched from the map to the travel-time table. Since the travel time estimates were organized by road, and multiple roads were needed to reach the destinations, users became quickly frustrated by having to scroll between roads, to decide which segments of a road were going to be traveled on, and to estimate the travel times for trip segments that did not coincide exactly with a road segment that contained a travel time.

3. *The users were confused when travel time estimates were "Not Receiving."*

   Several sections of road were under construction during the scenarios. The travel-time estimates for these sections were reported as "Not Receiving" on the travel-time table to indicate that the information was unavailable. The expert users were frustrated and annoyed by this type of error message. One commented that he would prefer any information, even old information, rather than none. None of the users ever connected the lack of travel times with the construction. A better way to handle the lack of information would have been to explicitly state that the travel time was unavailable due to construction and provide a link to the relevant construction information.

Goal 4: Note Any Problems Along the Route

Noting the problems along the route involved two steps. First, the user had to zoom the overview map into a particular region. This allowed the user access to the cameras, variable message signs, and incident and construction reports. As discussed earlier, several users had difficulty finding this information. Four of the 5 users were unable to find this information during the first scenario without prompting from the experimenter. The experts were all satisfied with the information provided by the overview map and travel-time tables, and simply assumed that no further information was available. (Thus, the experts did not even attempt to zoom into a region to find the cameras, incidents, etc.). The experts based their route decisions mostly on the color coded map, avoiding red (slow) areas and assuming that there was an accident or heavy traffic there.

The second step to noting any problems along the route was to check the cameras, VMSs, and incident and construction reports. Once this information was found, most of the users thought it was "neat" but did not find the VMSs or reports useful to planning their route. Three of the participants commented that the construction and incident reports would only be useful if an alternate route was provided. Two of the users also noted that the construction reports did not help their decisions, because real-time information was not provided in the reports. They would only avoid the construction if they knew it was going to be backed up and cause them long delays. In the absence of specific real-time information on the construction site, these users would risk taking the route through the construction area and hope that the delays were not significant.

Aside from the loop-detector data, the camera snapshots were the only other source of real-time information used. However, the specific camera images were interpreted differently by the different users. One user may have looked at an image and decided that the road didn't look bad, while another used the same image to solidify a decision to avoid the road. Several participants also had difficulty visualizing the camera direction from the text description of the camera location and direction it was currently facing. One participant commented that he would rather have the camera icon on the map point the direction the camera was facing.

Task Performance

The task-completion times for scenarios 1 and 2 ranged from 10 minutes to 25 minutes. All of the subjects commented that they would never have spent more than a minute or two on the web site if they were using it in a nonexperimental setting. The actual route chosen by each participant (and their time estimate if they were able to give one) is listed in Table 16 for scenario 1 and Table 17 for scenario 2.

Table 16. Scenario 1 Route-Selection Results

Test Participant	Skill Level	Route Description	Time Estimate
1	Expert	Chose normal route home	50 minutes
2	Novice	Chose normal route home	not sure
3	Expert	I-696 E to I-75 S to I-94 W	60+ minutes
4	Expert	I-696 W to M-10 S to M-39 S to I-94 W	70 minutes
5	Novice	Chose normal route home	not sure

Table 17. Scenario 2 Route-Selection Results

Test Participant	Skill Level	Route Description	Time Estimate
1	Expert	I-96 E to M-39 N to M-10 S	not sure
2	Novice	I-94 E to I-75 N	not sure
3	Expert	I-94 E to I-96 W to local roads	60 minutes
4	Expert	I-94 E to M-10 N	70 minutes
5	Novice	I-94 E to I-75 N	not sure

For scenario 1, only 1 of the 3 participants who selected the normal route home was aware of the construction along that route. Both of the participants who rerouted to use I-94 were also unaware of the minor construction on that road, and the 1 participant who rerouted using M-39 was unaware of the construction on that road. In both cases, the decision to reroute was based on the accident and backup on I-275, which ironically, had little impact on their route home since the accident primarily affected the northbound lanes, not the southbound lanes.

Both of the novices were unable or unwilling to give a time estimate for the trip home. When the test participants had decided on their route home, the experimenter prompted them for their time estimate. If the test participant refused after the first prompt to give a time estimate, then the experimenter prompted the test participant to give their "best guess." A subject's refusal to give an estimate after the second prompting was recorded as "not sure."

For scenario 2, 3 of the participants selected the most direct route with the least number of freeway changes (I-94 E to M-10 or I-75 N) even though this route took them through heavy congestion. Two participants rerouted to use out-of-the-way freeways with less congestion, however, they were not able to predict how long their route would take, or how much time would be saved by avoiding the congestion.

All of the incidents and construction along the test participants' routes were properly noted during the second scenario. However, 3 of the test participants needed to be prompted or instructed on how to use all of the information available to them during the second scenario. Had these participants not been prompted, they would not have discovered the camera images, variable message signs, incident reports, or construction reports. The prompting phrases used included the following:

1. Do you think that you could find out more information about that area?
2. Do you think that more information might be available if you zoom into a region?
3. Would you think you could click on that icon to get more information?

Two of the experts required this prompting because they only considered the overview map during the first scenario. In order to gauge their responses to the implementation of the rest of the features, these test participants needed to be prompted to "dig deeper."

TRAFFIC-INFORMATION WEB-SITE-DESIGN GUIDELINES

Guideline Overview

Based on the review of the traffic-information web sites, the human-computer interaction and human factors literature, and the current web-design literature, a set of traffic-information web-site-design guidelines were developed. The set was organized into a principles and a guidelines section. The principles section deals with higher-level issues common to many of the guidelines. The guidelines section is divided into 4 general sections addressing particular aspects of the web site.

1. Site organization
2. Site navigation
3. Real-time traffic-information presentation
4. Real-time map colors, symbols, and design

As appropriate, three types of information were provided for each guideline: 1) a brief rationale describing the research on which the guideline was based, 2) an implementation section clarifying the guideline and providing tips or hints on how to effectively implement the guideline, and 3) examples or figures illustrating the intent of the guideline.

Principles

Web-site design should follow 8 basic principles:

1. Information must be <u>legible</u>.

   The user must be able to easily determine what appears on the screen under all circumstances. The fonts must be large enough to be seen. The colors and luminance levels selected must provide adequate contrast; threshold legibility is not acceptable. Moving text is also discouraged.

2. Information must be <u>readable</u>.

   Given the user can see what is presented, they must be able to decipher its meaning. This involves understanding how a page is organized and the use of language the user can comprehend.

3. Pages and page elements should be <u>consistent</u>.

   The site's appearance and the way the user interacts with the site should remain consistent throughout the site in order to remain consistent with the user's expectations. Similar actions should lead to similar results.

4. <u>Minimize the number of actions</u> required by the user to reach information.

   Users should never be required to enter the same request multiple times to reach the information they desire. A balance must be achieved between presenting the user with too many options at once (which clutters the screen) and burying the information too deeply in the site (requiring the user to dig for the information). The impact of this principle is to minimize task-completion time.

5. The user's status should be always apparent.

   Constant feedback must be provided to the user regarding what page in the hierarchy is currently being shown and what options are currently available. Information must also be provided on the status of information retrieval tasks (what is being retrieved, how much has been retrieved, and when the task will be completed).

6. Links should be apparent and their actions should be predictable.

   Clickable objects and text should be distinct and apparent to users. However, the users must also be able to predict where a link will lead, and what will happen when a link is clicked.

7. Plan for error correction.

   Users make lots of mistakes, so actions should be quickly and easily reversible. Allow users to readily back up to previous states.

8. Support for novice and expert users.

   Systems are used by a wide range of users, many of whom know much less about the domain than the developer.

Specific Guidelines

1 Site Organization

1.1 *Site organization*

Provide explicit navigation cues and link labels. Since there is no preferred method for organizing a web site, do not assume that a user will follow or understand the sites structure.

Implementation Notes	Example
As discussed in Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999), web users are generally unfamiliar with the site's domain (transportation engineering in the case of traffic-information web sites) and oblivious to a site's structure. Regardless of the site's structure, explicit navigation cues and link labels should be used because users cannot be expected to understand the sites structure or to travel through the site in a linear manner.	The common shell structure (Site -> Subsite -> Page), was used on the MDOT web site. MDOT (the site) had a home page and Michigan ITS (the subsite) had the MITS Detroit Traffic home page. The original site identifier made no reference to the subsite (Figure 20) which might cause confusion as to whether the home button referred to the site or the subsite. However, an attempt to add the subsite (Figure 21) only showed that users did not view the site in terms of MDOT's organization.

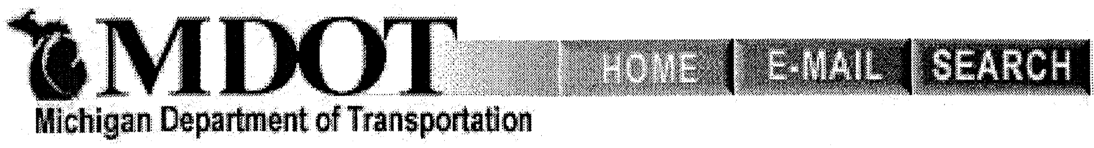


Figure 20. Original MDOT site identifier with a link to the MDOT Home Page.

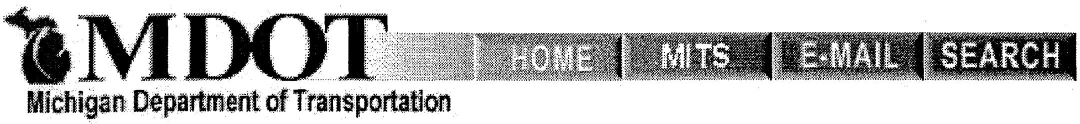


Figure 21. The new MDOT site identifier contained a link to the subsite (the MITS Detroit Traffic home page), however, usability testing showed that the button's label (MITS) was not explicit enough and users had no idea what MITS was. In this case, the users suggested that the "MITS" button should have been labeled as "Traffic."

1.2 *Avoid orphan pages*

Tie each page clearly to the overall site with consistent logos, colors, menu bars, or navigation bars. Each page should provide a set of common links or exits including one to the main index or home page.

Rationale

As cited in Nielsen's Top Ten Mistakes in Web Design (1996), orphan pages should be avoided because users may directly access each page on a site through bookmarks or search engines without previously going through the site as intended by designs. Further research by Omanson, Cline, Kilpatrick, and Dunkerton (1998) has also shown that consistent logos, background colors, fonts and graphics help to identify which pages belong to a particular site.

Implementation Notes

Given the rationale for providing site identifiers and links off of each page, ambiguous labels such as "Home" or "Back" should also be avoided since a directly accessed page would have no context or meaning for a link entitled "Back."

1.3 *Avoid links to unfinished pages*

Avoid links to pages which say "coming soon, under construction, or feature not yet implemented." If a page is not completed, disable the links to it.

Rationale: According to Nielsen (1997c), current web users expect more comprehensives from sites than they did in years past. Links leading to unfinished pages with under construction signs were considered disrespectful of the user's time.

1.4 *URL naming structure*

Keep URL addresses readable and useful:
• **Avoid long and complex URLs.**
• **Avoid capital letters.**
• **Use descriptive directory and file names.**
• **Avoid naming structures that must change frequently.**

Rationale: As cited in Nielsen (1996) long and complex URLs should be avoided because users have trouble typing them in or sending the URL to others (Nielsen, 1999a). Capital letters should be avoided because most web servers are case sensitive and failure to capitalize will result in errors. Nielsen also noted that descriptively named URLs can aid the user in navigation since the URL for a link appears by default in the status window when the mouse passes over the link (see Figure 22). The traffic-information web-site heuristic evaluation confirmed these recommendations. When the links on the map were named with human-readable directory and file names, the status window could be used to indicate what camera or VMS the cursor was over on the map (Figure 23). Finally, frequently changing page names should be avoided since they disrupt users' direct bookmarks, links from other sites, and search engines that only update their links infrequently (Nielsen, 1998b).

Example: The following is an example of a human-readable URL:

http://www.mdot.state.mi.us/detroit_traffic/cameras/camera1.html

From this address, one could infer that the page leads to a camera image showing Detroit traffic information.

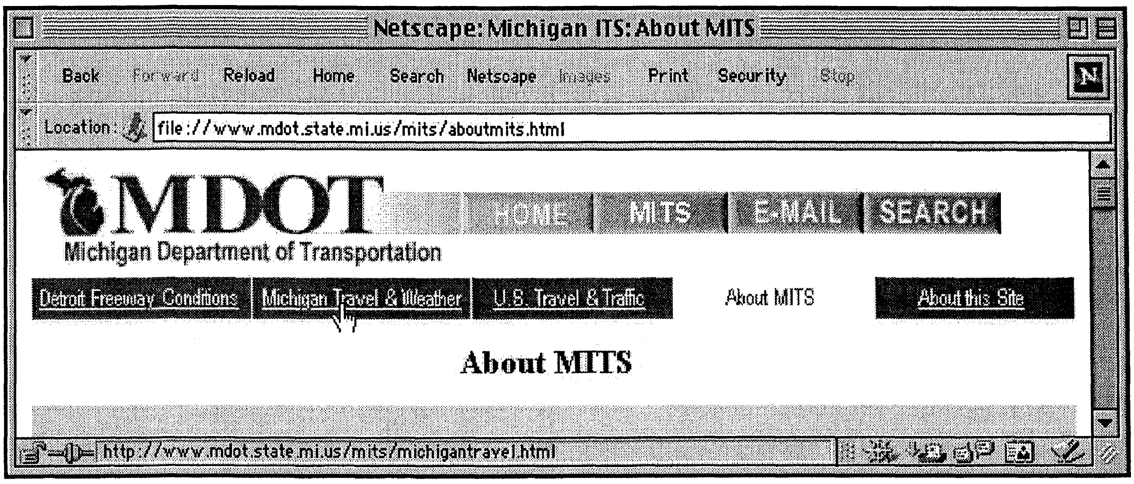


Figure 22. The status bar default displays the URL for a link if the mouse is over it.

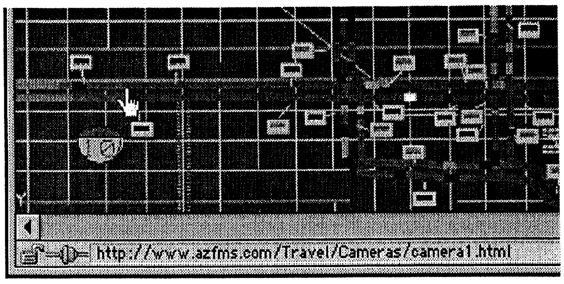


Figure 23. Status bar use on the Phoenix web site.

1.5 *Screen Size and Scrolling*

Design the site to be function on a 640X480 screen to reach the widest range of users, even if the page is optimized for use on a higher resolution monitor.

