A Human Factors Approach to the Design of Traffic-Information Web Sites

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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 many web-site-design guidelines exist, no design guidelines were found specific to the construction of traffic-information web sites. The project upon which this paper was based set out to develop such guidelines. In the process, 4 methods used to help design a usable web site were evaluated: (1) user analysis, (2) heuristic evaluation, (3) guideline application, and (4) user testing. This paper describes the major findings from each method and the strengths and weaknesses identified for each method. Although there were distinct benefits from 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 (TMC) to develop a traffic-information web site.

INTRODUCTION

Traditionally, traffic information has been disseminated to the public through commercial radio and TV, variable message signs (VMSs) installed along the roads, highway advisory telephone (HAT), and through highway advisory radio (HAR), a low-powered broadcast dedicated to local traffic information (Nowakowski, Green, and Kojima, 1999). (HAR areas are usually denoted by freeway signs such as “Tune to 890 AM for Traffic Information.”) These information dissemination mechanisms can be classified into 2 categories: (1) pretrip and (2) enroute. A comprehensive, information-dissemination strategy will include a combination of both pretrip and enroute information sources. One new, promising, low-cost, pretrip information source is Internet web sites.

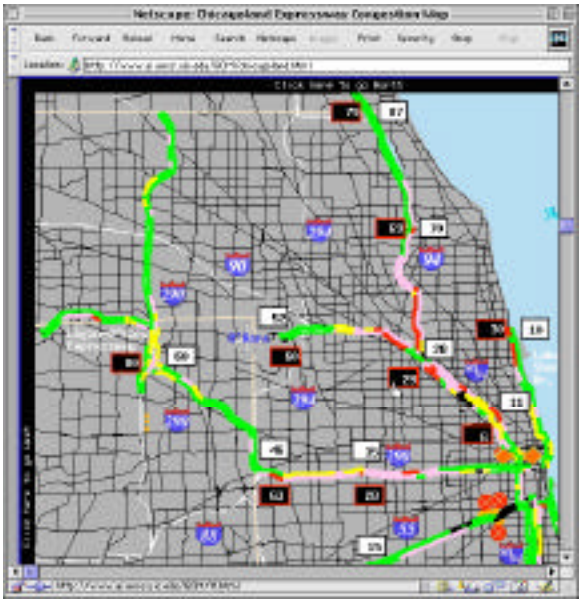
According to the Oak Ridge National Laboratory Intelligent Transportation Infrastructure Deployment web site (http://itsdeployment.ed.ornl.gov), at least 70 major U.S. cities engage in freeway traffic management. Of these, at least 30 cities have web sites that provide drivers with real-time traffic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

Designers face many crucial decisions when building a traffic-information web site. For example, designers must choose between text or map displays and make other content decisions based on assumptions of user screen size and acceptable download times. Although early web users were more tolerant of site crashes and limited functionality, the current generation of web users will only give a site 1 or 2 chances before completely abandoning an unusable or poorly designed site (Nielsen, 1997). Thus, poor designs that frustrate users and can quickly lead to a loss of the sites credibility, defeating its purpose.

