Vehicle Speed Information Displays for Public Websites
A Survey of User Preferences

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Abstract

The paper reports on a study comparing alternative presentations of freeway speed data on maps. The goal of the study was to inform the design of displays of real time speed data over the Internet to the general public. Subjects were presented with a series of displays and asked to rate their preferences. We looked at different choices of color (3 colors, 6 colors or a continuous range), and proposed line, sensor, and segment representations of the speed data. We also collected feedback on more complex displays such as comparison between current and "normal" speeds, and a chart of speed variation over a period of time at given locations.

1. Introduction

As advanced highway management information systems become widespread and the use of the Internet by the general public grows, transportation agencies are encouraged to make some of their data available in real time over the Web. City and state agencies create Web sites providing information about the status of their network of roads. Some Web sites are simple, merely providing lists of planned roadwork or incident locations, while others provide extensive information about highway traffic and incidents, camera views, travel times, or even comparison between routes, or transportation modes. All advanced transportation Web sites provide a map showing a view of the road network covered by the system, and display graphically the traffic speed at various points on the map.

The goal of the study was to help the state of Maryland highway administration decide how to revise and improve their current public Web site. We first reviewed existing Web sites [1], and then selected a series of alternative displays that we felt depicted useful information. The questions that were frequently brought up were: (1) Should we change the color used to show speed data? (2) Should we continue to show the speeds as colored lines on links, or instead, show the data as colored dots at sensor locations? In particular, there was concern over showing data on a whole link when the sensor might be located farther from the region. (3) What other information about speed could we show effectively on the map? We chose a limited set of alternatives and ran a user study.

As we submit the paper, we can only report on the results of the interviews of 23 users, but we are continuing to interview users and will recruit more subjects representing an even more varied pool of users. The survey explores how users respond to different ways to display current and historical traffic data.

1. Display options

2.1 Apparatus

A Java applet was designed for the test. It displays a map and provides controls allowing the interviewer to modify the display according to several parameters (Figure 1).

We used a Java applet in our test to simplify the generation of all the options, but we do not advocate or envision using a Java applet for the actual public Web site. Unfortunately, such applets are still a serious problem when universal access to the information is a requirement, because too many users experience difficulties installing Java or loading Java applets.

The controls allow the interviewer to present series of displays, which vary by their display method, display color, method to show comparative data.

We created a sample speed dataset for a sample set of sensors and links. Since this apparatus is only meant to be used for the survey the java applet merely draws the colored icons and lines on top of a bitmap map. We grabbed an existing map and reduced it size to avoid any zooming or panning. The result is a poor quality map but this is irrelevant for this study since we wanted users to focus on the speed information.

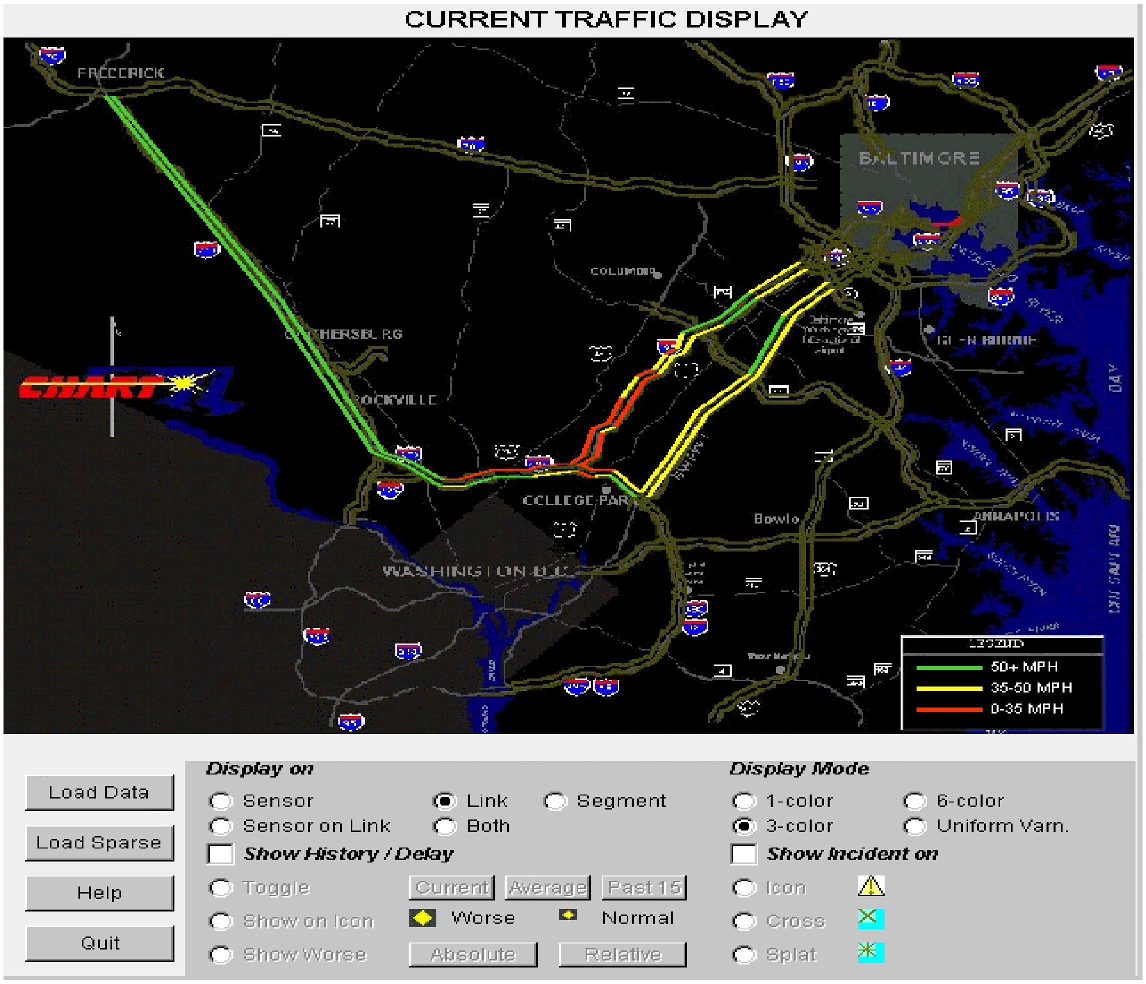


Figure 1: Screen shot showing the web application used during the survey. The interviewer can use the control to present the different displays to the users, who are later free to use the controls or to ask the interviewer to review the options at will.

