Preliminary Investigation

Caltrans Division of Research, Innovation and System Information

DRISI

Impact of Roadside Graphic Displays on Drivers

Requested by
Sean Nozzari, District 4 Deputy District Director, Traffic Operations

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The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Table of Contents

Background

Caltrans' District 4 requested approval from FHWA to post graphical images of routes on the Variable Message Signs (VMS) associated with Active Traffic Management system on I-80. FHWA rejected the request, indicating the research on this topic needs to be done first before they can allow graphical images on the signs.

Roadside Graphic Display Examples

1) Ontario Province Deployment of Graphical Signs
2) Study Conducted by Texas Transportation Institute (TTI)
3) Study conducted by University of Rhode Island
4) Study conducted by American Association of State Highway and Transportation Officials (AASHTO)
5) Impact of Roadside Advertising on Road Safety – Australian Roads Research Report

Ontario Province Deployment of Graphical Signs

The province of Ontario in Canada had a unique challenge. According to Canadian law, they were supposed to put all messages on roadway in both English and French but physical limitations on Variable Message Signs (VMS's) made it impossible to display messages in both languages. The province law also prohibited having 2-phase messages on VMS's, which made the situation more challenging. So the authorities were looking for out of the box solution. They thought about pictogram solution, putting pictures and graphics with different colors on the VMS's. Pictograms transcend language barriers and can improve reading and understanding time. A picture is worth thousand words. Additionally, with new VMS technology, better images can be displayed. So they embarked on that route. They used the following roadmap for pictogram VMS message development:

- Public Sessions
    - Create new symbol ideas
    - Assemble most common themes for each symbol message
    - Test which symbol is most understood by motorists who will see the message
- Design Charrette
    - They called the experts into a design charrette and discussed various symbols/pictures in different sizes and colors which will be easily understood by the motorists
- Field observations on full size VMS's
    - They observed the decided symbols on full size VMS's in parking lots and received feedback from professionals and ordinary motorists.
- Extensive human factor testing
    - Two rounds of testing
    - Criteria: Valid driver license and testers drive on freeway
    - 3 cities, 3 language groups (English, French and other), 3 age groups
    - Sample size: 324 motorists
    - Testing Format
        - What did sign say?
        - What should drivers do?

Findings:

- Good understanding by end of testing session
- Pictogram messages better at depicting more complex configurations
- Pictograms enable new "combination" messages
- Redundancy reinforces understanding
- Most Important: Pictograms understood by ALL language groups

Implement Roll out plan to deploy these VMS signs with graphics/pictures on Ontario freeways:

- The Province of Ontario is now deploying full color overhead VMS on mass scale
- So far they have deployed almost 500 of these signs.
- The Ministry's goal is that, over time, messages will evolve to images with little or no text as drivers become familiar with the new symbols.

Use of Symbols and Graphics on Dynamic Message Signs – Texas Transportation Institute

The information below is from a study done by Texas Transportation Institute (TTI). This study was published in 2009. The results are relevant and the study promotes the use of graphical route information panel (GRIP) with color to display real-time traveler information to drivers

This project has taken a step toward defining how graphic and symbol displays can improve or assist communication with drivers. Through three human factors evaluations of alternative designs, researchers identified specific design elements that should or should not be used in graphic displays. Additionally, some of the key benefits identified for the use of graphic displays as compared to equivalent text messages are:

- A graphic display appears to improve the ability of drivers to identify available lanes in a problem area.
- The delivery of incident descriptor information (e.g. accidents or work zones) through the use of graphic symbols improves comprehension levels of non-native-language drivers (e.g., a driver whose primary language is Spanish).
- The viewing time required for comprehension by a non-native speaker may be shortened as a result of the use of graphics and symbols.
- The use of graphics makes it possible to effectively illustrate unusual operational scenarios, such as high-occupancy vehicle lanes or adjacent toll lanes, through graphic representation of roadway geometry, logos, shields, etc.

In this study, the researchers used the following method to come to their conclusions:

- Focus Groups
- The Level 1 Human Factor Laboratory Study
- The Level 2 Human Factor Laboratory Study
  - The Level 2 study was done after modifying the symbols pointed out by human factor study in Level 1

The Level 2 Laboratory Study evaluated the ability of drivers to comprehend and use information presented in a graphical electronic format and compared this information to that of text-based DMS messages. Through this study, researchers identified elements within these signs that enhance or detract from this information. In the summary below, researchers highlighted the main findings of this study:

- The information in text messages did not convey to participants how many lanes were available past an upcoming incident as effectively as graphic displays.
- The inclusion of delay on graphics did not have a significant impact on either expected delay or route decisions of the participants.
- Text (e.g., delay time, situation descriptors) should be avoided when designing graphic displays, as this approach adversely affected the participants' ability to comprehend the messages in a timely manner.
- Route change decisions are primarily influenced by the number of lanes that are closed or blocked.
- Graphic and symbol displays had decreased viewing time as compared to equivalent text messages, and should therefore be considered for use when portraying complex information to a driver.
- With regard to incident situations, the data indicate that participants used a combination of the information provided by a symbol representing an incident and roadway congestion levels to make decisions regarding severity.
- Incident severity was not the primary deciding factor for choosing to take an alternate route and additionally did not have a significant influence on delay expectations.
- Both text and symbol representations of "roadwork" were well understood by participants. However, using text is a primary concern for non-native speakers because the symbol for "roadwork" was better understood by the Spanish-speaking participants and should be used in graphic designs.
- Use of a symbol to indicate a work zone did not have a negative impact on viewing times (i.e., it did not significantly increase viewing times).
- The imagery used to represent closed lanes for a work zone was well understood by participants.
- Participants' likelihood of changing routes was affected by their comprehension of the situation ahead. The lower the comprehension level was for a scenario, the less likely participants were to identify that they would take an alternate route.

A GRIP is a sign that graphically displays parts of a road network in color-coded form and can display relevant information, such as the location and degree of congestion, on segments of the road network. The use of color to display real-time information to drivers in a GRIP format was a concept that Dudek and Jones, in a study in 2009, investigated for Texas Department of Transportation (TxDOT). The study indicated that drivers preferred unique design features such as color to distinguish between normal and abnormal conditions. GRIP's should be placed at strategic locations in advance of major driver decision points and alternative routes, where the network itself and/or the traffic situation are very complex. Japan has used such signs since 1980; Australia has signs displaying travel time and traffic level; and experimentation is beginning to increase in the Netherlands. In addition to the advantages cited earlier for symbols and pictograms, researchers have reported that GRIP's have the following advantages over word messages:

- More information can be given.
- Complex information becomes easier to understand. This point becomes important when congestion occurs at several locations in a network or when the network is complex.
- Drivers are able to figure out where on the network a crash has occurred. The information relative to drivers with different destinations can be presented simultaneously.
- It accommodates foreign travelers that may not comprehend English messages.

Along with the advantages of GRIP's, there are some disadvantages. Research shows that drivers who are not comfortable with reading maps do not do as well with GRIP's as their more map-proficient counterparts.

Animation and Color: In a study reported by Lerner, the researchers investigated the current state of application and guidance for the use of animation and color on dynamic displays. The researchers made the following observations:

- Neither animation nor color has yet found widespread use in the United States. While a variety of examples were found, these were generally demonstration projects or one-of-a-kind applications on arterial streets.
- The United States appears to be behind various other countries in experimenting with or implementing color-coded freeway displays. While the authors did not find widespread use of animation anywhere, Japan and Australia use color, and it is the subject of demonstration projects in Europe.
- DMS displays in the United States are predominantly alphanumeric text rather than diagrammatic or symbolic/pictorial. Animation and color could be used with text messages, but may be more compatible with diagrammatic or pictorial displays. The capabilities offered by full-matrix DMS's for displaying images, animation, and color do not appear to have been well-considered or well-exploited.

Adding Graphics to DMS Messages - University of Rhode Island

They used the following roadmap for pictogram DMS message development:

- Graphic aided DMS messages
  - Preferred by most drivers
  - Faster response
- Left of Text
  - Preferred location for graphics
- Older drivers
  - Slower and less accurate responses to messages in text format
  - Response improved by graphic messages
- Non-native English Speaking Drivers
  - Language background significant
  - Improved by graphic messages

Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs

A study, conducted under the auspices of American Association of State Highway and Transportation Officials (AASHTO), was conducted in 2009. While it was focused on advertising, some of the conclusions may be applicable to implementation of GRIP's. This study essentially was a literature search that reviewed various studies on the topic.

In 2007, a study by Clark investigated how a driver's reaction time to driving-relevant information was affected by different levels of out-of-vehicle distraction, and whether these impacts were related to a driver's level of expertise. The study produced some interesting findings. There was a consistent increase in reaction time to the road signs as load from distracting stimuli increased, suggesting that the higher loading driving tasks (as represented by the number of advertisements

visible) were "detrimental to road safety." The implications of this study are that advertisements should be kept to a minimum at busy junctions and areas where drivers need to concentrate."

Young conducted a simulator study in 2007. The independent variable for this study was the presence or absence of billboards on the roadway. The participants were not told the objective of the study and were told to simply drive. The driver mental fatigue was measured on the NASA TLX scale. NASA TLX scale is a subjective, multidimensional assessment tool that rates perceived workload in order to assess a task. The study found that the presence of billboards adversely affected driving performance in terms of lateral control and crashes. Longitudinal control was not adversely affected. These findings would suggest an increase in side-swipe crashes vs. rear-end crashes, but no information is provided as to the types of crashes found. The presence of billboards also had an adverse impact on driver attention in terms of the number of glances made at billboards.