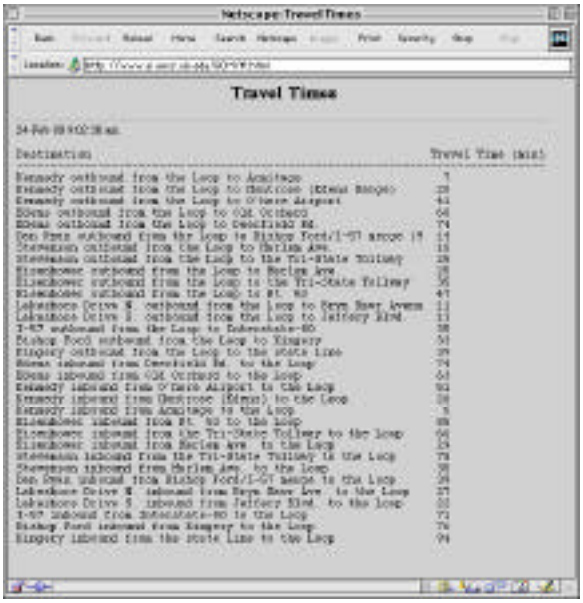
Inconsistencies both between and within sites were common. As an example, clicking on a specific road section, location, or icon usually brought up detailed information about that location (e.g., the actual speed readings for various sensors, the details of an incident, the message on a variable message sign, etc.). However, on many sites, this expectation was often violated for select features. As shown in Figure 1, one particular site followed the expectation allowing users to click on construction icons which returned detailed information on the construction at that location. However, on the same site, the travel time icons shown on the map did not follow the expectation. Clicking on a specific travel time did not produce more information about that travel time (e.g., the bounds of the travel time), instead it brought up a list of all of the travel times in the system. Thus, the initial location information in the first mouse click was lost and the users were required to reselect the location of interest using only text based descriptions (which proved to be both difficult and frustrating to users).

The purpose of this paper is (1) to present the results of a human factors approach to the design of traffic-information web sites and (2) to describe the strengths and weaknesses of various techniques based upon that experience. The approach described in Nowakowski, Lenneman, Kojima, and Green (1999), the report on which this paper is based, consisted of 4 steps:

1. An analysis of the current users of the Internet and of traffic-information web sites
2. A heuristic evaluation of 7 traffic-information web sites used to construct guidelines
3. Prototyping a traffic-information web site based on the guidelines
4. Usability testing the prototyped traffic-information web site



A mouse click on a specific travel time…



Returned a list of all travel times.

Figure 1. Example of a location specific mouse click returning general information.

USER ANALYSIS

Who are the users of the Internet?

An early step in the design of products or services is to identify the user population. Recent estimates state that by the end of 1998, there were 147 million Internet users world wide, and 52 percent (77 million) of those users resided in the U.S. (The Internet Index, http://www.openmarket.com/intindex/, May, 1999). Other statistics regarding web users appear in the Georgia Tech's Graphic, Visualization, and Usability Center's (GVU) 10th WWW User Survey (Rossignac, Pitkow, Rogers, Aggarwal, Sutton, and Malholtra, 1998). For example, at least 92 percent of the Internet users are over the age of 21, and the 86.2 percent of the web users reside in urban or suburban locations.) 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. About 66.5 percent of the Internet users are still primarily connected by 28.8, 33.6, or 56 Kb/s modems, though users who have internet access at work may have faster connections while they are at work (e.g., ISDN, 128 Kb/s, or greater). Similarly, 11.6 percent of the users still use 640x480 compared to the 30.7 percent that use 800x600 and the 27.7 percent use 1024x768.

The major strength of these user population surveys was identification of current trends in equipment. These trends can help answer questions such as "What screen resolution should I design for?" and "How long will it take the average user to

download a page?" Based on the user population surveys, designers can evaluate the impact of designing the web site for some minimum screen resolution. For example, if the designers choose a minimum screen resolution of 800x600, they would know that 11.6 percent of the population are still using 640x480 and therefore would have difficulty viewing the site. As technologies change, the recommendations based on the typical user equipment will change. Future user surveys will continue to provide valuable information on how to design traffic-information web sites to meet the needs of the users.

Who are the users of traffic-information web sites?

For the project described in this paper, 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 on that site. 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). The Chicago data were for a period from November 1, 1995 to March 15, 1999, and Detroit data were summarized by month for December, 1998, and January and February, 1999. By tracing a random selection of IP (Internet protocol) numbers (with over 100 of requests) to their domains, 6 categories of the companies, organizations, and users of traffic-information web sites were identified. This analysis helped to identify potential participants for focus groups or for usability tests.