Rationale

According to a 1998 Georgia Tech survey of Internet users, 11.6% use 640x480, 30.7% use 800x600, and 27.7% use 1024x768 which constitutes 70% of the users. Of the remaining users, 13% were using large resolutions, and 17% either did not know or were using resolutions not listed in the survey. It should be noted, however, that as new, smaller technologies emerge (PDA web browsers, in-vehicle systems, etc.), designing for a wide range of users will become increasingly more difficult.

Implementation Notes

Although there is some disagreement as to whether or not usability problems exist with scrolling pages (Nielsen, 1996, Nielsen, 1999a, and Spool, et al., 1999), important information should be as visible as possible without scrolling, or the information may be missed by the user (as found in both the heuristic evaluation and the usability testing). Therefore, the best recommendation is to run usability tests on the web site at varying screen resolutions to find any usability problems that may result from screen resolution or scrolling.

1.6 *Use of Frames*

Implement frames in a way that prevents problems with bookmarking, searches, the browser's back function, and the question of where information will appear when a link is clicked.

Rationale: Several current usability reports (Nielsen, 1999a, and Spool, Scanlon, Schroeder, Snyder, and DeAngelo, 1999) have indicated that the well implemented uses of frames on web pages neither hurts nor helps usability. Frames can prove useful for the application of the interactive map on traffic-information web sites. However, the following issues associated with the use of frames need to be addressed to prevent any usability problems from occurring:

Common usability problems with frames.

1. Frames cannot be seen by all browsers. Therefore, the use of the NOFRAMES HTML tag is required to assure backwards compatibility.
2. Most browsers cannot properly bookmark frames. The browsers can only bookmark the frameset, not a particular page in the frameset. Thus, it is often impossible to bookmark (or to copy and send the URL for) what is currently being viewed.
3. Usability problems can occur when users cannot predict what will happen when they click on a link in a frame (e.g., In which frame will the new information appear?).
4. The use of frames can cause problems with the browser's back button. Since a single click in a frame can affect multiple frames on a page (through the use of javascript), a single click of the back button may have unpredictable effects by changing back only one of the frames that were affected by the user's previous click.
5. Frames are difficult to program and often contain code bugs that do not allow users to use the frame properly. Examples include disabled frame resizing or scrolling when the frame was designed for a larger screen but viewed on a smaller one and forgetting to remove the frame when linking to pages external to the frameset.
6. Search engines have difficulty properly locating and cataloging frames.

1.7 *Download time*

Keep web page downloads under 10 seconds at average speed of the users connections (currently a fast modem, 33.6 Kb/s).

Rationale

Ten seconds was cited in Nielsen (1993) from previous research (Miller, 1968, and Card, et al., 1993) as the limit for keeping the user's attention focused on the current task. According to a Georgia Tech (1998) survey of Internet users, 66.5% of the Internet users are connected by 28.8, 33.6, or 56 Kb/s modems. Although Internet bandwidth is postulated to follow an exponential growth curve with a 50% annualized growth (increasing by a factor of 57 every 10 years), the low-end, current modem users will not be upgraded to take advantage of the bandwidth until at least 2003 (Nielsen, 1998a) necessitating the need to design pages for use with modems.

Implementation Notes

Although the generally cited download time is 10 seconds, any delay over 1 second should provide the user with feedback. According to a study cited in Bickford (1997), the average user will stop a computer process after about 8.5 seconds with no feedback. As the level of feedback increased, the users were willing to wait longer. Since the actual download speed is dependent upon the server, its connection, the user's connection, and current network traffic, every means to speed up the download and display of the web page should be implemented.

Examples: 9 ways to speed up a web page from various *tips* web sites

1. Use graphics conservatively. Avoid using images of text since text will download much faster than an image. Consider alternatives such as style sheets and colored tables.
2. Balance the size and number of graphics on the page. Many small graphics may download faster if they are merged into one single graphic, or one large graphic may download faster if broken into several smaller ones.
3. Avoid large background images, animated gifs.
4. Include ALT, HEIGHT, and WIDTH tags for all images. This allows the browser to lay out the rest of the page before the images are completely downloaded.
5. Make sure the top of the page loads quickly (save complex images or page items for lower on the page).
6. Images that are also links should have redundant text links. The text link will load faster than the image and allow the user to move off the page if they find the link they want before the entire page has downloaded.
7. Long, complex tables take time to render on the screen. Break them into several smaller ones to decrease the apparent download time.
8. Consider using frames to minimize the amount of screen that must be redrawn constantly.
9. Use a server that supports HTTP keep-alive.

2 Site Navigation

2.1 *Menu bar location*

Place menu or navigation bars at the top or bottom of each page, rather than down the sides of the page.

Rationale: This recommendation was from Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999) based on the limitations of screen size. Having navigation bars on the side of the page caused users to horizontally scroll the bar off the screen to view the page (especially when the page was designed for a wider resolution).

2.2 *Using a menu bar as a site identifier*

Use a consistent menu bar header or footer on *every* page as a site identifier. The site identifier should contain at least 2 links, one to the site's home page and one to its search page.

Rationale: This guideline was recommended by Nielsen (1997b) to aid users in navigation and to prevent orphan pages (see Guideline 1.2). The site identifier (see Figure 24 for examples) lets users know where they are relative to the web as a whole, whether or not they have left the current site, and it provides easy emergency exit options from the page. Further studies by Omanson, Cline, Kilpatrick, and Dunkerton (1998) have shown that the site identifier logo was the most important factor used to determine which web pages belonged together.

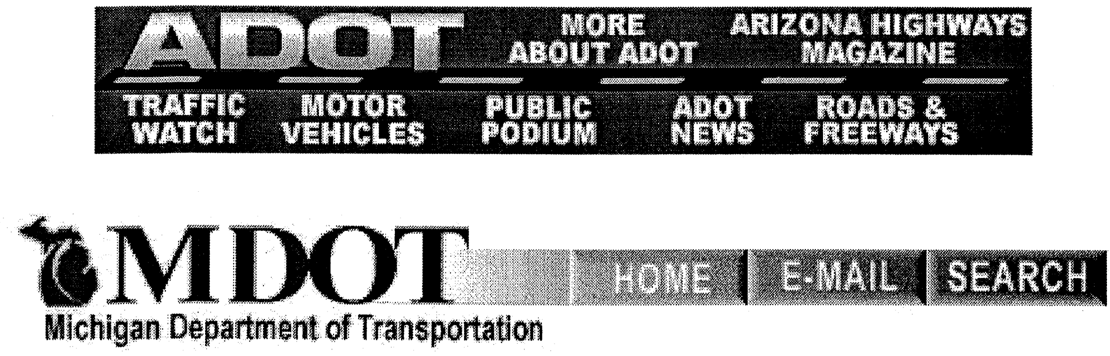


Figure 24. Examples of site identifiers.

2.3 *Menu bar Appearance*

Make the menu bars should be visually distinct from the rest of the page, and make the links within the menu bar visually distinct from each other.

Rationale

According to Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999), a successful link depends on: 1) how well the user can predict where the link will lead and its relevance and 2) how well the user can differentiate one link from another.

Several web sites reviewed in the heuristic evaluation confirmed that this problem existed as the sites contained pages where the menu bars (links) were not immediately noticed, causing users to search several wrong paths for the information needed.

Implementation Notes

The use of size, font, color, separation, and grouping can make a page element visually distinct. As an example (in Figure 24 above), the MDOT site separated the links Home, E-Mail, and Search by placing them in buttons, allowing the users to easily distinguish a link from any background text.

Larger sizes and bolder colors usually indicate greater importance and capture attention. In Figure 25, the menu bar was overshadowed by the graphics on the page.

Figure 25. Example of a menu bar hidden by graphics.

2.4 *Menu bar consistency*

Use a consistent location and format for menu bars from page to page. The core menu bar should not add items, lose items, or change the order of items from page to page.

Rationale

The rationale for this guideline came from problems found in the heuristic evaluation. Once the user finds the menu bar on one page, he should not have to search each additional page to find the same menu bar. Therefore, a consistent location, format, and core set of menu items is recommended. A well designed menu bar should not only provide the user with options of where to go, but it should help to communicate the site's structure to the user.

Implementation Notes

The implementation of menu bars will vary greatly according to the site structure and design. With a small site (only 5 or 6 distinct pages), this may be accomplished with a single static menu bar; however, larger sites may need to consider other options since the number of menu items that can be displayed effectively is limited. Two possible options include: 1) using an expanding tree menu (Figure 26) or 2) breaking the site into several distinct smaller sites.

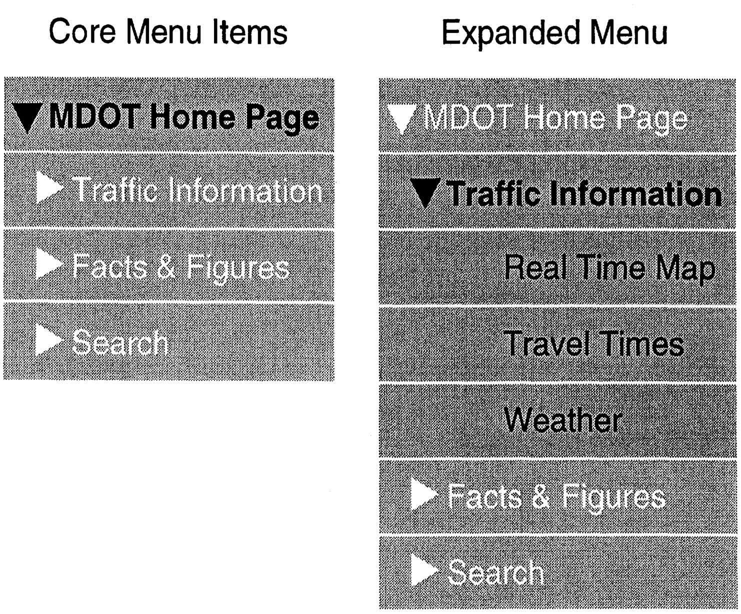


Figure 26. Example of an expanding tree menu.

2.5 *Location feedback on the menu bar*

Indicate the user's current location in the web site on the menu bar, and disable any redundant menu bar links to the current page (i.e., a page should not link to itself).

Rationale	Implementation Notes
According to Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999), one common problem with web navigation occurs when users easily get lost in a sites hierarchy. Thus, it was recommended that menu bars provide feedback as to what page in the site the user is currently on.	The location feedback can be given by bolding the currently displayed menu item (shown in Figure 26), changing its color, or highlighting it (Figure 27). However, the currently displayed page should not be indicated by removing the menu item that violates Guideline 2.4 (menu bar consistency). The currently displayed menu item should also not be clickable since linking the current page to itself would be redundant.

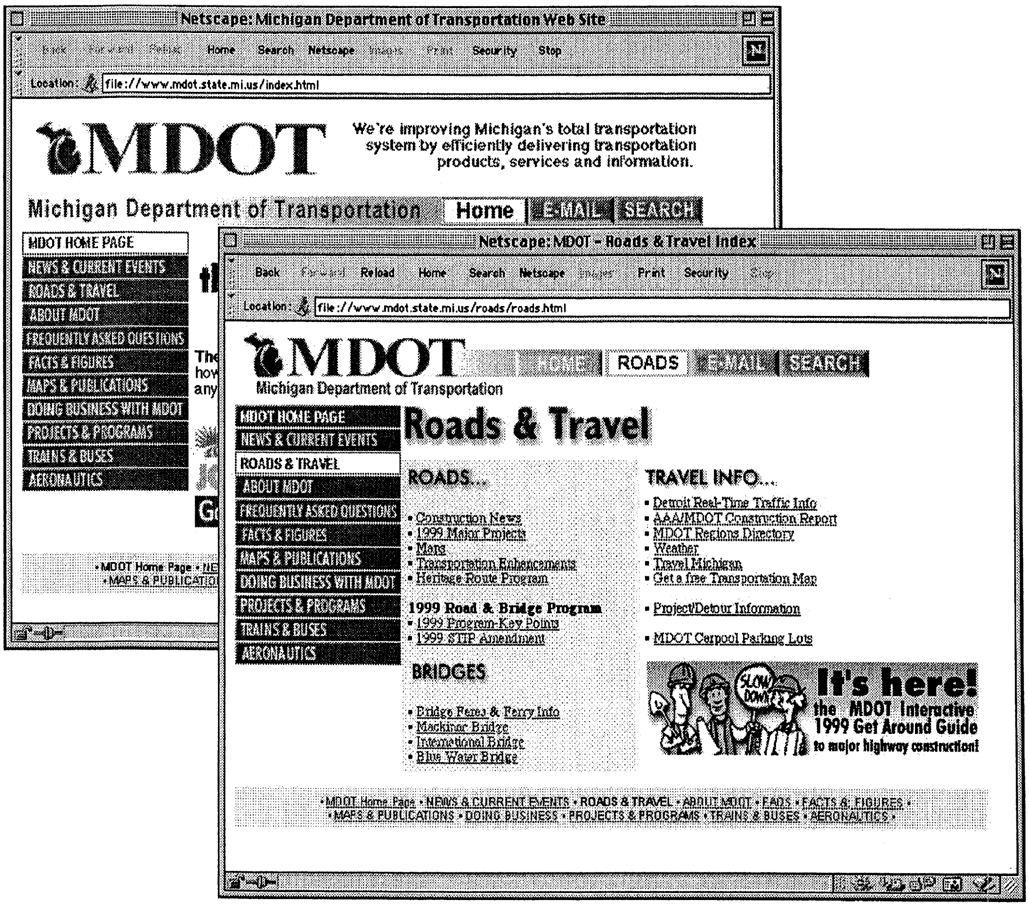


Figure 27. This example shows the left menu providing location feedback by highlighting the current item and disabling its link as the user moves between pages.

2.6 *Page titles and headings*

Use page titles and headings that (1) are consistent with the links to the page, (2) accurately reflect the content of the page, and (3) reflect the user's language and expectations.

Rationale

The rationale for this guideline came from problems found in the heuristic evaluation and usability tests. Page titles and page headings provide feedback to the user about what site they are looking at, what page in the site they are looking at, and what information can be expected to be found on that page. However, page titles also serve as link titles for bookmarks and search engines. Pages that do not provide an accurate and descriptive title (through the <TITLE></TITLE> HTML tags) will not be easily distinguished when bookmarked and will not be easily found through Internet searches.

Examples

1) During usability tests, subjects questioned whether a page title labeled as "Current Traffic Information" was the same as "Real-Time Traffic Information," which was the precedent on the site for all of the other pages.
2) Users do not understand and are often confused by the language or conventions used by the traffic management center, such as when road regions are referred to by the hardware system that monitors them or boundaries set by others (e.g., police districts).

2.7 *Links and link labels*

Avoid ambiguous link labels. Instead, use link labels that accurately and descriptively preview the page to which the link leads.

Rationale

According to Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999), a successful link depends on: 1) how well the user can predict where the link will lead and its relevance and 2) how well the user can differentiate one link from another.

Ambiguous and out-of-context link labels (back, home, forward, etc.) hinder the user's ability to predict where the link will lead and decide if the link is relevant to the current task.