2.2 Display Method options:

The options include showing speed as:

(a) Colored dots at sensors location (Sensor displays)

Two options show the sensor data either

- beside the road (Sensor display – Figure 2) or
- on the road (Sensor-on-link display - Figure 3).

(b) Colored lines corresponding to whole links (Link display – Figure 4)

(c) Both sensors and links (Dual display - Figure 5)

(d) Smaller colored lines of limited extent away from the sensor (Segment display – Figure 5)

Users were presented the series of option in this exact order. This allowed us to see users reactions when they were realized that the link data was extrapolated from the sensor data.

Note that both the Sensor-on-Link and the Segment display were added after the beginning of the study in response to users feedback and fewer users rated their preference for it. We decided that adding options after the beginning of the study was acceptable as it would a lead to a better understanding of users preferences at the cost of a longer study with more users.

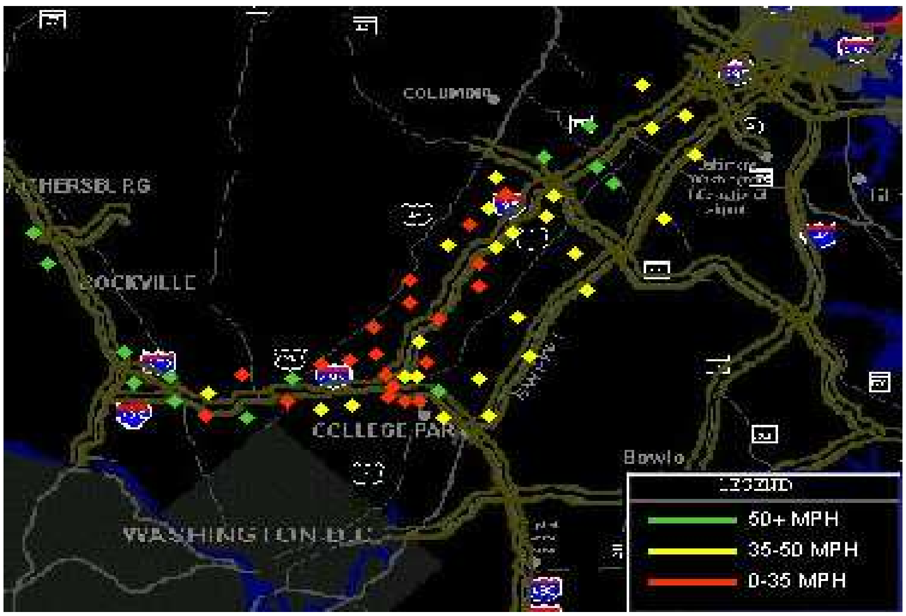


Figure 2. Sensor display with sensors placed beside the road

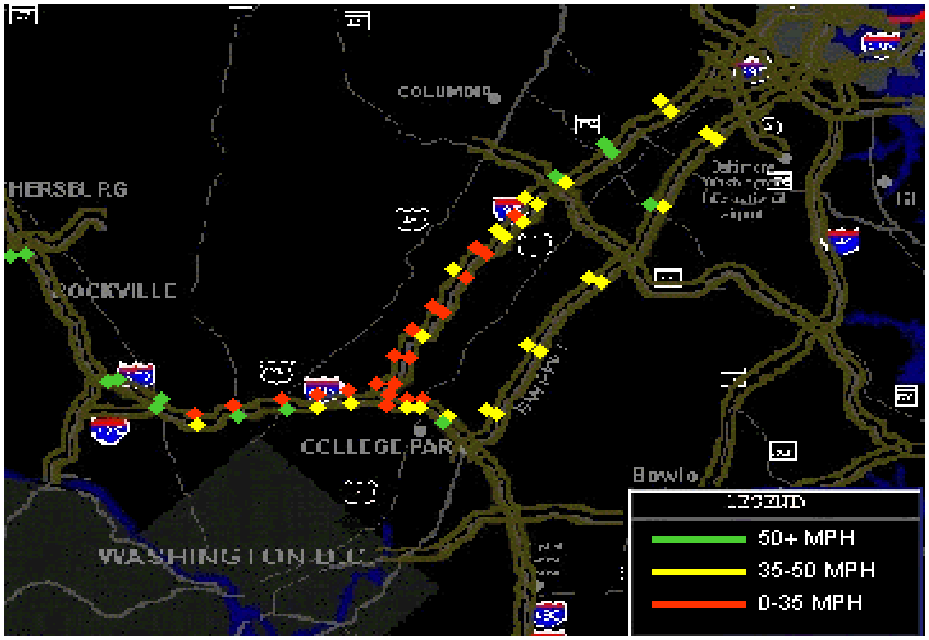
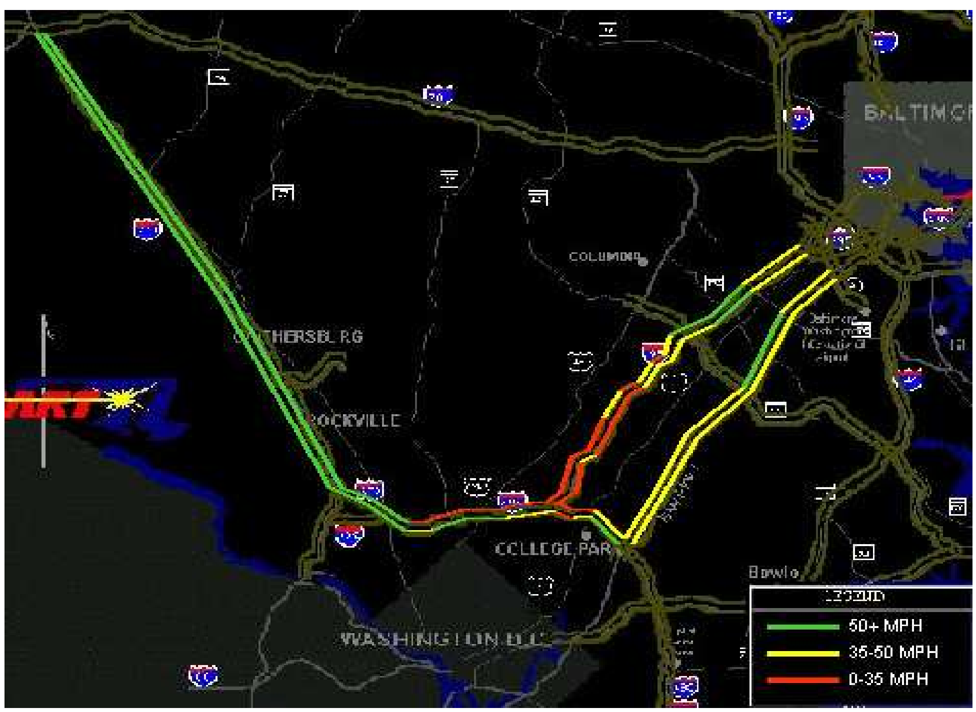