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

   America Online, CompuServe, MediaOne, 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 probably used the web site to plan personal trips or commutes.

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

   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. It is more likely that these companies are using the web sites to support just-in-time manufacturing.

4) *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 campus). 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.

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

Several companies (Sears, A1-Computing, Dominant Systems) in the business of making on-site deliveries or providing on-site services (such as computer repair) were found to check the web sites. 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). Similarly, in Detroit, Metro Networks (http://www.metronetworks.com), was one of the largest single users of the site.

When do users check a traffic-information web site?

The data collected from current web-site use also provided information on the distribution of web-site hits throughout the day. Given that the peak traffic hours would typically be the morning and afternoon commutes, it would be expected that the number of web-site requests would increase during or prior to those times. As expected, the number of web-site requests in Chicago (Figure 2) increased and almost doubled during the afternoon commuting hours between 3 and 7 PM. However, only a slight increase in the number of web-site requests was seen during the morning commuting hours between 7 and 9 AM. A similar trend was found for the Michigan ITS: Detroit Freeway Conditions traffic-information web site (Figure 3).

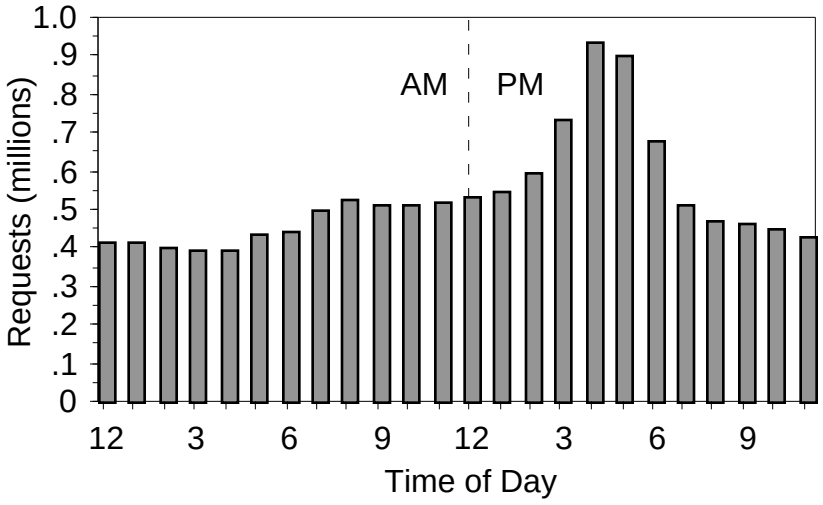


Figure 2. Chicago traffic-information web-site requests by time of day.

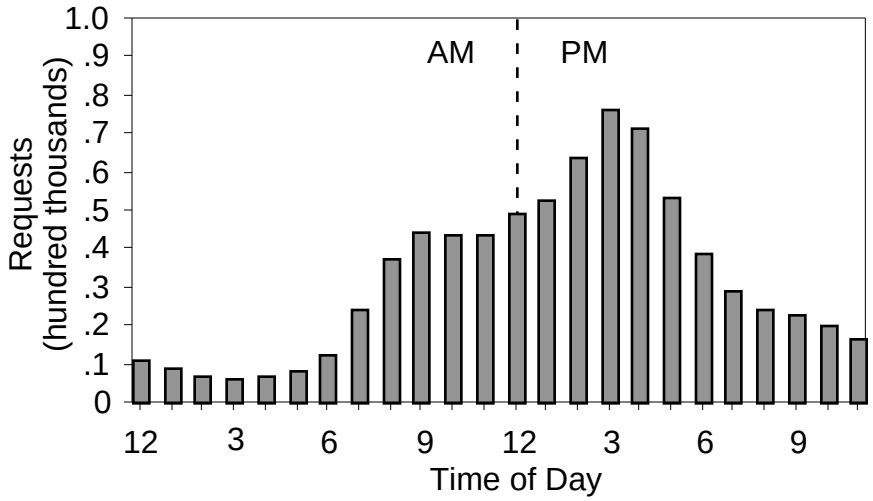


Figure 3. Detroit traffic-information web-site requests by time of day.