Implementation Notes

As noted in Guideline 2.6 (page titles and headings), the link label should be consistent with the page title or heading to which it leads. This provides immediate feedback that the link actually took the user to the intended information.

Link labels should also avoid organizational and domain-specific terms that users will not understand (e.g., while most Michigan drivers will understand the acronym MDOT, none are likely to know that the traffic surveillance is done by the MITSC).

3 Real-Time Traffic Information Presentation

3.1 *Real-time traffic information overview*

Format the real-time traffic information so that a single web page (either a real-time map or travel-time table) can give users an overview of traffic conditions (including incidents and construction) for an entire metro area.

Rationale: A review of the web server statistics for the Detroit and the Chicago metro-area, real-time web sites revealed that the most frequently accessed web pages were the real-time overview map and the travel-time overview table. Usability tests reinforced that the users preferred to have all of the information needed to make a decision on one representation. A site without an adequate overview page requires the users to check several different pages or "dig" for the information. Having to "dig" for the information during the usability tests took more time and made comparisons of different routes more difficult since the user has to remember the conditions on the first route while investigating the second route.

3.2 *Real-time information status*

Display the date and time for the currently displayed real-time information prominently on all real-time map pages, travel-time overview pages, and video images.

Rationale: Time-stamping the real-time information (e.g., "last updated:") assures the user that the information is up-to-date, and that the system is not malfunctioning. Although time-stamping all real-time information pages would be ideal, at minimum, the overview pages (maps and travel times) should be time-stamped since they are the site entry points for most users (as revealed in an analysis of the web server statistics for the Detroit and the Chicago web sites). Video images should also be time-stamped since the refresh rate for the video may be different than the refresh rate for the sensors and other types of information.

3.3 *Travel-time format*

Include (1) the road name and number, (2) the direction of travel, (3) the start point, (4) the end point, (5) the distance, (6) the current estimated travel time, and (6) reference to all major construction and incidents in all travel-time tables. As the technology becomes available, customized travel-time reports should replace or supplement static travel-time tables.

Rationale: Dudek, Huchingson, Stockton, Koppa, Richards, and Mast (1978) noted that only daily commuters were familiar with the local freeway names, and the meaning of travel-time estimates. Infrequent travelers and those with novel destinations should be provided with additional information such as the start point, end point, and distance in order to properly interpret the traffic conditions based upon the travel time (see Table 18). As demonstrated in the usability tests, noncommuters were easily frustrated by travel-time tables when they had to add links on different roads to estimate a single trip. They also found it difficult to match the text road names and directions to the spatial map of their route (e.g., users continually had to switch back to the map to remember what their next road segment was or which direction they were traveling). These users indicated that they would rather receive a customized estimate from their origin to their destination.

Table 18. Example Travel-Time Table.

Freeway Name	Direction of Travel	Starting Point	Ending Point	Distance (miles)	Travel Time (min)
I-94	Inbound (East)	Airport	M-10	20	45
I-94	Outbound (West)	M-10	Airport	20	25

3.4 *Accessing detailed information from the real-time map*

Format the real-time map such that clicking on an item on the real-time map produces location-specific information. A click on the map should not bring up a list of options.

Rationale: As discussed in the heuristic evaluation, the real-time map acts as a spatial representation of the detailed information available (cameras, variable messages signs, incidents, construction, loop or speed detectors, etc.). If the user clicks on a particular camera icon depicted somewhere on the map, the user has already selected the camera he or she wishes to view, and thus, the user should not be required to reselect the camera from a list.

3.5 *Limiting the clickable area on the map*

Format the real-time map so that areas of the real-time map that do not link to location specific information are not clickable (i.e., the default for the map should not be a link or an error message which states that the user should only click on the certain items).

Rationale: According to Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999), a successful link depends partly on how well the user can differentiate one link from another. Since the cursor on most browsers provides feedback as to when it is over a link (by changing from a black pointer to a white hand as shown in Figure 28), making only the parts of the map that provide location-specific information clickable will aid the user in distinguishing what on the map is a link.

Cursor not over a link | Cursor over a link

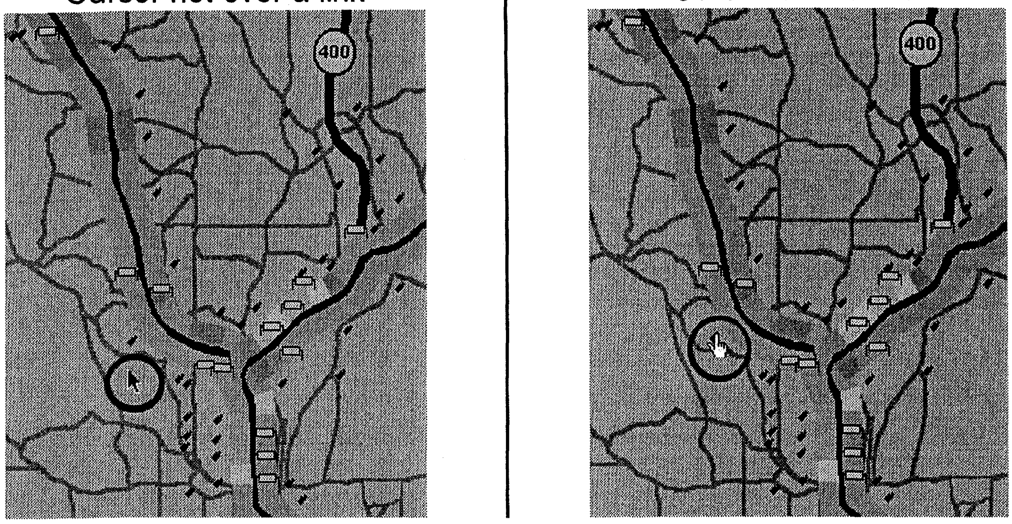


Figure 28. Feedback is provided when the cursor changes as it moves over a link.

3.6 *Using the browser status window*

Provide feedback to the user as to what the cursor is over (on the real time map) through use of the browser's status window.

Rationale	Implementation Notes
According to Spool, Scanlon, Schroeder, Snyder, and DeAngelo (1999), a successful link depends on: 1) how well the user can predict where the link will lead and 2) how well the user can differentiate one link from another. Proper use of the status window can assist the user in both tasks.	By default the status window displays whatever follows the HREF attribute of an anchor tag (whether it is a URL or a Javascript function call); however, by using the anchor tag's ONMOUSEOVER attribute, the status window message can be changed to provide better feedback. (See Figure 29).

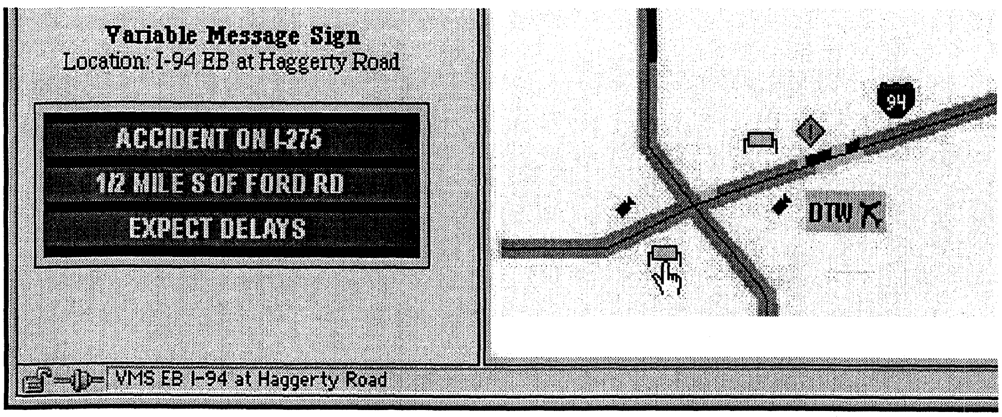


Figure 29. Status window message providing feedback on what the cursor is over.

3.7 *Map pan and zoom controls*

Provide well labeled controls and an orientation map (Guideline 3.8) to support map pan, zoom, and preselected area functions.

Rationale

In keeping with Guideline 3.5 (limiting the clickable area on the map) the pan and zoom controls should not be represented by hidden links on the map background (e.g., a click near the top of the map would recenter the map to the north). Hidden pan and zoom controls on the map's background hinder link preview making it more difficult to predict what will happen when a location on the map is clicked.

Implementation Notes

Many different types of controls can be provided to control the map's pan and zoom capabilities. Figure 30 only shows a few examples such as external buttons, a clickable map border, and a pull-down menu of preselected areas. Keep in mind that the best design may even use a combination of controls to allow the user flexibility in selecting the desired map area. However, whatever controls are used, should be consistent throughout the site.

Labeled pan and zoom controls

Pull-down menu

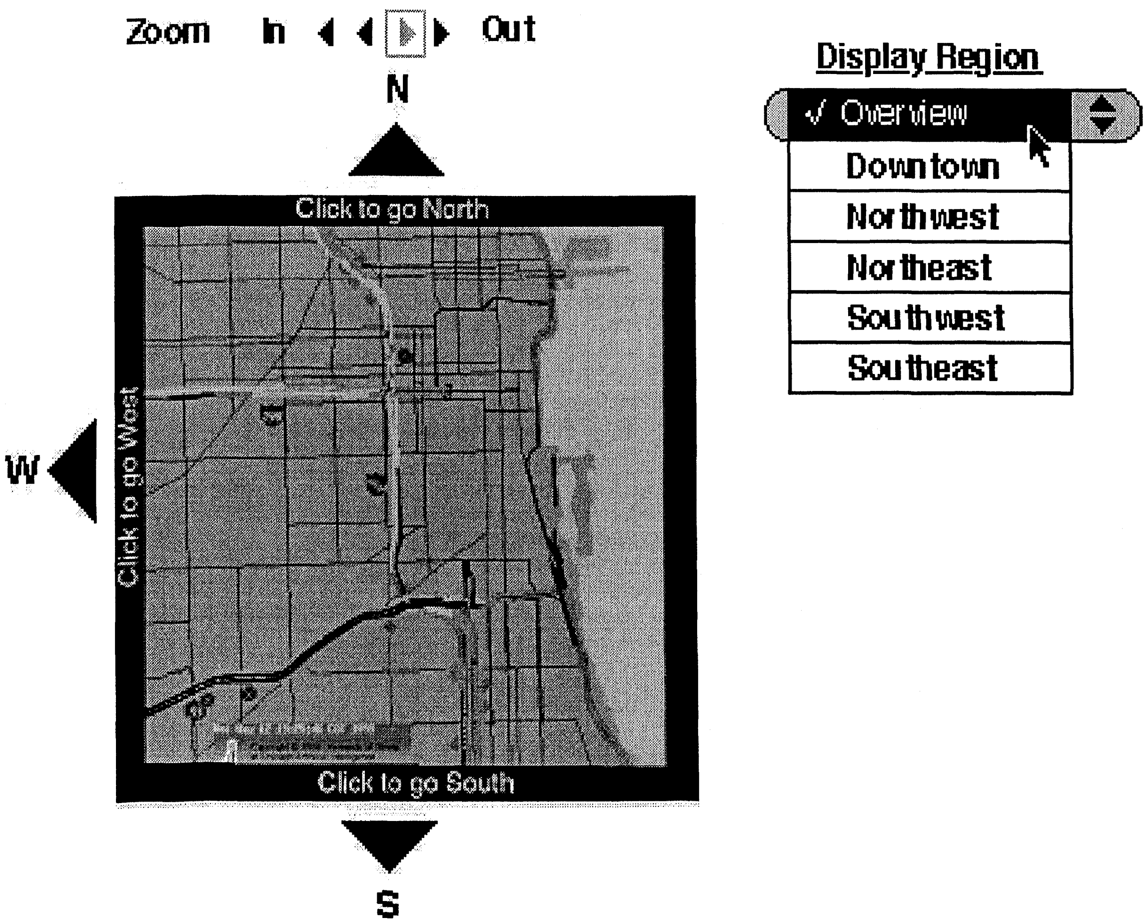


Figure 30. Examples of visible map pan and zoom controls.

3.8 *Orientation overview maps*

Provide feedback on the currently displayed map location through an orientation map instead of providing feedback through headings and labels which may be missed or misinterpreted by users.

Implementation Notes: A small orientation overview map (provided at the top of the screen, in the legend, etc.) not only gives the users instant graphic feedback about what part of the overall roadway is being shown, but the orientation overview map provides a means of directly manipulating the pan and zoom capabilities of the map. The examples shown in Figure 31 allowed the users to click on the orientation overview map to recenter the image displayed on the main map. As mentioned in Guideline 3.7 (map pan and zoom controls), the best design would combine an orientation map with several other zoom-and-pan control methods to allow the users flexibility.

Chicago | Minneapolis

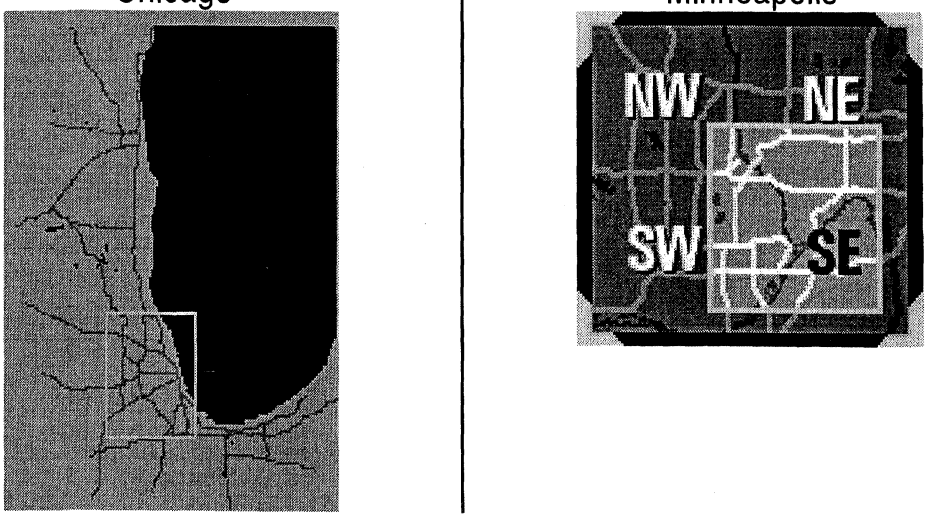
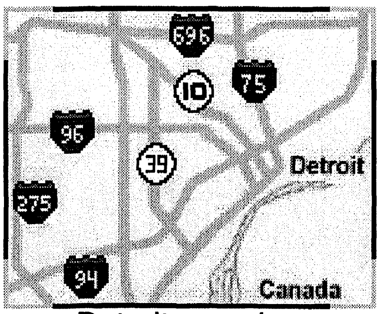


Figure 31. Examples of orientation maps.

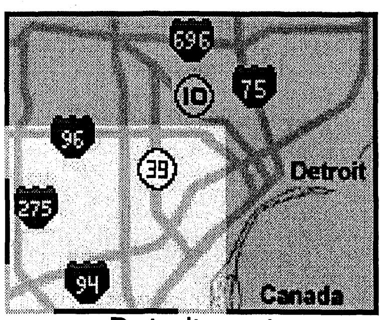
3.9 *Map pan and zoom controls through the orientation overview map*

Provide explicit cues to preview what will happen when the user clicks on the orientation overview map.