Figure 3. Sensor display with sensors on the road



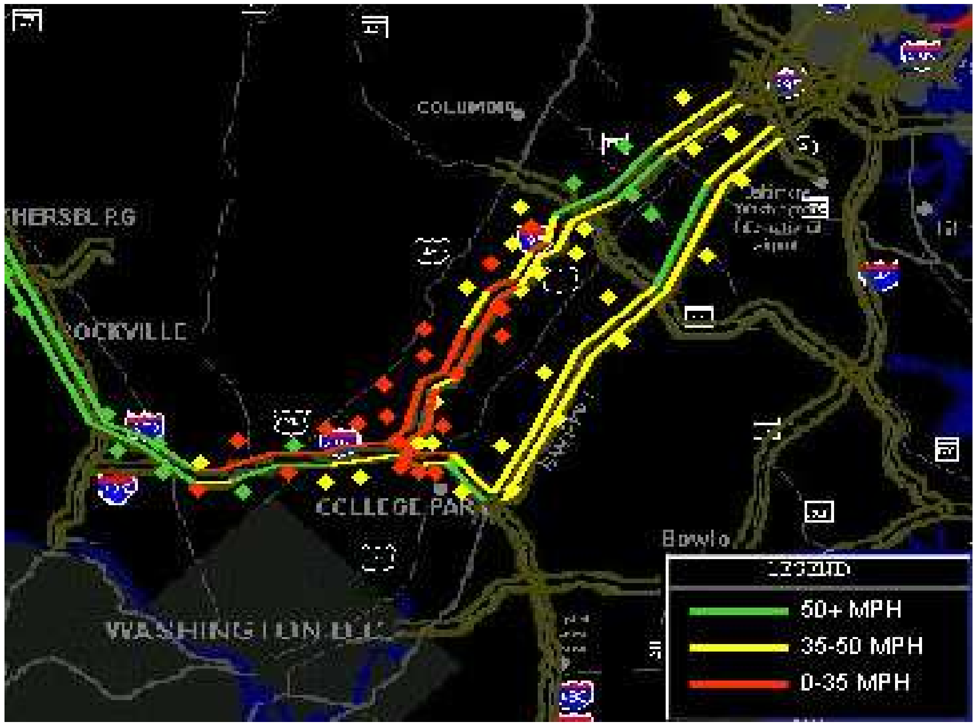


Figure 5. Dual Display. Both the link and the sensor icon are shown.

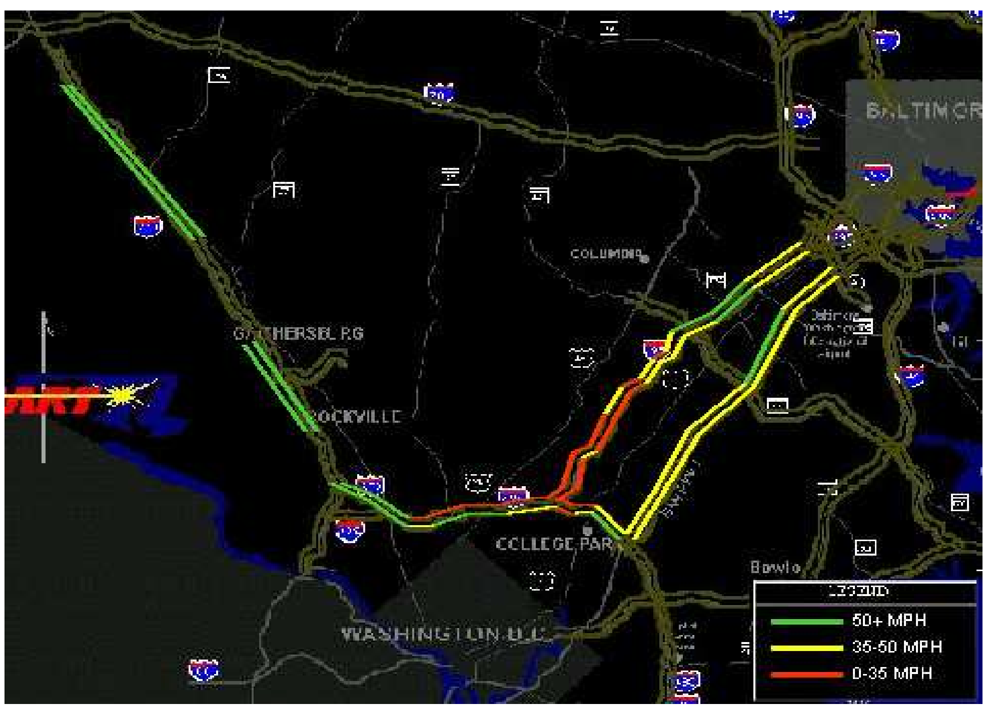


Figure 6. Segment Display. Only a section of limited length is extrapolated from a sensor data point. Therefore the coverage is not complete in areas where there are fewer sensors available.