The low use of the traffic-information web site in the mornings might be counterintuitive given that 78 percent of the internet users have daily access from home (in the mornings), while only 57 percent have access from work (in the afternoon). The disparity may result from the fact that users currently find it 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. Alternatively, users may feel that having pre-trip traffic information in the mornings would not help (since it's too late to wake up earlier to leave earlier). Although future technologies may change morning web-site usage through high-speed, continuous home Internet connections, traffic-information web sites are currently not the most effective means to reach morning commuters.

What information do users typically request?

Simple summaries of the number of requests for each page can provide valuable insight into what pages are being viewed by the users. 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 (see Table 1). Note that the directory index or main menu page was often skipped over, and the next most requested page on the Chicago site 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. The Detroit site had no corresponding travel-times page.

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
	· Various area specific maps and more detailed loop detector info	
Least		

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, any observations based on current usage should be applied with care. The preferred format or web page in one city may not be preferred in another city. As an example, freeway travel times have been used in radio broadcasts for years in Chicago, but are rarely given in the Detroit area. An attempt to add freeway travel times to a Detroit traffic-information web site based upon the popularity of Chicago travel time web pages resulted in much confusion for the users. The popularity of the travel time pages on the Chicago web site was likely linked to use of travel times in radio broadcasts around the city. Current site usage also cannot predict what will happen when new features are added, such as real-time video.

GUIDELINES, PROTOTYPES, AND USABILITY TESTS

Heuristic Evaluation

Insights as to how existing web sites can be improved can be obtained from various types of usability analyses. In this instance, a heuristic evaluation, an approach commonly used for interface analysis (Molich and Nielsen, 1990, Nielsen and Molich, 1990, and Nielsen, 1994a and 1994b), was used.

In this heuristic evaluation, 3 expert evaluators independently examined the 7 sites listed in Table 2 using the original 10 heuristics recommended by Nielsen (Table 3). Each problem identified with a site was recorded along with the relevant heuristic. Problems were also scored and ranked in order of severity (by the evaluators as a group) based on the problem's impact, frequency, and persistence.

Table 2. Listing of the 7 traffic-information web sites chosen for analysis.

Web-Site Location	URL
Phoenix, AZ	http://www.azfms.com
Chicago, IL	http://www.ai.eecs.uic.edu/GCM
Atlanta, GA	http://www.georgia-traveler.com
Los Angeles, CA	http://www.smartraveler.com
Detroit, MI	http://www.mdot.state.mi.us/mits
Minneapolis/St. Paul, MN	http://www.trafficview.twincities.sidewalk3.com
Minneapolis/St. Paul, MN	http://www.smartraveler.com

Table 3. 10 usability heuristics recommended by Nielsen.

Heuristics	Frequency Cited
1. Visibility of the system status	18
2. Match between system and the real world	7
3. User control and freedom	3
4. Consistency and standards	12
5. Error prevention	3
6. Recognition rather than recall	4
7. Flexibility and efficiency of use	9
8. Aesthetic and minimalist design	6
9. Help users recognize, diagnose, and recover from errors	1
10. Help and documentation	0

The heuristic evaluation generated a large list of usability problems and comments that 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 the visibility of the options or information on the page was impaired.

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 design of the real-time map were with color and symbol use. Some sites used low contrast color combinations, blue on blue or gray on black, and others used colors inconsistently.

While the evaluation produced a good list of usability problems on the sites, the quality of output of a heuristic evaluation can be limited by the evaluator's skills and expertise. An ideal evaluator should be an expert in both human factors and the domain of traffic information; however, this expertise can often hinder the evaluators ability to see the site as a typical user would, leading to missed usability problems (Kanter and Rosenbaum, 1997).