Rationale	Example
There are many different ways an orientation overview map could react when a user clicks on it. The map could recenter, recenter and zoom in, or display a preselected area that contains the click within its boundaries. The usability tests conducted in this report showed that without explicit cues to show how the map worked, users became confused when the orientation overview map did not function as they expected.	1) The previous examples in Figure 31 contrast maps with no visual cues (Chicago) and maps with explicit visual cues (Minneapolis) to show the user how the map functions. The Minneapolis map is divided into labeled quadrants. Clicking on the quadrant label or in the quadrant recenters the map on that quadrant. 2) The example in Figure 32 shows the problem found in the usability tests. Since no cues were provided on how the map functioned, users were often surprised that clicking on the map zoomed in on a section similar to the Minneapolis map, rather than simply panning the focus of the map.



Detroit overview



Detroit west

Figure 32. Example of an overview map without cues to preview what a click does.

3.10 *Displaying real-time information accessed from the map*

Display real-time information accessed from the map in a consistent manner and location. It is also recommended that location-specific information accessed through the map appear without replacing the real-time map.

Rationale: During the heuristic evaluation, the users were faced with following 2 questions while they were interacting with the real-time map:

1) Where will the information appear?
2) What will it replace?

While a consistent interaction method will help to provide preview for the experienced users, any screen design should attempt to provide cues to allow the novice user to determine where the information selected from the real-time map will appear. The real-time map functions as both a traffic overview and an index to the available cameras, VMS's, and incident/construction reports. Since users may wish to look at several cameras, signs, or reports during a session, the user should not have to reload the map each time to select a new piece of information to view, and thus, the information accessed through the map should not replace the map. An example of one screen layout which adopts this guideline is shown in Figure 33. In this example (adopted from the Atlanta web site), clicking on a sign icon on the real-time map displayed the sign's message on the lower left-hand frame. A similar system (without the use of frames) was used on the Microsoft Network's Minneapolis traffic-information web site for camera images.

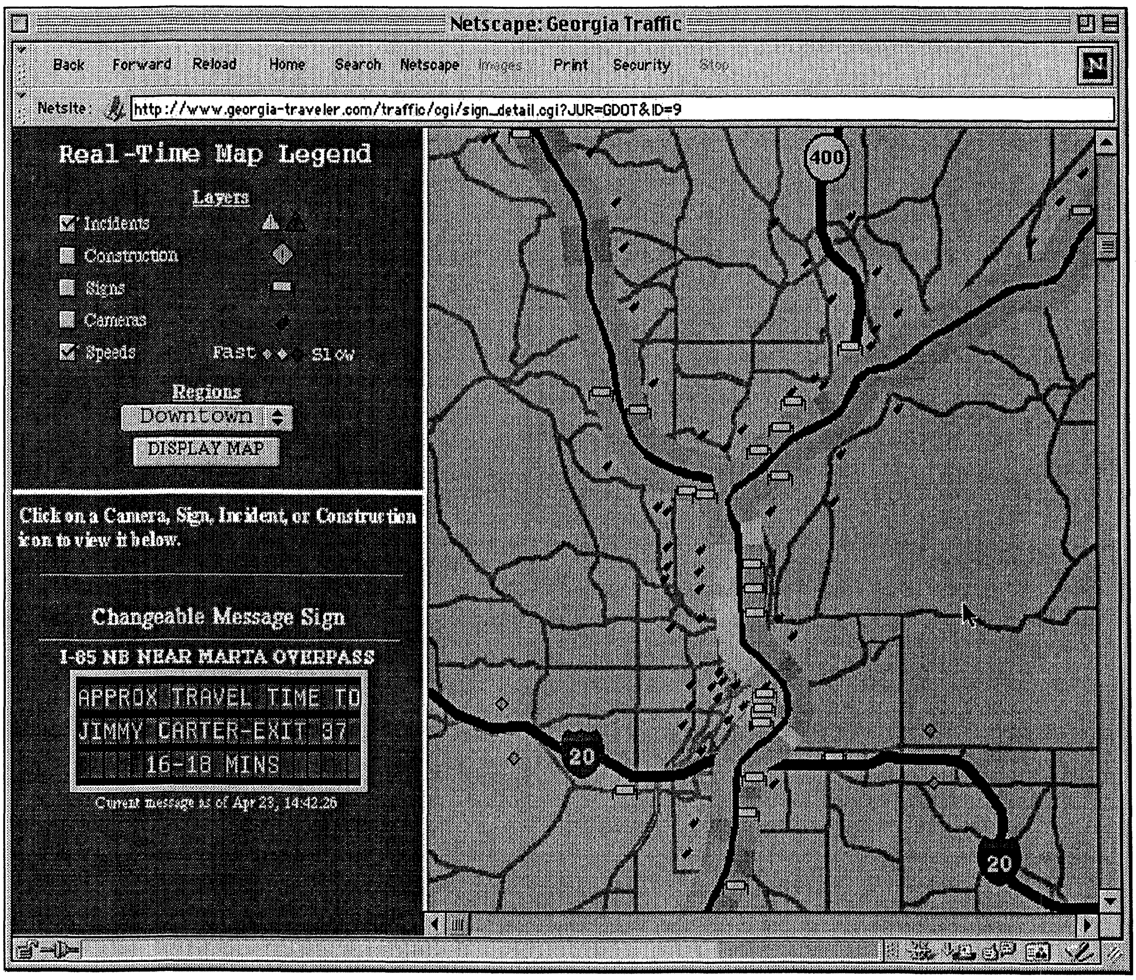


Figure 33. Example of one possible screen layout adapted from the Atlanta site.

3.11 *Depiction of camera direction*

State explicitly, if possible, which direction cameras are pointing. However, if comparison images must be used to determine the camera direction, the reference images should match the zoom, time of day, and season. Reference images should also be given relative to the road instead of absolute north, south, east, and west camera directions (e.g., camera looking west on I-94).

Rationale: Difficulty was encountered during the heuristic evaluation in determining the camera direction on several web sites. Using reference images to determine the camera direction was difficult when the reference images did not match the current conditions. For example, difficulty was encountered when trying to match a daytime reference to nighttime image or a summer reference to a winter image (where several feet of snow covered the roadway shoulders). Difficulty was also encountered when determining image direction when the reference was given in absolute compass directions, since the roads often do not run in absolute compass directions. (See Figure 34.)

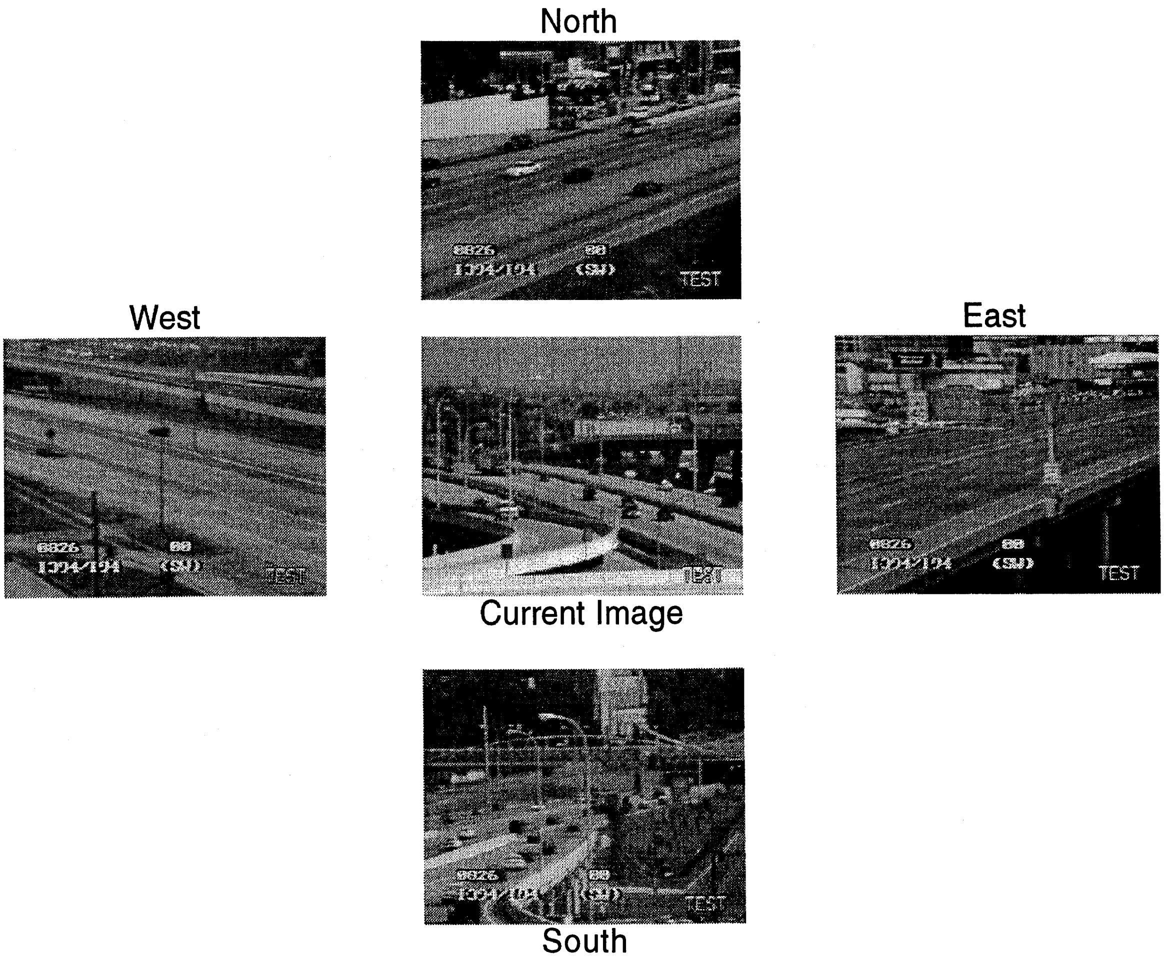


Figure 34. Example of the difficulty determining the current direction when the reference images are given relative to the compass directions.

4 Real-Time Map Colors, Symbols, and Design

4.1 *Display Contrast*

Assure that the color choices for symbols, text, and the map background have sufficient contrast to be easily readable. Avoid dark map backgrounds. Dark text on a light background is preferred.

Rationale

Dark text on a light background is generally preferred for most lighting conditons. Light text on a dark background is only preferred for dark-adapted environments (which is unlikely to apply to most traffic-information web site users).

Example

An example is shown in Figure 35 of the Los Angeles metropolitan area traffic-information web site. Dark objects were used on a light gray background, but the shades of yellow and green for the real-time congestion were placed against a white background reducing their contrast and making them more difficult to see.

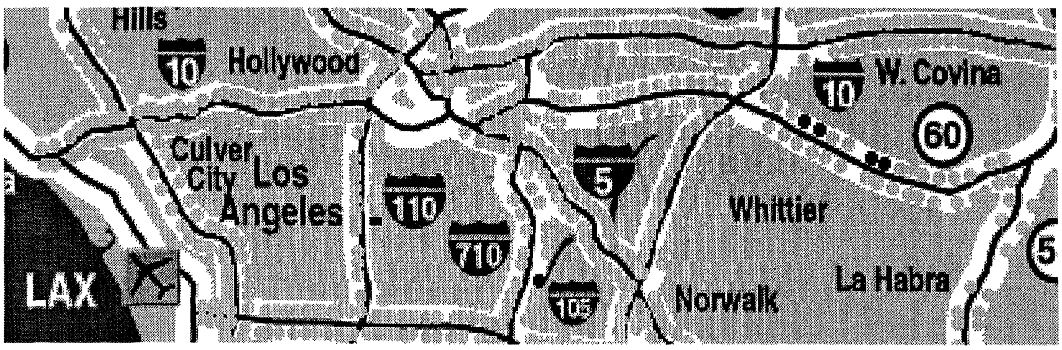


Figure 35. Background-foreground contrast on the Los Angeles web site.

4.2 *Redundant coding*

Avoid differentiating between multiple types of information by using only one coding method (e.g., color). Multiple codes (e.g., shape and color) should be used to differentiate icons representing different kinds of traffic information.

Rationale

Icons that are similar in size, shape, or color imply similarity in meaning. When it is necessary to distinguish one type of information from another through icons, multiple codes should be used (e.g., shape and color).

Example

Figure 36 shows that on the Georgia Navigator web site, the only coding difference between 2 levels of incidents and construction was color. A separate shape should have been used for the construction icon to distinguish it from incidents (e.g., a diamond or an icon of a construction barrel).

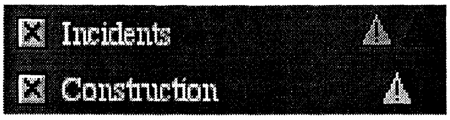


Figure 36. Icons used for incidents and construction on the Georgia web site.

4.3 *How many colors to use to represent information*

Limit the number of colors used to represent real-time data to between 5 and 7, and avoid using shades of a single color as a method for coding multiple levels of a particular piece of traffic data (e.g. speed). Separate colors should also be used for not monitored, no data, and construction.

Rationale

As the number of colors or shades of a single color increase into the 5 to 9 range (the generally accepted short-term memory limits), the task of interpreting the colors changes from an absolute judgment task (where the user can immediately interpret the colors on the map) to a task of relative judgment, comparing the map to the legend (which slows the user).

Example

Figure 37 is an example from the Arizona Trailmaster web site of using 6 colors to represent a continuum of traffic data (3 of the colors are shades of a single color, green, used to indicate speeds above 45 mph). The legend does however distinguish between roads that are not monitored and roads that are temporarily not receiving data.

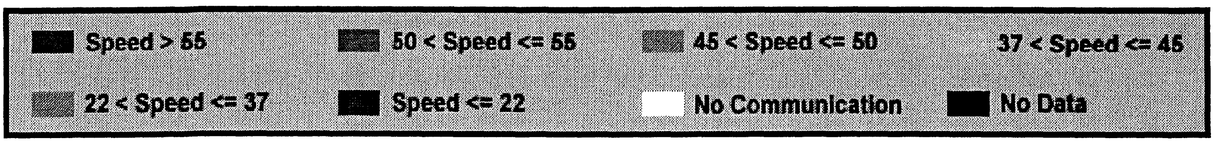


Figure 37. Color coding legend used on the Arizona Trailmaster web site.

4.4 *Color coding and user stereotypes*

Design to exploit popular color stereotypes (e.g., red, yellow, and green, respectively, imply stop, caution, and go according to the traffic-light metaphor or orange may be associated with construction signs since the standard color for all construction signs is orange).

Rationale: Wickens (1992) identified three benefits that result from color coding:

1. Color coding creates objects that are easily recognized and noticed.
2. Color coding can integrate objects within a display.
3. Color coding can enhance the redundancy of a coded object.