1.2 Display Colors options

These options vary the number of speed ranges and corresponding color-coding. The red-yellow-green palette is the original color palette used by Maryland. Those 3 colors have a strong natural mapping to speed. One question we wanted to investigate was what other style of color coding would be appealing and understandable to users.

We chose the following options:

(a) Single color (green)
(b) Three-color (green-yellow-red) variation (Figure 4).
(c) Six-color variation based on highway levels of service (Figure 8).
(d) Uniform (Gradient) variation from green to red (Figure 9).

One important aspect we are also considering is readability of the colors by users with color blindness (either red-green confusion - the most common case, or total color blindness). Just as traffic lights remain red and green despite of that known problem, it seemed important to verify that colorblind users could use the displays that we proposed. This part of our survey has only been partially conducted (see results section for a discussion of the issue)

Figure 7. Single-color Variation

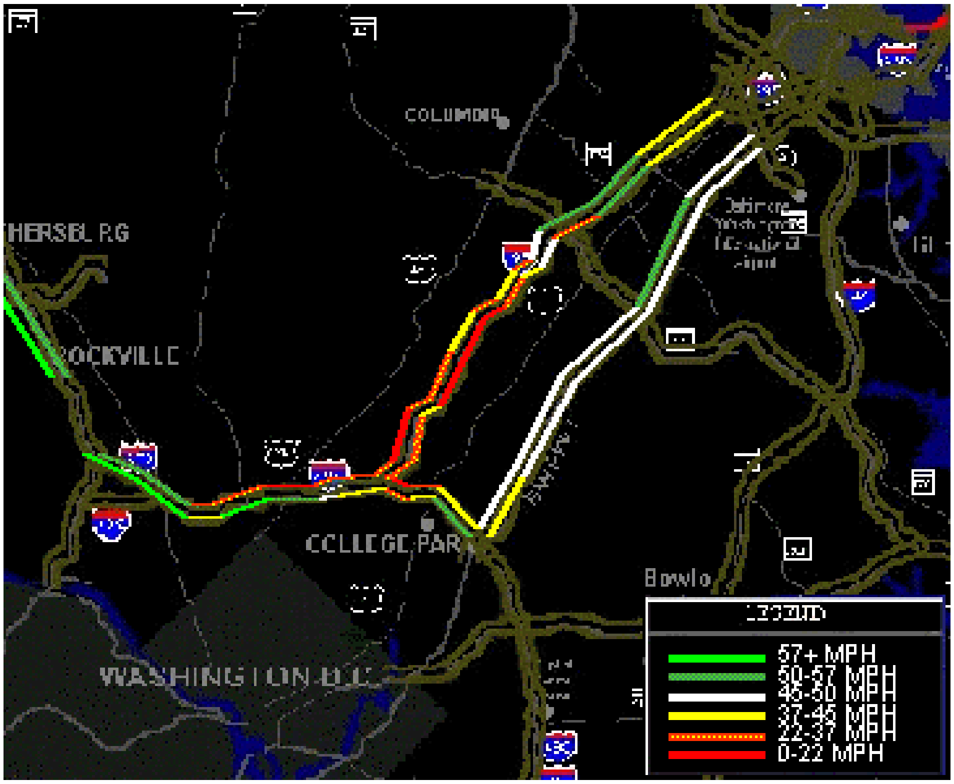


Figure 8. Six-color Variation

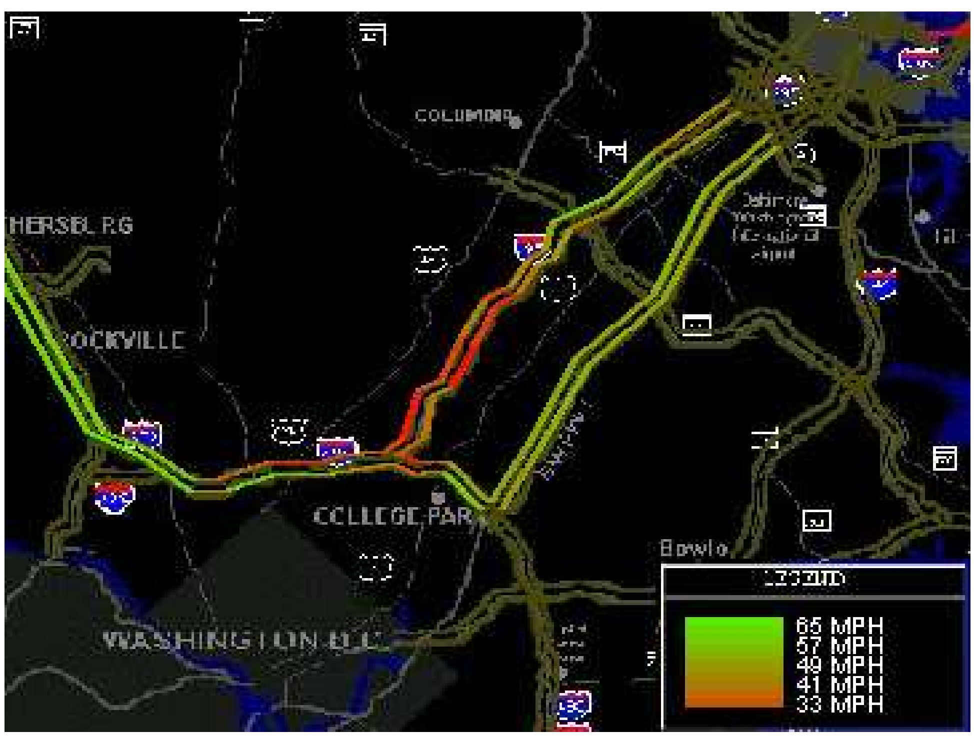


Figure 9. Uniform Variation – continuous from red to green

2.3 Displays comparing current conditions with "usual" conditions

The comparative displays allow the comparison of current traffic speeds with the "usual" speeds (i.e. the hypothetical average speeds at a similar time on a similar day – e.g. the "usual" Monday morning work day with good weather.)
Those displays would answer questions such as "How is the traffic today? Better or worse than usual? Is there unusual congestion?"