Guidelines

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, and even traffic-information web-site-design guidelines, Nowakowski, Lenneman, Kojima, and Green, 1999), guidelines can only provide a start or direction for design. As noted by Nielsen (1999), simply conforming to design guidelines does not guarantee a good or usable site.

As an example, a guideline recommended the use of a small overview map (Figure 4) to provide users feedback on what part of the city the real-time map was currently focused (assuming that the real-time map contained pan and zoom controls). Although the tested design looked and functioned similar to the examples provided in the guidelines, users still had difficulties with the design. The designer had divided Detroit freeways into 3 unlabeled regions based on his knowledge of how the roads were monitored, but this confused drivers for two reasons:

1. The overview map lacked sufficient visual cues to show that a click would result in centering the map on 1 of the 3 regions. Without any cues about the 3 preset regions, the users assumed that a click on the overview map would center the real-time map at their click, and they quickly became frustrated and disoriented when that did not occur.
2. The roads in Detroit were not thought of in terms of 3 regions by typical drivers.

Ideal overview map | Overview map lacking sufficient visual cues

Figure 4. Example of a good guideline producing a poorly implemented design.

Prototypes and Usability Tests

Prototyping and usability testing can occur almost anywhere in the design process (e.g., paper prototypes can be used before any design decisions are even made). The study described in this paper began prototyping fairly late in the design process. Using basic HTML, a site was constructed that provided a static snapshot of traffic in the Detroit area. The key to rapidly prototyping and testing the site was the fact that the site did not have to provide real-time traffic information, rather it had to merely appear to function as if it was providing real-time traffic information. Testing a static web site also makes sense, because the programming to provide the real-time information should be transparent to the user. The tests, therefore, did not focus on debugging the code. Instead, the testing focused on how to present and access the traffic information.

Consistent with contemporary usability practice, 5 computer users (3 experts, 2 novices), all licensed drivers living in southeastern Michigan, were asked to use a prototype of the Detroit area traffic-information web site to plan 2 hypothetical trips (Virzi, 1992). Generally, there are 4 types of tasks used in the usability testing of web sites (Spool, Scanlon, Schroeder, Snyder, and DeAngelo, 1999): (1) simple fact finding, (2) locating enough information to make a judgment, (3) locating 2 facts for comparison, and (4) locating information to make a comparison of 2 judgment tasks. The trip planning task that the usability test participants completed emphasized the judgment and comparison of judgment tasks since the users were required to evaluate several information sources and choose their preferred route.

The first trip-planning task simulated a daily commuter planing a trip home. The test participant was given a preferred route home, an expectation of what traffic is normally like along that route, and how long the commute typically takes. The second trip simulated a novel trip where the user did not know the best route to take or how long it would take to reach the destination. The use of novice web users proved most beneficial in highlighting that the minor problems experienced by the experts became major problems for the novices.

The user testing identified the following 5 types of usability problems:

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

   Examples include an instructions box that was skipped by the expert users, and did not provide enough detail for the novices. Construction information was also rarely used in the decision making process because traffic information was not provided in the construction zones (which would be typical). Users generally would not avoid construction unless they knew that the traffic would be bad in that area.

2. *Confusing icons or legends*

   The prototyped legend was not complete since it did not define gray colored roads. Similar to other sites, gray colored roads represented no signal (usually due to construction). However, since this was not clearly defined in the legend, the users were unsure about the meaning of a gray colored road on the map during the user testing.

3. *Features that 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 information formats that caused frustration*

   The travel-time tables caused problems for all of the users tested. Although the travel-time table page was highly viewed in Chicago, travel times for the Detroit area freeways are not broadcast as they are in Chicago. The preferences for the travel-time tables in Chicago were likely influenced by the radio broadcasts that use the travel time format. If travel time information were provided to Detroit users, the users would prefer to enter their origin and destination, and get a single travel time for their route. Similarly, the traffic overview map did not provide all of the construction and incident information, which frustrated the users because they preferred not to "dig" for the information.