However, Wickens (1992) also noted 4 limitations of color coding:

1. There is no ordered continuum of color.
2. Population stereotypes can be associated with particular colors.
3. Humans are poor at performing absolute judgment tasks with color.
4. Color coding not relevant to the display can be distracting.

4.5 *Color coding consistency*

Use a consistent color-coding scheme throughout the web site. The colors used for congestion should also match regardless of the medium used to measure congestion (e.g., slow ramp meters should be coded the same as slow traffic or heavy congestion).

Rationale: The rationale for this guideline came from usability problems noted on a web site which used a 3-color scheme for traffic congestion and a 4-color scheme for loop detectors. The a single-color scheme for both loop detectors and ramp meters would have been preferred to avoid confusing the color interpretations between devices.

4.6 *Displaying speed versus congestion*

Use either speed or congestion consistently throughout the site.

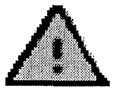
Rationale: Katz, Green, and Fleming (1998) showed that there was no difference in performance or preference for route selection between congestion and speed displays.

4.7 *Similarity between icons and real-world objects*

Base icons on easily recognized symbols or on real-world objects.

Rationale	Example
According to Wickens (1992), a code should be meaningfully related to the object it is referring to. The degree to which an icon represents the object of interest can influence the users' ability to read or interpret the information efficiently.	Figure 38 presents the icon used to represent construction on the Georgia Navigator web site. Instead, an icon in the shape of an orange barrel often used in construction can be used to represent construction on a map. In addition, the web site map should be designed similar to paper maps for the targeted area. Whenever possible, use similar levels of road detail and icon representation.

Old Icon For Construction



Proposed Icon for Construction

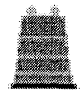


Figure 38. Example of a construction icon based on real-world representation.

4.8 *Excessive map clutter*

Avoid creating clutter that can make the information difficult to read or interpret.

Rationale

Providing more information is not always better. Displays that are cluttered make it difficult to distinguish one link from another. It becomes increasingly difficult to select the correct link with a mouse.

Implementation Notes

One way to solve this problem is to allow users to select the information they would like to view. Many users may not be interested in every piece of information so it may not be necessary to display all of the information on a map.

Zoom capability can increase a user's ability to select the correct link in a cluttered display.

CONCLUSIONS

Although there are many guidelines for the design of web sites available both in print and on the web (e.g., Ameritech Web Page User Interface and Design Guidelines, Apple Web Design Guide), no guidelines were found specific to traffic-information web sites. Thus, the goal of this study was to develop a set of web design guidelines specific to traffic-information web sites. The approach taken to develop the guidelines was based on melding 3 types of usability analyses:

1. An analysis of the web-site server statistics for 2 current traffic-information web sites
2. A heuristic evaluation of 7 traffic-information web sites
3. Usability testing of an ideal traffic-information site based on preliminary guidelines

What information was provided by identifying the current users?

The first analysis examined the current use of the Gary-Chicago-Milwaukee Corridor and the Michigan ITS: Detroit Freeway Conditions traffic-information web sites. Combined with general web-user surveys, traffic-information web-site-user profiles were created.

The general web-user surveys provided information on the current user hardware. These surveys are particularly critical for web development, given the frequency of computer upgrades and the speed at which connection rates are increasing. As an example, a large majority of web users still listed their primary connection as a 33.6K or 56K modem and their primary monitor resolution as between 640X480 and 1024X768. From these statistics, the guidelines for acceptable download times and recommended screen sizes were created. However, general surveys can't provide specific information on the behaviors and preferences of traffic-information web-site users.

The web-site server data from the current traffic-information web sites was more useful in defining the subset of traffic-information web-site users. For example, traffic-information web-site users were found to check the traffic-information web sites most frequently during the afternoon rush hours (between 2 p.m. and 6 p.m.). Although there was a slight increase in the amount of web-site traffic during the morning hours, the number of web-site requests during the afternoon rush hours was double the number of requests during the mornings and afternoons. This suggests that web sites are currently an effective means to reach morning commuters. Web site are, however, more effective at reaching afternoon commuters.

The web-site server statistics also showed which pages are viewed most frequently, thereby providing some evidence of user preferences. However, it should be noted that this method cannot predict the use of new features, and the user preferences may not always transfer between cities. As an example, the Chicago web site showed a high preference for travel-time information, but a similar page developed for and tested with Detroit users was found to be frustrating to the users.

A final use for the web-site server data was to identify the types of users that visit the site. Although this information was not used in this study, it could be used to select members for focus groups or to choose subjects to participate in the paper prototyping of new features or formats. The web-server data from Chicago and Detroit revealed the following 6 user types or profiles:

1. Personal use through an ISP via dial-up, ISDN, or cable modem
2. Personal use by the employees of primarily white-collar companies in the city
3. Use by manufacturing companies to aid in routing trucks and parts
4. Personal use by university faculty and students of "commuter" schools
5. Use by companies providing on-site delivery or services
6. Use by third party traffic-information providers

What types of usability problems were found in the heuristic evaluation?

The heuristic evaluation generated a large list of usability problems and comments which were sorted into 4 categories:

1. Screen layout and design

   Most screen layout problems dealt with clutter, scrolling, or the use of frames in a way that impared the visibility of the options or information on the page.

2. Menu and navigation structure

   Most menu problems dealt with the design of menu bars, links, and link labels. Consistency was often not maintained between the links and the page headings. Menu bars and menu items were also not consistently used between pages, and headings and links were often misleading.

3. Real-time map interaction

   Serious usability problems were found with the design and use of real-time maps. The most widespread problem was that a click on the map did not produce location relevant information. Instead, users were confronted with text lists and required to reselect the area of interest from the list. Other problems included the design of pan and zoom controls, and the determination of camera direction.

4. Real-time map colors, symbols, and design

   Problems with the look of the real-time map were focused around the color and symbol selections. Several sites used low-contrast color combinations, light blue on blue or grey on black. Colors and symbols were also not used consistently within sites and between sites.

The problems that were found using the heuristic evaluation were centered around the following 3 heuristics or principles:

- Visibility – does the user know where he is and where he can go next?
- Consistency – do features look, feel, and function similarly?
- Flexibility and efficiency – are excessive steps needed to find the information?

While the evaluation produced a good list of usability problems on the sites, there were several disadvantages to this method. First, an ideal evaluator should be both an expert in human factors and familiar with the domains of traffic information and web-site design. A typical traffic-information web-site design team would be lucky to have 1 such expert, let alone the 3 to 5 required for a comprehensive heuristic evaluation.

Second, since the quality of the evaluation is based on the evaluators' skills and expertise, minor problems often went unnoticed because the evaluator was only playing the role of the typical user. The evaluators' expertise can often hinder their ability to see the site as a typical user would (Kanter and Rosenbaum, 1997). Designs that seemed consistent with other web pages and caused little problems for the evaluators were, in fact, often frustrating to real users.

As an example, the activation of a pull-down menu with a separate "go" button was commonly found on many web sites, and thus the evaluators made no mention of it. However, when users were actually asked to use the menu, most experts were annoyed by having to click both the menu item and the go button, because typical computer applications do not work that way. More importantly though, novice web users had never seen this implementation before, and were unable to figure out how to activate the menu.

What types of problems were found with user testing?

The final part of the this study used the guidelines to create an ideal traffic-information web site. The prototype designers were familiar with the guidelines and had participated in the work, so the web site that was created was fairly good in terms of usability. Although the guidelines developed in this project provided a start or direction for the design, simply conforming to the design guidelines of using human factors experts did not guarantee a good or usable site (also noted in Nielsen, 1999b).

Five typical users were selected to test the web site (3 were expert web users, 2 were novices). The users were asked to use the prototyped web site to plan a trip. Simple observation of the users resulted in recognizing the following 4 types of problems:

1. Instructions or features that were not noticed, not used, or caused confusion

   Instructions were generally ignored by expert web users, yet did not provide enough information for novices. Construction information was also rarely used in the decision making process because traffic information was not provided in the construction zones.

2. Confusing icons or legends

   Since the guidelines do not specify what icons or colors to use, user testing found problems with icons that were not interpreted correctly. For example the grey roads in construction areas were mistaken for variable message signs.

3. Features did not function as the user expected

   A pull-down menu was implemented similar to many found on the web. After selecting the item from the menu, a second button, "go, display selection, etc.," needed to be pressed to activate the selection. While experts were only slightly annoyed by this, novices completely failed to figure out how to activate the menu.

4. Features or formats caused frustration

   The travel-time tables caused problems for all of the users tested. Although the format worked well in Chicago, the users in Detroit had no prior basis for receiving travel-time information (since Detroit travel times are not broadcast each day on the radio as they are in Chicago). If the travel-time information was provided, the users would prefer to enter their origin and destination, and get a single travel time for their route.

Even if the guidelines are used to help design the a traffic-information web site, user testing is recommended to test and fine tune the design. The user testing was conducted relatively quickly (20 to 40 minutes per user for 5 users), and it provided a great deal of immediate feedback on usability problems, insights on user preferences, and even helpful ideas on how to improve the site.

However, in order for the user testing to provide accurate feedback, care must be taken in the selection of the users to test. Web designers, TMC control-room operators, and DOT management personnel may be easy to recruit to test the web site, but they are experts, not typical users. The recommended way to recruit subjects to test the web site would be use the user profiles generated from an analysis of people actually looking at the traffic-information web site. It is also recommended to use a combination of both experienced and novice web users since the novices were often completely unable to use features that caused only minor problems for experienced web users.

The only major drawback of prototyping and user testing was that the users often became stuck at the first major problem and, thus, failed to completely explore the site or find additional problems. Rules were needed on when and how to provide the users with help while they were using the web site. Most of the major problems with the site were found with the first 3 subjects, and the novices were the most prone to becoming "stuck" with the implementation of a feature. However, an easy solution to overcome this limitation would be to plan a short iterative testing cycle, where problems are fixed after every few subjects, and fixes are then tested with new subjects.

This project examined the usability of a sample of contemporary traffic-information web sites. Using that information and data on web-site users, a traffic-information web site was prototyped and tested by real users. All of that information, in turn, was then used to develop a set of traffic-information web-site-design guidelines. A total of 8 general principles (e.g., consistency, readability, etc.) and 33 specific guidelines in 4 categories (site organization, site navigation, real-time traffic-information presentation, and real-time map colors symbols, and design) were created. The next logical step in this progression is for these guidelines to be used by interface designers, in this case, by the sponsor both in the United States and in Japan. The authors are curious (1) how useful the guidelines will prove to be and (2) what other support designers need to develop easy-to-use and useful traffic-information web sites.

REFERENCES

Bickford, P. (1997). *Interface Design : The Art of Developing Easy-to-Use Software.* San Diego, CA: Academic Press. 128.

Card, S., Robertson, G., and Mackinlay, J. (1991). The information visualizer: An information workspace. *Proceedings of the ACM CHI'91 Conference,* New Orleans, Louisiana: (28 April-2 May), 181-188. As cited in Nielsen, J. (1993).

Dudek, C. L.; Huchingson, R. D.; Stockton, W. R.; Koppa, R. J.; Richards, S. H.; Mast, T. M. (1978). *Human Factors Requirements for Real-Time Motorist Information Displays. Vol. 1 - Design Guide* (Report No. FHWA-RD-78-5), Washington D.C.: Federal Highway Administration, U.S. Department of Transportation.

Georgia Tech Research Corporation (1998). *GVU's 10th WWW User Survey.* Atlanta, Georgia. [Online]. Available: http://www.cc.gatech.edu/gvu/user_surveys/ [October 1998].

Green, P., Levison, W., Paelke, G., and Serafin, C. (1993). *Preliminary Human Factors Guidelines for Driver Information Systems* (Technical Report UMTRI-93-21), Ann Arbor, MI: The University of Michigan Transportation Research Institute (also published as FHWA-RD-94-087, McLean, VA: U.S. Department of Transportation, Federal Highway Administration, December, 1995).

Instone, K. (1997). *Usability Heuristics for the Web.* [Online]. Web Review - Usability. Available: http://webreview.com/wr/pub/97/10/10/usability/sidebar.html [October 10, 1997].

Katz, S., Green, P., and Fleming, J. (1998). *Organization and Structure of Traffic Management Centers: Two Case Studies in Michigan* (Technical Report UMTRI-98-35), Ann Arbor, Michigan: The University of Michigan Transportation Research Institute.

Kelly, M.J. (1995). *Human Factors Handbook for Advanced Traffic Management Center Design.* Atlanta, Georgia: Georgia Tech Research Institute.

Kojima, M., Nowakowski, C., and Green, P. (1999). *Human Factors in Traffic Management Centers: A Literature Review* (Technical Report 99-13). Ann Arbor, Michigan, The University of Michigan Transportation Research Institute.

Miller, R. (1968). Response time in man-computer conversational transactions. *Proceedings of the AFIPS Fall Joint Computer Conference, 33*, 267-277. As cited in Nielsen, J. (1993).

Molich, R., and Nielsen, J. (1990). Improving a human-computer dialogue. *Communications of the ACM. 33*(3) March, 338-348.

Nielsen, J., and Molich, R. (1990). Heuristic evaluation of user interfaces. *Proceedings of the ACM CHI 1990 Conference*, Seattle, Washington: 249-256.

Nielsen, J. (1993). *Usability Engineering.* Boston, MA: Academic Press. [Online]. Available: http://www.useit.com/papers/responsetime.html [January 11, 1999].

Nielsen, J. (1994a). Enhancing the explanatory power of usability heuristics. *Proceedings of the ACM CHI 1994 Conference*, Boston, Massachusetts: 152-158.

Nielsen, J. (1994b). Heuristic Evaluation. In Nielsen, J., and Mack, R.L. (Eds.), *Usability Inspection Methods.* New York, New York: John Wiley & Sons.

Nielsen, J. (1996). *Top Ten Mistakes in Web Design.* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/9605.html [May 1996].

Nielsen, J. (1997a). *Do Websites have Increasing Returns?* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/9704b.html [April 15, 1997].

Nielsen, J. (1997b). *Lack of Navigation Support in v.4.0 Browsers?* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/9711a.html [November 1, 1997].

Nielsen, J. (1997c). *Changes in Web Usability Since 1994.* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/9712a.html [December 1, 1997].

Nielsen, J. (1998a). *Nielsen's Law of Internet Bandwidth.* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/980405.html [April 5, 1998].

Nielsen, J. (1998b). *Web Pages Must Live Forever.* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/981129.html [November 29, 1998].

Nielsen, J. (1999a). *"Top Ten Mistakes" Revisted Three Years Later.* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/990502.html [May 2, 1999].

Nielsen, J. (1999b). *Do Interface Standards Stifle Design Creativity?* [Online]. Alertbox: Jakob Nielsen's Column on Web Usability. Available: http://www.useit.com/alertbox/990822.html [August 22, 1999].