The display options included:

(a) Toggle option: in which the user can toggle between maps showing the current speeds, the "normal" speed, and the speeds 15-minutes-ago.

(b) Worse-Only option, which colors only "slower-than-usual" links and shows:

- Absolute speeds (with the same color codes as the current speed – Figure 10)
- Relative speeds (with a new color coding for the speed differences – Figure 11).

(c) Size-of-icon option: The differences in speed are shown on sensor locations by varying the size of the dot: a small icon for a speed faster than usual, a large icon for speeds slower than usual (Figure 12). This option was considered in the case users would prefer to see the current speeds with the sensor display.

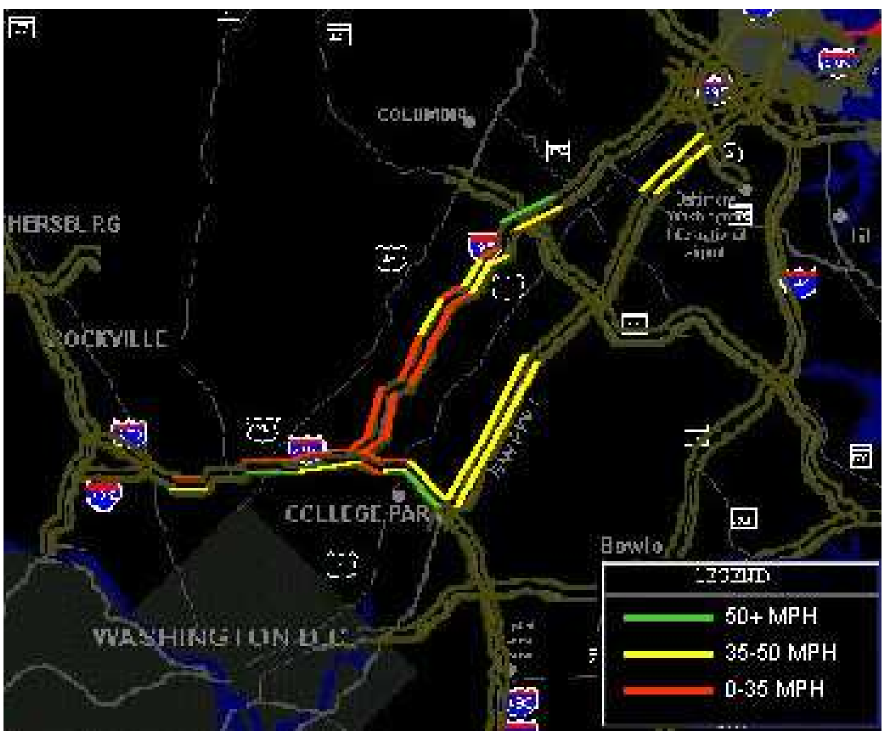


Figure 10. Comparative display showing only the areas where the traffic is worse than usual. The color-coding remains the same, showing absolute speeds.

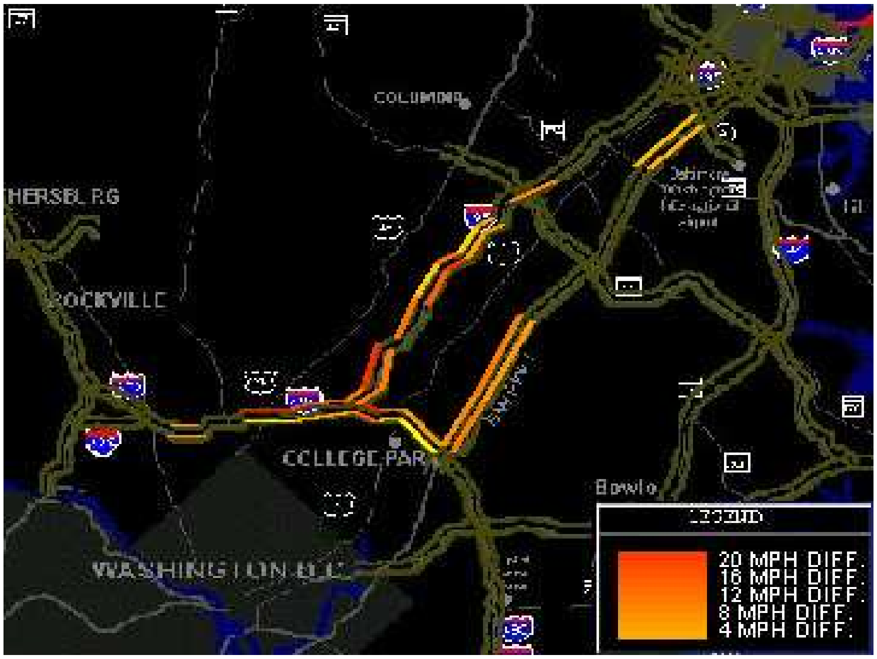


Figure 11. Comparative display – Worse Only with Relative Speeds. It shows that the traffic today is generally worse than usual, and the very red areas have the worse speed difference compared to usual.