5. *Information that was interpreted ambiguously*
   Video images were provided on the prototyped web site. Although most of the users found them useful, the information provided was ambiguous. One test participant may have looked at an image and decided that traffic did not look bad, while another test participant used the same image to solidify the decision to avoid the area.

The major drawback of prototyping and user testing was that the users often became stuck at one problem and failed to completely explore the site or find additional problems. For example, users who could not figure out the pull down menu or map zoom features, quickly gave up using them and missed testing features that could only by accessed if the map's zoom function was used.

CONCLUSIONS

The purpose of this paper was (1) to identify who actually uses traffic-information web sites and (2) to demonstrate how human factors methods can be used to design and evaluate these sites. Three analyses of traffic-information web sites and users resulted in the following conclusions about the design and use of these sites:

1. The peak site usage occurred during the afternoon rush hours, but little increase was seen during the morning rush hour implying that the web site was not as effective at influencing morning travelers or traffic.
2. Six types of users were identified. Aside from various types of commuters, the sites were used to support trucking traffic, companies that engage in on-site delivery or services, and third party traffic-information providers.
3. The most frequently viewed web pages contained congestion overview maps or travel times. User testing also showed that most users preferred to only have to look at one web page to tell them what to expect on their trip, they did not want to "dig" through different pages to find the details of congestion, incidents, or construction.
4. User preferences for information types and formats may vary from city to city.

The second purpose of this paper was to describe the strengths and weaknesses of the various human factors methods that can be used to create and evaluate a traffic-information web site. Four methods were examined: user analysis, heuristic evaluation, the application of guidelines, and user testing.

The user analysis provided information on the current hardware trends, what types of users were currently looking at the site, and what parts of the site were looked at most frequently. Although this information was helpful in providing a target for the design, there were two major drawbacks of the user analysis: (1) a frequently looked at page does not imply that the page is without usability problems and (2) the user analysis cannot predict the results of changes and new features.

The heuristic evaluation method provided a good first cut at eliminating usability problems that dealt with (1) interface inconsistencies, (2) inefficient interfaces, and (3) navigation or feedback problems. However, 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.

The use of traffic-information web-site-design guidelines provided a good start or direction for the design. Guidelines can provide solid answers to some questions such as “How fast should the page download?” However, simply conforming to design guidelines did not guarantee that all features were implemented without problems. Even if guidelines are used to help design a traffic-information web site, user testing is recommended to help fine tune the design.

The user testing was conducted relatively quickly (20 to 40 minutes per user for 5 users), required no special equipment (other than video cameras and a computer to television signal converter for video recording), and provided immediate and useful results with only minor training in human factors and usability testing. However, in order for the user testing to provide accurate feedback, care must be taken in the selection of the users to test. Although web designers, TMC control room operators, and DOT management personnel may be easy to recruit to test the web site, they are often experts, not typical users. To achieve valid results, the users that are tested must be typical traffic-information web-site users with varying degrees of web expertise. Some of those users should be novices since novices were often completely unable to use features that caused only minor problems for experienced web users.

Even though traffic-information web sites are still in their infancy, any human factors input at this stage is better than none. Although the effectiveness of any single human-factors analysis method may depend upon the resources available to the TMC, each of the methods described in this paper provided some human factors benefit. If 3 human factors experts are not available as evaluators for a heuristic evaluation, 1 evaluator can still provide some valuable feedback. In this case, using 1 evaluator as a preliminary method would help to eliminate some of the initial problems making other methods (such as user testing) more effective. As the technology becomes available to provide more services (e.g., customized travel reports or door-to-door driving directions that include traffic information), more emphasis will need to be placed on human factors to assure that traffic-information web sites provide drivers a with quick and effective means of getting traffic information.

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