Nowakowski, C., Green, P., and Kojima, M. (1999). *Human Factors in Traffic Management Centers: A Literature Review* (Technical Report 99-5). Ann Arbor, Michigan, The University of Michigan Transportation Research Institute.

Office of Highway Information Management. (1995). *Highway Statistics Summary To 1995.* [Online]. Washington D.C.: Federal Highway Administration, US Department of Transportation. Available: http://www.fhwa.dot.gov/ohim/Summary95/index.html [March 5, 1998].

Omanson, R., Cline, J., Kilpatrick, C., and Dunkerton, M. (1998). Dimensions Affecting Web Site Identity. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting* (429-433). Santa Monica, California: Human Factors and Ergonomics Society.

Rossignac, J., Kehoe, C., Pitkow, J., Rogers, J., Aggarwal, G., Sutton, K., and Maholtra, N. (1998). *GVU's 10th WWW User Survey.* [Online]. Atlanta, Georgia: Georgia Tech. Available: http:www.gvu.gatech.edu/user_surveys/survey-1998-10

Spool, J, Scanlon, T, Schroeder, W, Snyder, C, and DeAngelo, T. (1999). *Web Site Usability: A Designer's Guide.* San Francisco, California: Morgan Kaufmann Publishers, Inc.

Wickens, C.D. (1992). *Engineering Psychology and Human Performance*, Second Edition. New York: Harper Collins.

APPENDIX A - LIST OF U.S. TRAFFIC-INFORMATION WEB SITES

State	City (Provider)	Web Site URL
Arizona	Phoenix (AZTech)	http://www.azfms.com
	Phoenix (Etak)	http://www.etaktraffic.com
California	Los Angeles (Maxwell)	http://traffic.maxwell.com
	Los Angeles(Etak)	http://www.etaktraffic.com
	San Diego (Maxwell)	http://traffic.maxwell.com
	San Diego (Etak)	http://www.etaktraffic.com
	San Francisco (Maxwell)	http://traffic.maxwell.com
	San Francisco (Etak)	http://www.etaktraffic.com
	San Francisco (Bay Insider)	http://www.bayinsider.com
	San Francisco (Contra Costa County)	http://www.hotcoco.com/drive/traffic/files/coinc.htm
	Sacramento (Transierra)	http://www.transierra.com/traffic1.htm
Colorado	Denver (Etak)	http://www.etaktraffic.com
	Washington D.C. (SmartRoute)	http://www.smartraveler.com
	Washigton D.C. (Etak)	http://www.etaktraffic.com
Georgia	Atlanta (Navigator)	http://www.georgia-traveler.com
	Atlanta (Maxwell)	http://traffic.maxwell.com
	Atlanta (Etak)	http://www.etaktraffic.com
Illinois	Chicago (GCM)	http://www.ai.eecs.uic.edu/GCM
	Chicago (Maxwell)	http://traffic.maxwell.com
Indiana	Northwest (GCM)	http://www.ai.eecs.uic.edu/GCM
	Indianapolis (Etak)	http://www.etaktraffic.com
Massachusetts	Boston (SmartRoute)	http://www.smartraveler.com
	Boston (Etak)	http://www.etaktraffic.com
Michigan	Detroit (MDOT)	http://www.mdot.state.mi.us/mits
	Detroit (Etak)	http://www.etaktraffic.com

State	City (Provider)	Web Site URL
Minnesota	Minneapolis/St.Paul (MSN)	http://trafficview.twincities.sidewalk3.com
	Minneapolis/St.Paul (SmartRoute)	http://www.smartraveler.com
	Startribune	http://talk.startribune.com/stonline/traffic
	Minneapolis/St.Paul (Streamline)	http://www.twincitiesexpress.com/ trafficconditions.asp
	Minneapolis/St. Paul (Etak)	http://www.etaktraffic.com
Nevada	Las Vegas (Etak)	http://www.etaktraffic.com
New York	New York(Etak)	http://www.etaktraffic.com
Ohio	Cincinnati (SmartRoute)	http://www.smartraveler.com
Pennsylvania	Philadelphia (SmartRoute)	http://www.smartraveler.com
Texas	Houston (Maxwell)	http://traffic.maxwell.com
	Houston (Transtar)	http://traffic.tamu.edu
	Dallas (Etak)	http://www.etaktraffic.com
Washington	Seattle (WDOT,SmartTrek)	http://www.smarttrek.org
	Seattle(Etak)	http://www.etaktraffic.com
	Tacoma (WDOT,SmartTrek)	http://www.smarttrek.org
Wisconsin	Milwaukee (GCM)	http://www.ai.eecs.uic.edu/GCM

APPENDIX B - HEURISTIC EVALUATION METHOD

This appendix was provided as a reference for those unfamiliar with the heuristic evaluation method. Jacob Nielsen's 10 origninal usability heuristics appear in bold. Nielsen's description of each heuristic appears in italics. The remaining commentary (Instone, 1997) describes how each heuristic applies to web design and can be found at the following URL: http://webreview.com/wr/pub/97/10/10/usability/sidebar.html.

1. Visibility of system status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

Probably the two most important things that users need to know at your site are "Where am I?" and "Where can I go next?"

Make sure each page is branded and that you indicate which section it belongs to. Links to other pages should be clearly marked. Since users could be jumping to any part of your site from somewhere else, you need to include this status on every page.

2. Match between system and the real world

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

On the Web, you have to be aware that users will probably be coming from diverse backgrounds, so figuring out their "language" can be a challenge.

3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

Many of the "emergency exits" are provided by the browser, but there is still plenty of room on your site to support user control and freedom. Or, there are many ways authors can take away user control that is built into the Web. A "home" button on every page is a simple way to let users feel in control of your site.

Be careful when forcing users into certain fonts, colors, screen widths or browser versions. And watch out for some of those "advanced technologies." Usually user control is not added until the technology has matured. One example is animated GIFs. Until browsers let users stop and restart the animations, they can do more harm than good.

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
Within your site, use wording in your content and buttons consistently. One of the most common cases of inconsistent wording I see deals with links, page titles and page headers. Check the titles and headers for your pages against the links that point to them. Inconsistent wording here can confuse users who think they ended up in the wrong spot because the destination page had a title that differed vastly from the link that took them there.

"Platform conventions" on the web means realizing your site is not an island. Users will be jumping onto (and off of) your site from others, so you need to fit in with the rest of the Web to some degree. Custom link colors is just one example where it may work well for your site but since it could conflict with the rest of the web, it may make your site hard to use.

And "standards" on the Web means following HTML and other specifications. Deviations form the standards will be opportunities for unusable features to creep into your site.

5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

Because of the limitations of HTML forms, inputting information on the Web is a common source of errors for users. Full-featured, GUI-style widgets are on their way; in the meanwhile you can use JavaScript to prevent some errors before users submit, but you still have to double-check after submission.

6. Recognition rather than recall

Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

For the Web, this heuristic is closely related to system status. If users can recognize where they are by looking at the current page, without having to recall their path from the home page, they are less likely to get lost.

Certainly the most invisible objects created on the Web are server-side image maps. Client-side image maps are a lot better, but it still takes very well-crafted images to help users recognize them as links.

Good labels and descriptive links are also crucial for recognition.

7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Some of the best accelerators are provided by the browser, like bookmarks.

Make pages at your site easy to bookmark. If a user is only interested in one corner of your site, make it easy for him to get there. Better that than have him get frustrated trying to get from your home page to what he is looking for.

Do not use frames in a way that prevent users from bookmarking effectively.

Support bookmarking by not generating temporary URLs that have a short lifespan. If every week you come out with a new feature article for your site, make sure your URL lives on, even after the content is taken down. Web Review uses long-term locations by putting date information into the URLs. Or, you could re-use your URLs for the newer content.

Consider using GET instead of POST on your forms. GET attaches the parameters to the URL, so users can bookmark the results of a search. When they come back, they get their query re-evaluated without having to type anything in again.

All of these rules for "design to be bookmarked" also help you design to be linked to. If the contents of your site can easily be linked to, others can create specialized views of your site for specific users and tasks. Amazon.com's associates program is just one example of the value of being easy to link to.

8. Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Extraneous information on a page is a distraction and a slow-down. Make rarely needed information accessible via a link so that the details are there when needed but do not interfere much with the more relevant content.

The best way to help make sure you are not providing too much (or too little) information at once is to use progressive levels of detail. Put the more general information higher up in your hierarchy and let users drill down deeper if they want the details. Likewise, make sure there is a way to go "up" to get the bigger picture, in case users jump into the middle of your site.

Make sure your content is written for the Web and not just a repackaged brochure. Break information into chunks and use links to connect the relevant chunks so that you can support different uses of your content.

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Errors will happen, despite all your efforts to prevent them. Every error message should offer a solution (or a link to a solution) on the error page.

For example, if a user's search yields no hits, do not just tell him to broaden his search. Provide him with a link that will broaden his search for him.

10. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Some of the more basic sites will not need much documentation, if any. But as soon as you try any complicated tasks, you will need some help for those tasks.

For the Web, the key is to not just slap up some help pages, but to integrate the documentation into your site. There should be links from your main sections into specific help and vice versa. Help could even be fully integrated into each page so that users never feel like assistance is too far away.

APPENDIX C - EXAMPLES FROM THE PROTOTYPED WEB SITE

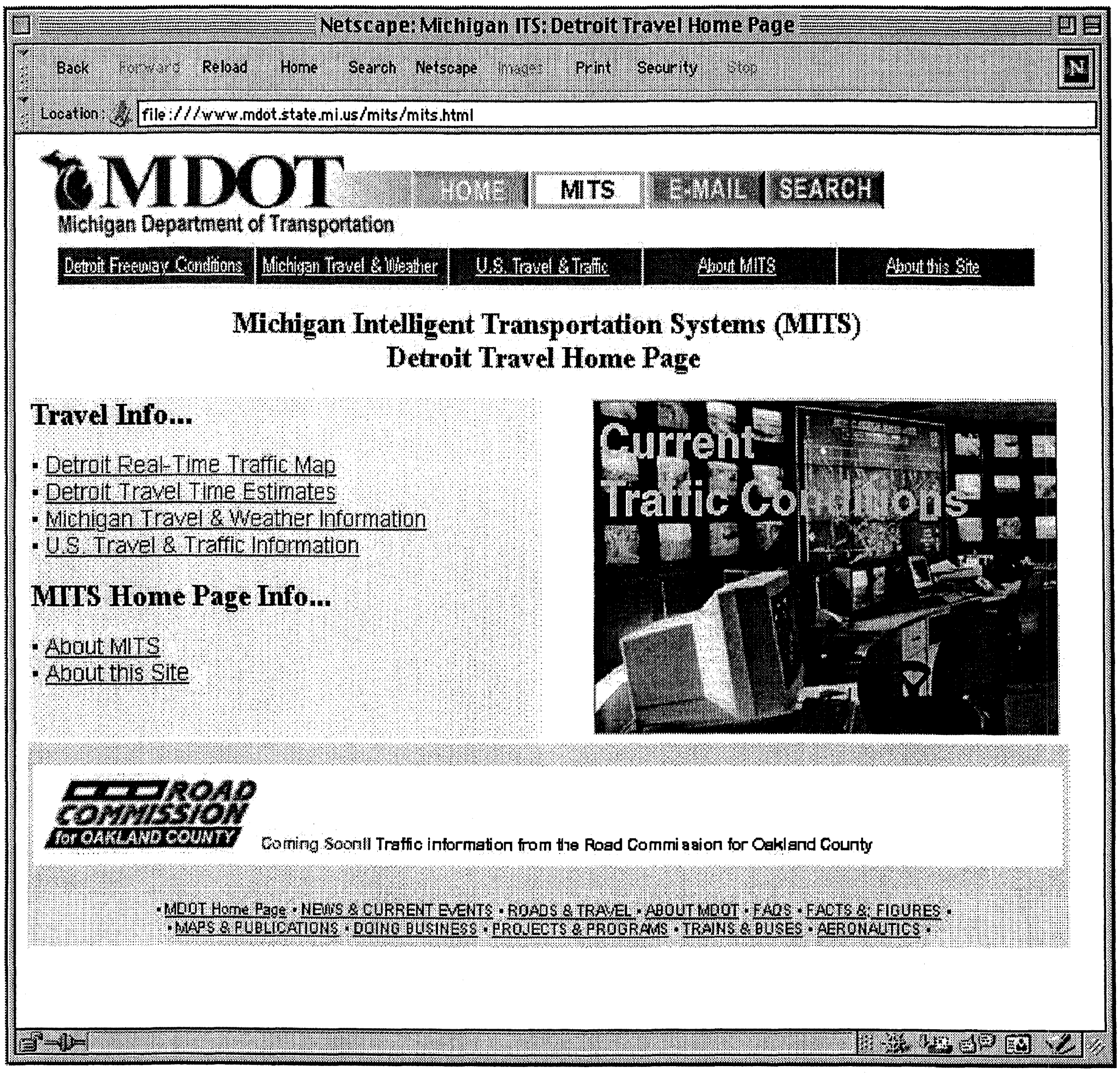


Figure 39. Prototyped Detroit Travel Home Page

All of the links referring to real-time Detroit traffic information from the prototyped MDOT Home Page led to the Detroit Travel Home Page. This page provided access to the real-time freeway overview map through the text link on the left or by clicking on the graphic on the right. It also provided access to the estimated travel times for selected Detroit freeways. The Michigan Travel & Weather Information link provided a page with a list of other Michigan traffic-information sites and a list of weather-related links. The U.S. Travel & Traffic Information link provided a page with a list of other U.S. Travel and ITS related links as well as links to several Internet based maps which allow users to locate addresses and plan routes. Additional pages describing the Michigan ITS facilities and the web site were also linked to from this page.