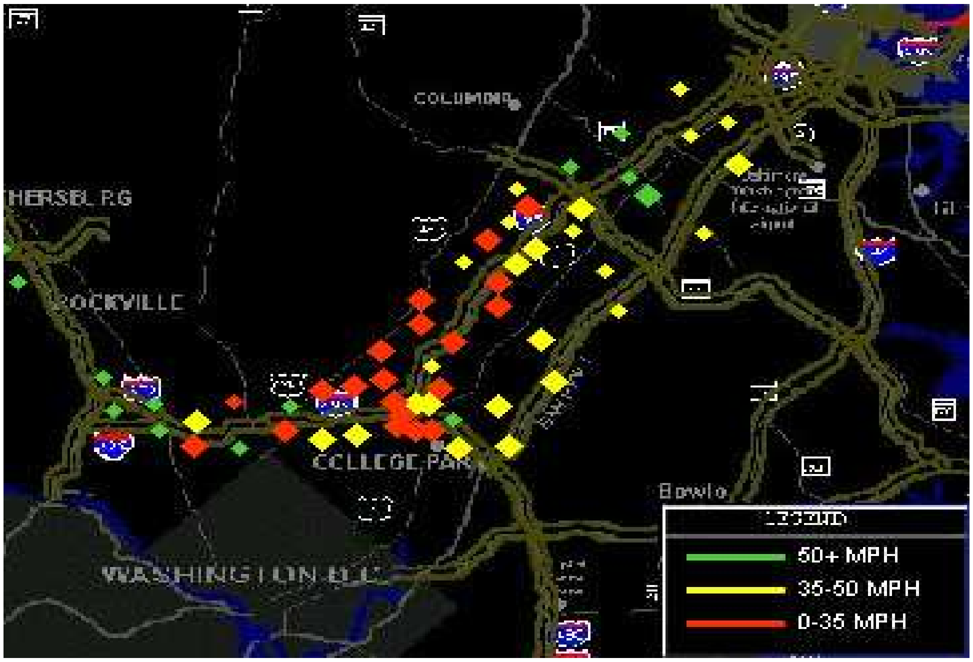


Figure 12. Comparative display - Size of Icons - Here the larger the dot, the worse it is compared to usual. Small dots are the same or better than usual.

2. 4 “Speed trends over a day” diagram

To explore how users would respond to more complex displays of speed information we showed them another prototype showing the speed variations over a day at a selected location (Figure 13.) In our prototype this display is obtained by double-clicking on a location on the map. This feature was envisioned to enable users to plan trips or understand when rush hours are in a city they don’t know well.

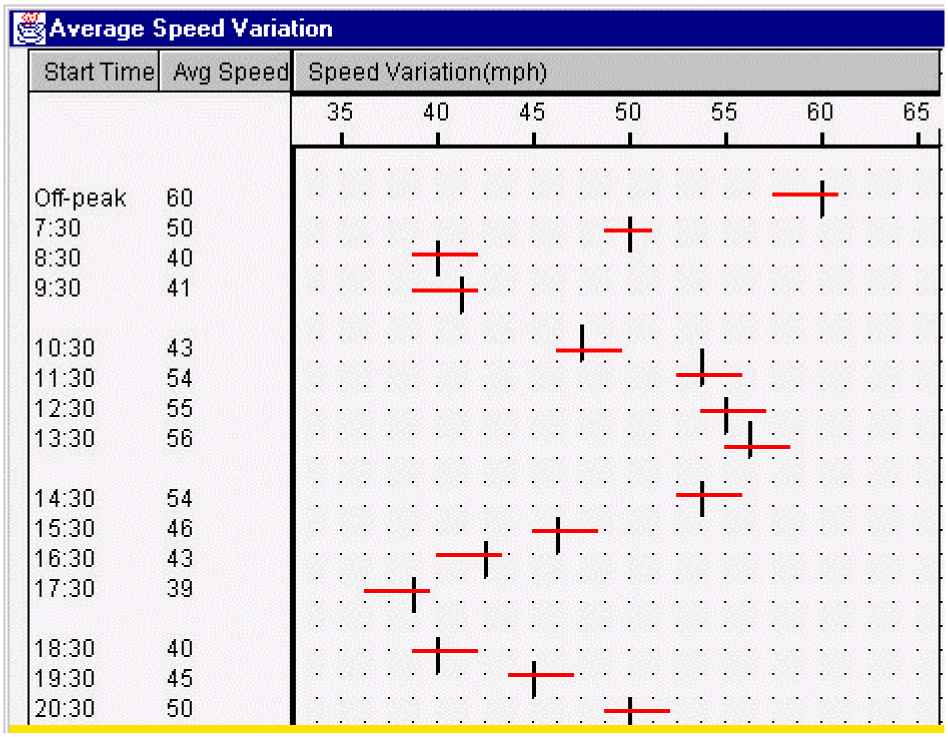


Figure 13. A more complex display: Speed trends over a day at a given location, showing the time of the rush hours and the effect on speed. The data is presented in both tabular and visual form. The visual display provides both the average speed and the range of normal variations.

3. Users

As of now, 23 users participated in the survey. These included students and professionals in engineering, transportation systems, and other disciplines. The distribution is shown below. In the coming weeks, we plan to double the number of users and to balance the proportion of engineering versus non-engineering users, and students versus professionals.

Students (Engineering)	10
Students (Non-engineering)	5
Professionals (Transportation)	3
Professionals (other - Engineering)	4

Professionals (Non-engineering)	1

4. Procedure

We used a fairly informal survey method. Users were encouraged to think aloud and freely describe what they understood from the displays. Questions were mostly meant to make users think about what they saw and talk about it. Finally users were asked to give their preference among displays.

After greeting the subjects, the interviewer presented each display in turn and asked specific questions to the user (see Appendix A). At first only the interviewer manipulated the controls since the purpose of the test was to compare the displays and not to judge the usability of the controls (which would most likely not exist in a final application). After the interviewer had shown each display of a series (e.g. all color variations) and asked the questions, the subjects were free to use the controls themselves to further review the displays in order to rate them – or ask the interviewer to do it for them.

The survey questions (Appendix A) attempted to cover the following aspects.

(i) The users ability to read the displays without help
(ii) The possibility of misinterpretation of the data
(iii) The interest of users in seeing more complex displays

5. Results

The results of the user survey are summarized below.