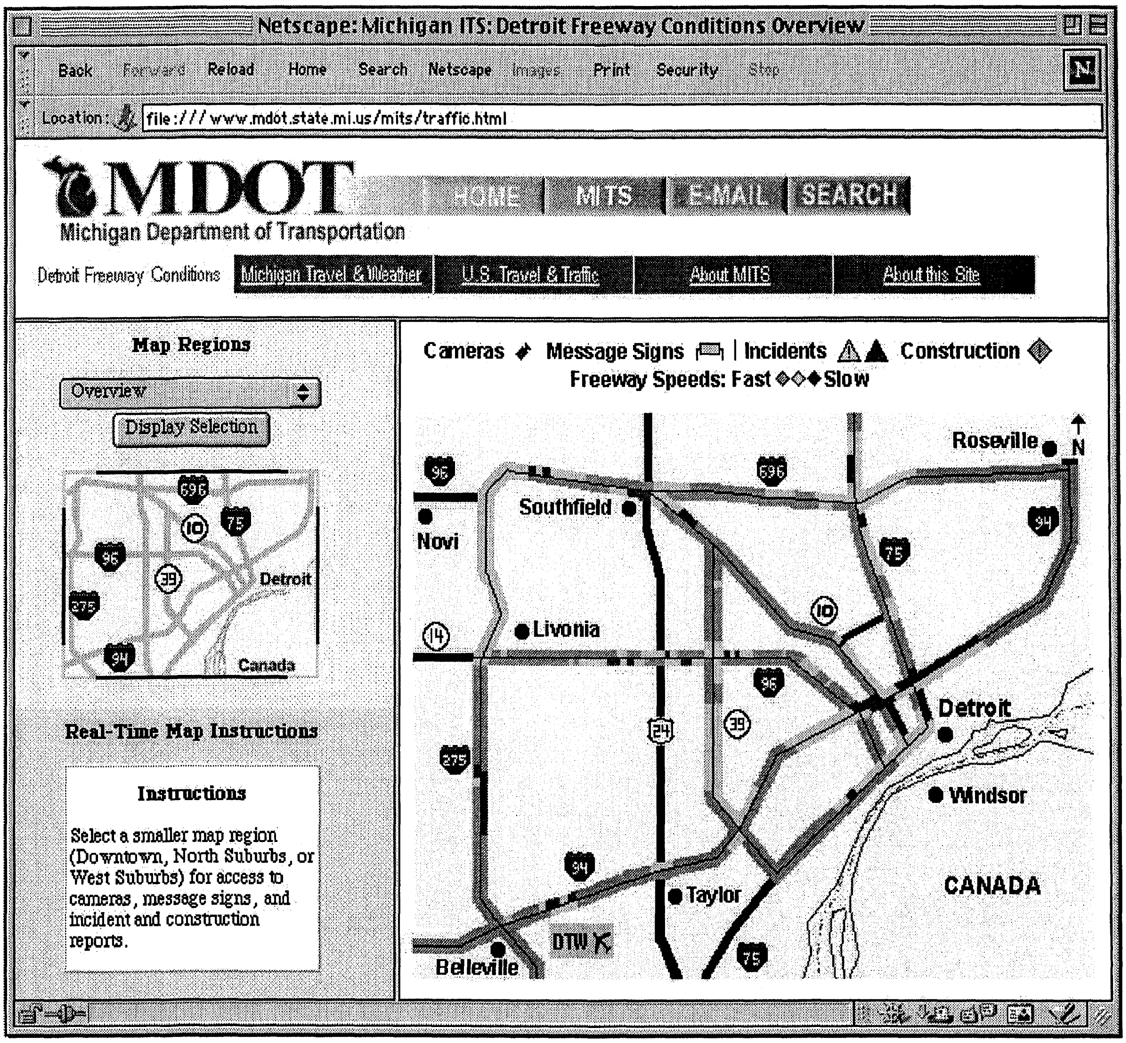


Figure 40. Prototyped Detroit Real-Time Freeway Conditions Overview.

The overview map provided color-coded speed information for the entire freeway area. Access to cameras, variable message signs, or incident and construction reports was not available directly from the overview map. Users were able to zoom into any one of 3 areas (Downtown Detroit, North Suburbs, and West Suburbs) by clicking directly on the small navigation map or by using the pull-down menu. Users were also able to access the estimated travel-times page through the pull-down menu. The instructions provided read, “Select a smaller map region (Downtown, North Suburbs, or West Suburbs) for access to cameras, message signs, and incident and construction reports.”

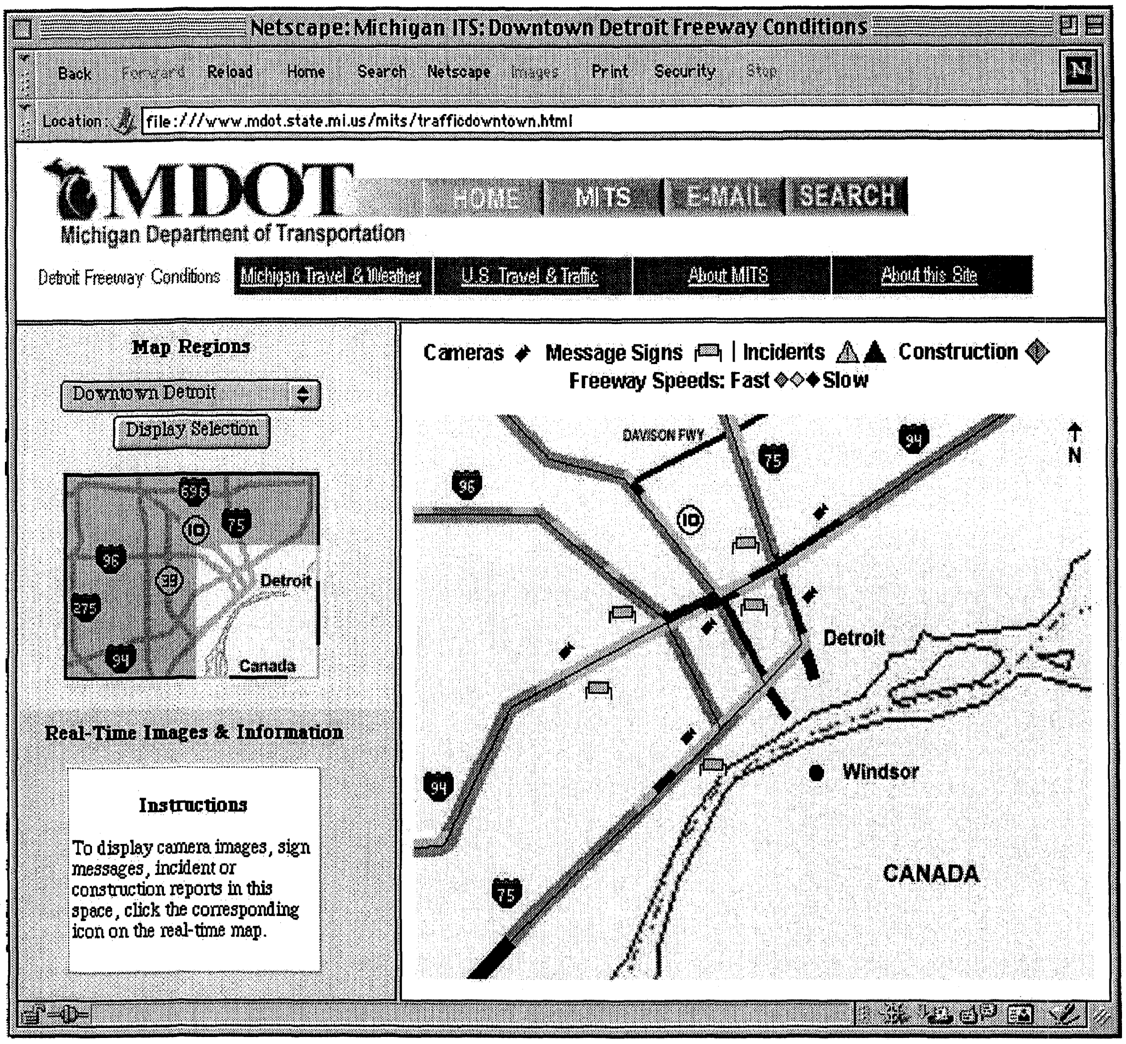


Figure 41. Prototyped Downtown Detroit Real-Time Freeway Conditions.

The downtown Detroit map provided color-coded speed information for the freeways in the downtown area. Icons for cameras, variable message signs, and incident and construction reports were presented on the map at their corresponding locations. The instructions provided read, "To display camera images, sign messages, incident or construction reports in this space, click the corresponding icon on the real-time map." The instructions were replaced by a camera image, sign message, or report when the user clicked an icon on the real-time map. Similar to the overview page, users were able to switch areas by clicking directly on the small navigation map or by using the pull-down menu. Access to the overview map or to the travel time estimates were only available through the pull-down menu.

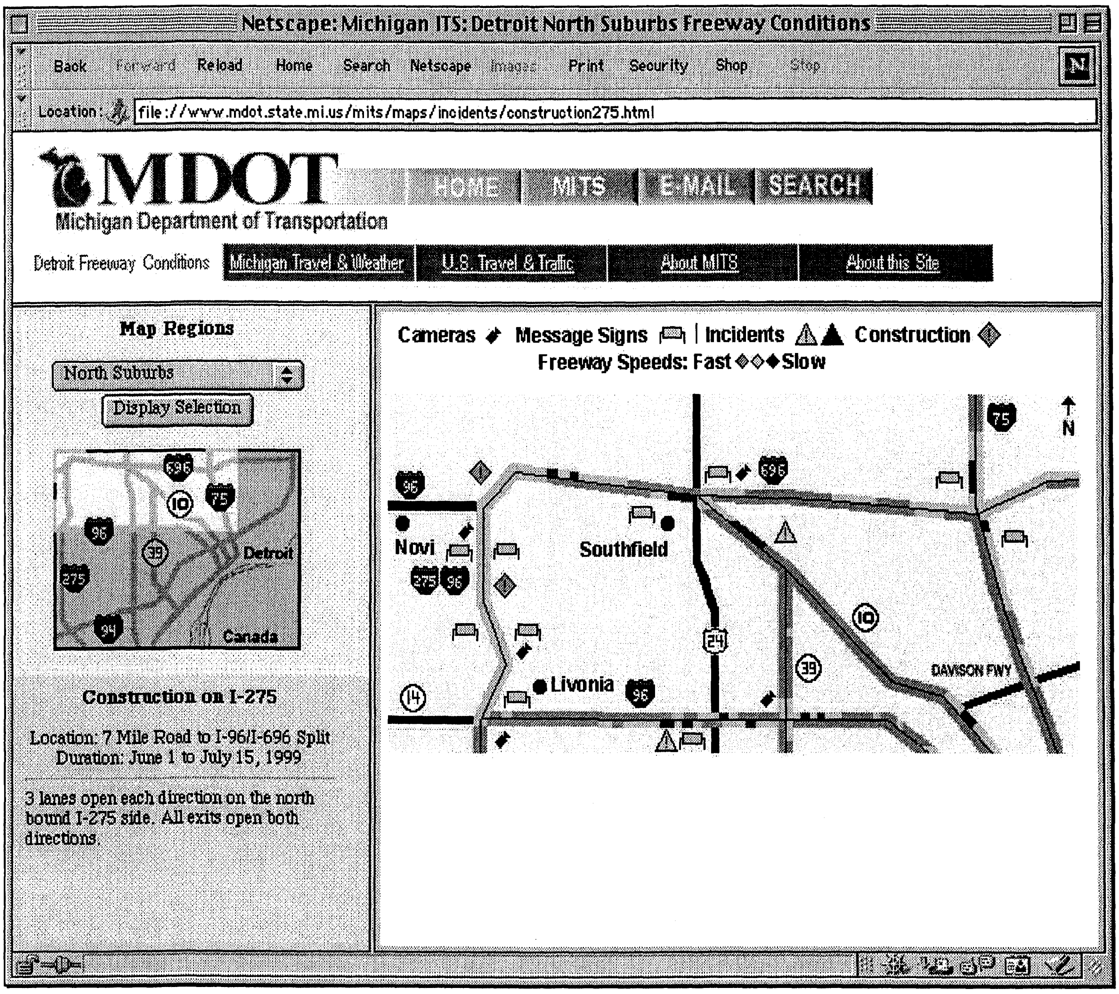


Figure 42. Prototyped Detroit North Suburbs Real-Time Freeway Conditions.

The north suburbs map provided color-coded speed information for the freeways in the northwestern area. Icons for cameras, variable message signs, and incident and construction reports were presented on the map at their corresponding locations. The instructions provided again read, "To display camera images, sign messages, incident or construction reports in this space, click the corresponding icon on the real-time map." The instructions were replaced by a camera image, sign message, or report (such as the construction report shown above) when the user clicked an icon on the real-time map. Similar to the overview page, users were able to switch areas by clicking directly on the small navigation map or by using the pull-down menu. Access to the overview map or to the travel-time estimates were only available through the pull-down menu.

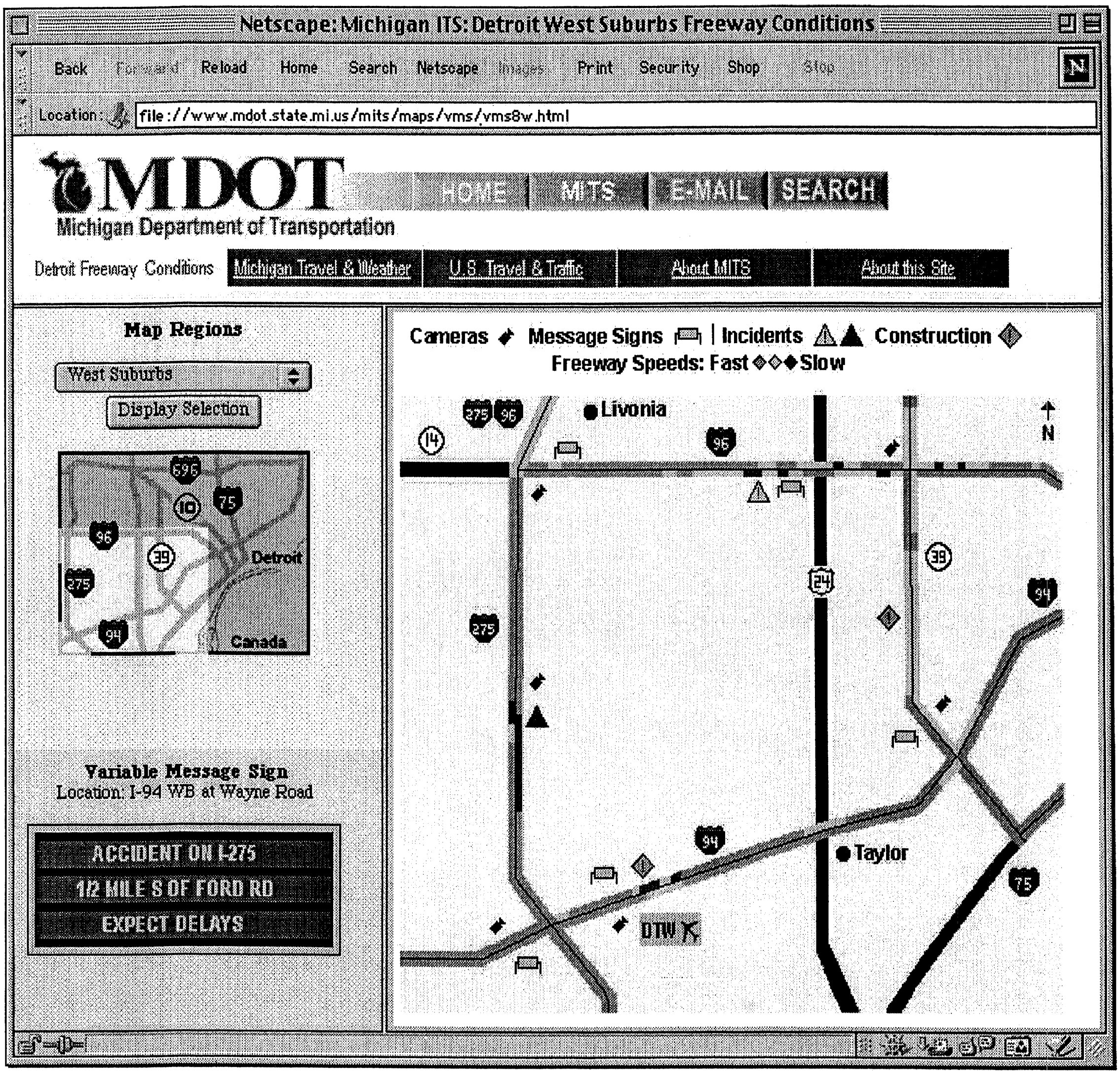
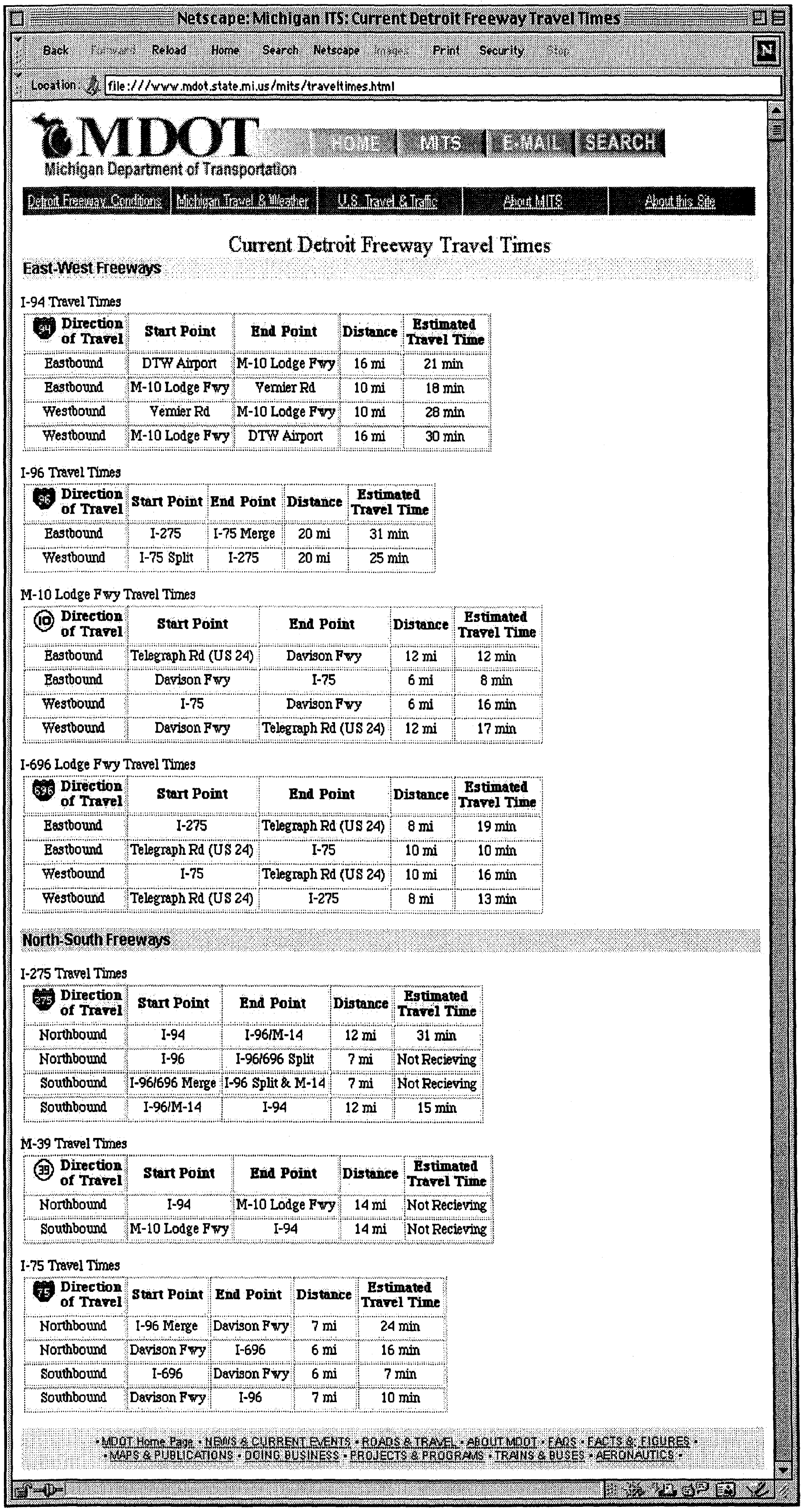


Figure 43. Prototyped Detroit West Suburbs Real-Time Freeway Conditions.

The west suburbs map provided color-coded speed information for the freeways in the southwestern area. Icons for cameras, variable message signs, and incident and construction reports were presented on the map at their corresponding locations. The instructions provided read, "To display camera images, sign messages, incident or construction reports in this space, click the corresponding icon on the real-time map." The instructions were replaced by a camera image, sign message (as shown above), or report when the user clicked an icon on the real-time map. Similar to the overview page, users were able to switch areas by clicking directly on the small navigation map or by using the pull-down menu. Access to the overview map or to the travel-time estimates were only available through the pull-down menu.


Netscape: Michigan ITS: Current Detroit Freeway Travel Times

Back Forward Reload Home Search Netscape Images Print Security Stop

Location: file:///www.mdot.state.mi.us/mits/traveltimes.html

MDOT HOME MITS E-MAIL SEARCH

Michigan Department of Transportation

Detroit Freeway Conditions | Michigan Travel & Weather | U.S. Travel & Traffic | About MITS | About this Site

Current Detroit Freeway Travel Times

East-West Freeways

I-94 Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Eastbound	DTW Airport	M-10 Lodge Fwy	16 mi	21 min
Eastbound	M-10 Lodge Fwy	Vernier Rd	10 mi	18 min
Westbound	Vernier Rd	M-10 Lodge Fwy	10 mi	28 min
Westbound	M-10 Lodge Fwy	DTW Airport	16 mi	30 min

I-96 Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Eastbound	I-275	I-75 Merge	20 mi	31 min
Westbound	I-75 Split	I-275	20 mi	25 min

M-10 Lodge Fwy Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Eastbound	Telegraph Rd (US 24)	Davison Fwy	12 mi	12 min
Eastbound	Davison Fwy	I-75	6 mi	8 min
Westbound	I-75	Davison Fwy	6 mi	16 min
Westbound	Davison Fwy	Telegraph Rd (US 24)	12 mi	17 min

I-696 Lodge Fwy Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Eastbound	I-275	Telegraph Rd (US 24)	8 mi	19 min
Eastbound	Telegraph Rd (US 24)	I-75	10 mi	10 min
Westbound	I-75	Telegraph Rd (US 24)	10 mi	16 min
Westbound	Telegraph Rd (US 24)	I-275	8 mi	13 min

North-South Freeways

I-275 Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Northbound	I-94	I-96/M-14	12 mi	31 min
Northbound	I-96	I-96/696 Split	7 mi	Not Recieving
Southbound	I-96/696 Merge	I-96 Split & M-14	7 mi	Not Recieving
Southbound	I-96/M-14	I-94	12 mi	15 min

M-39 Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Northbound	I-94	M-10 Lodge Fwy	14 mi	Not Recieving
Southbound	M-10 Lodge Fwy	I-94	14 mi	Not Recieving

I-75 Travel Times

Direction of Travel	Start Point	End Point	Distance	Estimated Travel Time
Northbound	I-96 Merge	Davison Fwy	7 mi	24 min
Northbound	Davison Fwy	I-696	6 mi	16 min
Southbound	I-696	Davison Fwy	6 mi	7 min
Southbound	Davison Fwy	I-96	7 mi	10 min

• MDOT Home Page • NEWS & CURRENT EVENTS • ROADS & TRAVEL • ABOUT MDOT • FAQS • FACTS & FIGURES •
• MAPS & PUBLICATIONS • DOING BUSINESS • PROJECTS & PROGRAMS • TRAINS & BUSES • AERONAUTICS •

Figure 44. Prototyped Detroit Freeway Travel Time Estimates.

APPENDIX D - PARTICIPANT CONSENT FORM

Subject Number: [ ]

TRAFFIC-INFORMATION WEB-SITE REVIEW
PARTICIPANT CONSENT FORM

As you may have read (or noticed), many large cities around the world have been adding sensors, cameras, and message signs to their freeways in order to monitor traffic conditions. The purpose of this experiment is to test an idea for a traffic-information web site. It is important to remember that problems encountered using the site are a reflection of design weaknesses, not you.

In this experiment, you will spend about 45 minutes using a prototype of a possible Detroit area traffic-information web site on a Macintosh computer. During the experiment, you will be given several "traffic problems" to solve with the help of the web site, but the "traffic problems" you will be solving do not really have correct answers. A sample problem might ask you to decide the best way home given the current traffic on the freeways. The traffic information that will be displayed during the experiment will not be real, but it represents a hypothetical set of traffic conditions.

As you proceed to use the web site, please "think aloud" and feel free to comment on the page or the task to help us understand what you are doing and why. Your actions and comments during the experiment will be recorded for further analysis or demonstration at a later time.

For your time and help, you will be paid the sum of $10 upon the completion of the experiment.

I HAVE READ AND UNDERSTAND THIS DOCUMENT.

____________________	____________________
Print your name	Date
____________________	____________________
Sign your name	Witness (experimenter)

APPENDIX E - SUBJECT BIOGRAPHICAL FORM

University of Michigan Transportation Research Institute
Human Factors Division **Biographical Form**

Subject: ______

Date: ______

Name: ______________________________

Male **Female** (circle one) **Age:** ________

Occupation (or major): __________________________

How often do you drive the freeways in Detroit and its suburbs?

Daily A few times a week A few times a month Once in awhile Never

Annual mileage: ____________ **Where do you go?** ________________

How often do you use a computer?

Daily A few times a week A few times a month Once in awhile Never

What operating system are you most familiar with?

Microsoft Windows Macintosh Unix/Linux Other: ________________

How often do you use the Internet for web browsing?

Daily A few times a week A few times a month Once in awhile Never

How long have you been surfing the web?

3+ Years 1-2 Years 0 to 1 Year Never

How comfortable/familiar are you with using the Internet?

Very |————————————————————| Not So

Rank the following activities on how frequently you do them online?

__ News __ Shopping __ Product/Company Info __ Hobbies __ Other

Which browser do you use most often?

Microsoft Internet Explorer Netscape Navigator AOL Other: _________

How often have you used a traffic information web site?

Daily A few times a week A few times a month Once in awhile Never

Which traffic information web sites have you visited? __________________________

Provide Test participant with first traffic scenario sheet:

Traffic Scenario - Daily Commute Home

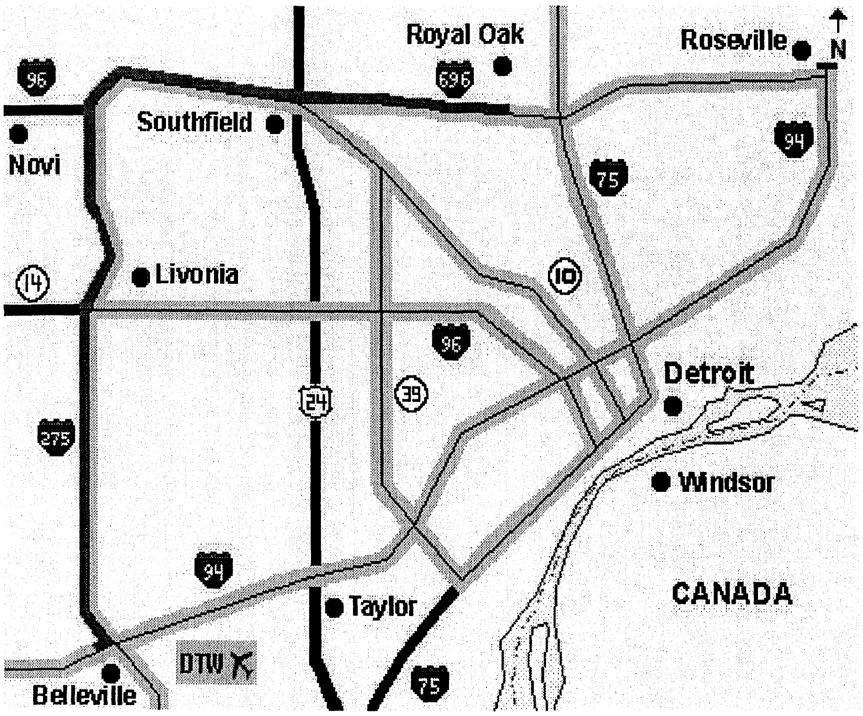
For this part of the experiment, we will assume that it is 4:40 PM, and you are currently planning your daily commute home from Royal Oak to Belleville. The table and map below provides information on your normal route home. Generally the fastest way home is to take I-696 West to I-275 South to I-94 West. Without traffic, it takes about 40 minutes.

Your task is to use the MDOT traffic-information web site to:

1. Plan your route home.
2. Estimate how long the trip will take.
3. Note any problems along the route.

Scenario Summary.

Description	Information
Current Time	4:40 PM
Current Location	Royal Oak (Off I-696 several miles west of I-75)
Home	Belleville
Normal Route Home	I-696 West to I-275 South to I-94 West
Average Commute Time	40 minutes
Freeway Miles Traveled	35 miles



Map of your normal route home.

Provide test participant with second traffic scenario sheet:

Traffic Scenario - Run Errands During/After Work

For this part of the experiment, we will assume that it is 4:40 PM, and you are currently planning to run an errand from Ann Arbor. Your destination is near the intersection of Wooward Ave and Highland Street in Highland Park. From your location in Ann Arbor, you have equal access to both M-14 and I-94 towards Detroit. The table below summarizes the information available to you.

Your task is to use the MDOT traffic-information web site to:

1. Plan your route to the destination.
2. Estimate how long the trip will take.
3. Note any problems along the route.

Scenario Summary.

Description	Information
Current Time	4:40 PM
Current Location	Ann Arbor
Destination	Woodward Ave&Highland St, Highland Park

Postexperiment Interview

For our third and final scenario, I'd like you to think back to a recent trip you've taken in the area, or a place you frequent. Using that trip as your basis, how would this web site have been useful? Narrate, if you could, what you would look at to decide how to get to that destination.

Use probing questions as needed:

1. Thinking back to a recent trip you've taken, how would this web site be useful?
2. What information on the web site would you have used?
3. Could you elaborate and show what you would check using the web site?
4. What other sources of traffic information did you recall consulting before the trip?...
5. During the trip?
6. Did you specifically seek out traffic information before or during the trip?
7. What other kinds of information do you normally check before a trip?..
8. During a trip?
9. Were there any problems or stumbling blocks you encountered with the site?
10. Do you have any further comments on how to improve the site?
11. Things you liked or didn't like?

Test participant Payment

Well, that about wraps things up.

Our final order of business is to fill out the payment paperwork. I'd like to thank you for participating today, your input has been very insightful.

Fill out forms.