Display mode (Sensor / Link / Dual / Segment)

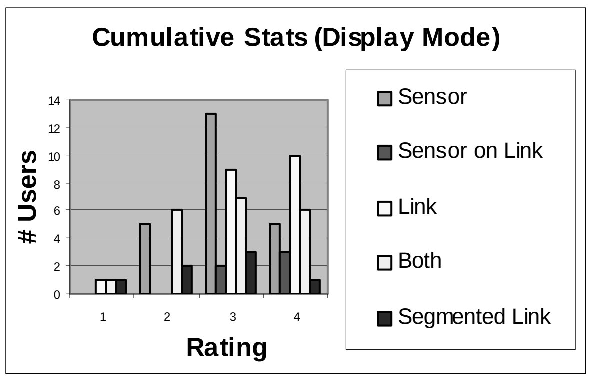
1. All users were able to interpret the Link display. For the Sensor display and the Dual displays only 60% of the users were able to understand and apply the detailed information presented without explanation. Those users –who could understand it- were mainly of engineering or related background (80% of them). In other words the sensor-only display was NOT understood by 40% of the users. Even though those users seemed to know that sensors are installed to measure speed, they didn't intuitively interpret the display. Those displays seemed to appear too busy and less integrated than the Link display.

2. All users liked the link display at first. After the comparison with the sensor display 20% changed their opinion when they understood that the link display was extrapolated and therefore potentially misleading. Some changed to sensor, or segment, or dual display, but overall all users found the segment display acceptable.

3. 90% of the users seemed prepared to trust the information given on such a web site given that they could see that the web site is updated frequently.

4. We will look at differences between user groups. We don't have results yet because of the still small number of users in the non-engineering group.

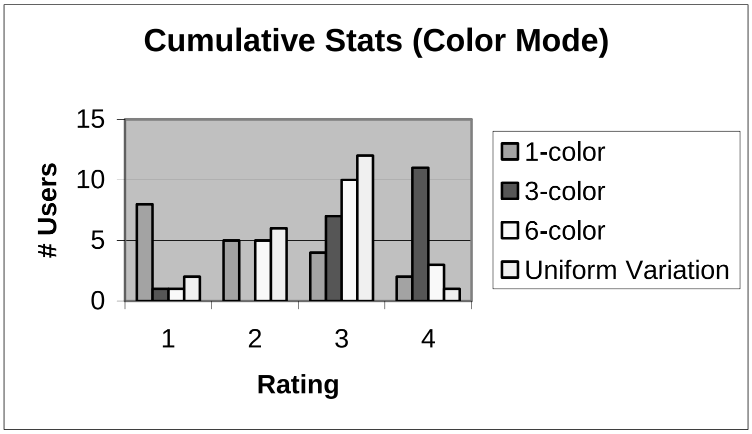
   In conclusion, our study seems to confirm that showing the speed data on links - as it commonly done- is an option that is liked by users and interpreted correctly. The segmented link that was introduced later in our study seems to be the alternative choice as it was suggested by users early on during the study but we need more subjects to confirm it. Remember that the numbers for the segment-link and the sensor-on-link display are low because these options were added after the beginning of the survey.



1- **U**nacceptable
2- **D**on't Like
3- **A**cceptable
4- **L**ike

Color Coding (single color gradient / 3 colors / 6 colors / 2 color gradient)

1. 70% preferred the 3-color option to other options. All but one found it acceptable but many users noted that it had a large a range of speed per color (including the user who found the 3-color option not acceptable for that reason). On the other hand, most users felt that the 6-color option gave too much detail, they had to repeatedly review the color legend and many found the color choice unintuitive. The continuous-variation option was not liked because it did not show the demarcation between links and hence did not seem realistic, but was acceptable for most users. The 1-color variation was usually not liked at all.



1- **U**nacceptable
2- **D**on't Like
3- **A**cceptable
4- **L**ike

Color blind users

To deal with the issue of color recognition we started by interviewing one color-blind user (with the common red-green). Unsurprisingly the red green color choices didn't work. The red was perceived as very brownish and the green and yello too similar. We had imagined that the one-color variation would have been acceptable because it didn't involved color recognition, but it turned out that it did anyway (intensity also plays a role in ordering the colors). None of the versions seemed acceptable… So we tried a black and white version (Figure 14). The variations could be read properlly but the roads of interest (for which there is data) do not stand out well and merge with the rest of the map. So we asked that to create its own palette (Figure 15). The result was a yellow-orange-red palette with a fairly dark red. Surpringly the user could not find a bright red (for us) that stood out enough for him.

Our next step will be to post this choice of color on the internet and send the URL to a large number of students asking all color blind persons to look at it if they are color blind and to either contact us by email or leave an anonymous not in a mailbox saying if they could interpret the map easily with those colors.

Figure 14 : A black and white version – The problem is that the roads of interest do not stand out from the rest of the map.

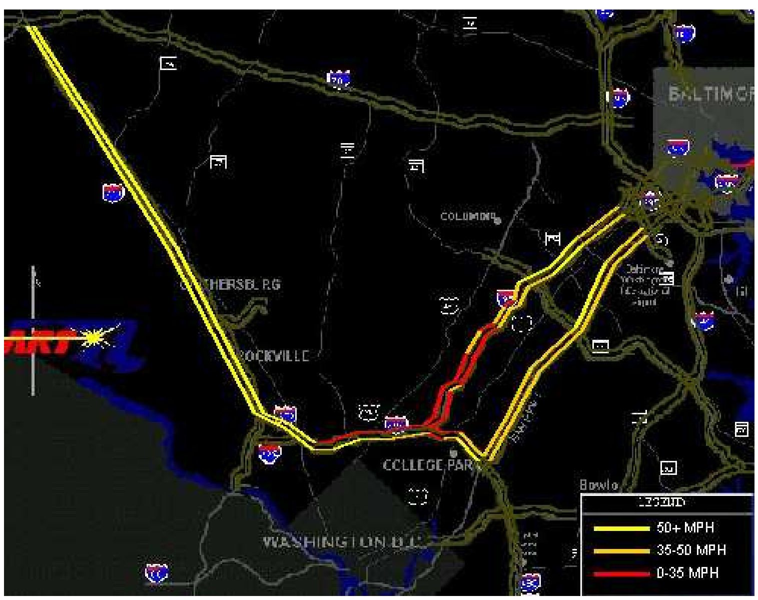


Figure 15 : A 3 color palette chosen by a color-blind users. It doesn't respect the green – red convention butis readable by all. It could serve asa good alternative map.

To conclude, the study suggests that the 3-color options seem the best compromise to satisfy most users, but that an alternative color palette will need to be offered for color blind users.

Comparative Displays

1. A majority of users regarded the displays comparing current and "normal" speeds as less important than the displays showing current speeds, but many felt it was a useful ancillary feature to have available.
2. Of the various options proposed 70% liked or found acceptable the Worse-Only-Absolute-Values option, compared to 60% for the Toggle option and only 30% for the Worse-Only-Relative-Difference option. Nobody liked the Delay-on-icon display.
3. Users commented that the Toggle option labels needed to be clarified.
4. Only showing the areas were the traffic is worse than usual was found useful and sufficient. The Relative-Difference option requires understanding yet another color legend and users felt that the chosen colors were not clear. Some users indicated that they would have enough information by just looking at the absolute values in the affected areas.

At this point, our recommendation would be to offer an option to show the Worse-Only-Absolute-Values display as a secondary display. It is liked by many users and it is easier to use than the Toggle option.

“Speed trends over a day” diagram

1. 80% responded that it would be useful in trip planning. Though, only about 40% could interpret it correctly. A continuous-graph display was suggested instead. Four out of five non-engineering students found it difficult to interpret as well.

Feedback from Traffic Engineers

Even though the tested displays were meant to be used by the general public, we presented them to 3 highway management system operators to get their feedback.

1. All 3 traffic operators felt the segmented-link display relayed information closer to available data. Display of actual speeds on sensors was found a needed complementary feature.

2. Because they use displays with 3 or 4 colors, they felt like the rest of the users that the 3-color display was acceptable and that 6 colors were too much.

3. Viewing only the worse areas was not found useful by the operators, as they felt that they are better aware of the normal traffic and can tell immediately what is worse on the normal speed displays.

6. Discussion and conclusions

Our survey confirms that there is a lot of variation in preference among users. Almost each version we created had one fan and one detractor.

Ideally one could imagine providing users with a variety of controls to choose display mode, colors, and other features. Unfortunately adding those controls will render the interface more complex to use and will most likely limit the universal accessibility of the Web site. Only specialized private services requiring user registration are likely to let users customize their displays and save the settings in a user profile. Therefore, our recommendation for web pages for the general public is to carefully select a small set of options (a maximum of 3 or 4). Based on our current data, a good set of choices might be:

- A 3-color display showing speed on links
- An alternative with a set of 3 different colors (readable by color blind users)
- A similar display but showing only the speeds in the areas worse than usual

Finally, showing the variation over time of speeds at give locations will be useful, but usable by only a portion of the user population.

Acknowledgements

We want to thank Phil Tarnoff for his guidance and encouragement during this study. Support for this project is provided by the Maryland State Highway Administration.

Related URLs

[1] HCIL report on Online Traffic Information Systems:
http://www.cs.umd.edu/hcil/highway/review/

[2] Project Web site at HCIL
http://www.cs.umd.edu/hcil/highway/

Appendix A: Survey Questionnaire

1. CHART Screen Questions:

This is a display of the Maryland SHA's traffic information display on the Web. How do you think traffic engineers know where the congestion and accidents are? How do they obtain the information on speeds? (Do you know about sensors?)

2. Links or Sensors:

2.1 (Links + 3-color)

2.1.1 Could you explain what you see and what you interpret from the graph?

2.1.2 If you saw the display on the screen before you hit the road to Baltimore from College Park, what would you do?

2.1.3 If you needed to go to BWI, what would you do or plan about?

2.1.4 Would you be satisfied with such a display if it was a new area you were visiting?

2.2 (Sensors + 3-color)

2.2.1 How is this display different from the previous one?

2.2.2 Which one would you prefer at first glance?

2.2.3 Why do you think the display appears only at those points?

2.2.4 Switch back to the previous display. Do you now feel differently about it now that there are so few sensors? Do you feel links are useful? Or are they misleading?

2.3 (Sensors + Links + 3-color)

2.3.1 What do you think of this one?

2.4 Can you to rate each of these displays as

Like
Acceptable
Don't Like

Unacceptable

Sensors	**U**	**D**	**A**	**L**
Links	**U**	**D**	**A**	**L**
Sensors + Links	**U**	**D**	**A**	**L**
Segmented Links	**U**	**D**	**A**	**L**

2.5 Which one would you prefer?

Sensors Links Sensors + Links

3. Colors

3.1 Go through all color palettes and rate each one of them as above.

1-color	**U**	**D**	**A**	**L**
3-color	**U**	**D**	**A**	**L**
6-color	**U**	**D**	**A**	**L**
Uniform Variation	**U**	**D**	**A**	**L**

3.2 Which one would you prefer? How do you think it is superior to the rest?

3.3 If you are a color-blind user, use PhotoShop to change colors.

4. Showing Accidents

4.1 How do you interpret the Estimate Travel Time information? What would you do if you were about to take the route? Can you express how much trust you would put in this information?

5.Comparative Display

5.1 Play with the three options to display a 'normal' or 'average' day's data. How would you rate the three options?

Toggle	**U**	**D**	**A**	**L**
Relative Difference	**U**	**D**	**A**	**L**
Show worse on Icon	**U**	**D**	**A**	**L**
Show worse only	**U**	**D**	**A**	**L**

5.2 Which one would you prefer?

5.3 Compare this with the current traffic display. Which one would you prefer to see first?

6. Daily speed variations at any sensor

6.1 How do you interpret this?

7. Miscellaneous

7.1 Would it be useful if we could show the information about the (possible) future for sections involved in incidents at any time?

7.2 What else would you like to see on such a Web site?