As a part of a larger study, Speirs conducted a survey to examine 1371 respondents' views on potential sources of in-vehicle and external-to-vehicle distraction, followed by a more specific focus on roadside advertising. Demographically, the respondents tended to be male, and between the ages of 25 and 59. They drove between 10,000 and 25,000 miles per year, and used the freeway more than five times per week.

In the on-line survey, a series of questions sought to examine whether some types of roadside advertising were considered to be more distracting than others. Participants were asked to select the types of advertising, if any, that they had found to be personally distracting while driving, and then to identify the single most distracting type of roadside advertising. The results are shown below:

- Billboards with changing images on video displays were reported to have distracted 72% of all respondents; 53% of the respondents found video display most distracting.
- Conventional billboards had distracted 61% of the respondents, and 17% found these to be the most distracting.
- Advertisements on vehicles had distracted 38% of respondents, but only 3% found these to be the most distracting.
- Advertisements on bus shelters had distracted 24% of the respondents; 9% found these to be the most distracting.
- Seven percent of the respondents found none of the advertising types to be distracting, and 11% mentioned other types of advertisements (such as ads on street furniture, on-premise signs, and small temporary roadside signs) as having been a source of distraction to them.

In order to evaluate the effects, if any, of roadside billboards on general driver performance, a series of statements were presented to the participants, who were asked to state whether they thought each statement was true or false. The statements, and the levels of truth assigned to them, were as follows:

- Can be confusing in urban environments (83%)
- Can be detrimental to overall driving performance (82%)
- Electronic ads with changing images are more distracting than static ads (82%)
- Is an unwelcome distraction to the driver (75%)
- A driver may steer slightly out of lane to read a roadside ad (58%)
- A driver may brake to read a roadside ad (53%)

- Keeps drivers alert (14%)
- Is not distracting in rural environments (12%)
- Is not distracting in urban environments (11%)
- Improves a driver's concentration (4%)

<u>Impact of Roadside Advertising on Road Safety -- AustRoads Research Report</u>

Literature search and recommendations for using roadside video displays was conducted under the auspices of various departments of transportation within the Australian government. The organization conducted the research is called AustRoads. This research looked at the effects of graphic displays located on the roadside, used for advertisement to the drivers. It was published in Australia in January 2013.

Survey of State and International Department of Transportation (DOT)

1) Washing State DOT
2) Minnesota DOT
3) Texas DOT
4) Virginia DOT
5) Florida DOT

<u>Bill Legg, State ITS Operations Engineer, Washington State DOT:</u>

WashDOT operates several ATM corridors in the Seattle Region, and all of them have overhead gantries like our I-80 project, with DMS's on the shoulder mast arm. Bill says that they have considered putting graphics, such as route information, on those DMS's, but they have not taken action to do so yet. They will be watching our experience to learn from it before they attempt it themselves.

<u>Ray Starr, Assistant State Traffic Engineer, Minnesota DOT:</u>

MinnDOT operates several ATM corridors in the Minneapolis-Saint Paul Region. They do not have DMS's on the overhead gantry mast arms, but are considering a pilot project to determine the best way to display the route information (north up, direction of travel up, straight line versus representation of actual road geometry, appropriate size, etc.).

<u>Jian-Ming Ma, Traffic Operations Division, Texas DOT:</u>

TxDOT does not a have any similar systems operating, and does not have a policy for displaying graphical information on DMS's. They recently attempted to initiate a pilot test of such a system in the Austin Region, but FHWA also denied their request to test.

Bill Legg mentioned that he thought the Harris County Toll Road Authority in the Houston Region might be using Graphical Route Information Panels, but the local district of TexDOT confirmed that they are not.

<u>Melissa Lance, Operations Systems Manager, Virginia DOT:</u>

VDOT operates an ATM corridor on I-66 near Washington, DC, but it only uses arrows and 'X's, with no other graphics images. They are also implementing a Fog Detection System on I-77, where they intend to replicate a regulatory speed limit sign on a graphics display as part of the

associated Variable Speed Limit. They are investigating the use of full-featured graphics for other applications, such as international symbols, but that's just in planning stages and no FHWA approvals have been sought.

<u>Fred Heery, State Transportation Systems Management and Operations Program Engineer, Florida DOT:</u>

FDOT has no similar systems and has no plans to build any soon.

<u>Tom Alkim, Reichswaterstaat, Netherlands DOT:</u>

We reached out to Tom Alkim of the Reichswaterstaat in the Netherlands to inquire about their related experience, as they operate numerous ATM corridors with overhead gantries similar to our configuration on I-80. Unfortunately, he is on the traditional European "Holiday" during the month of August, so we have not been able to talk with him. We are confident that he will provide additional input when he returns to the office.

Literature Review Results

1) A study by Lee, McElheny and Gibbons, conducted in 2007, concluded that digital billboards can be more distracting than conventional billboards. In this naturalistic study, drivers drove an instrumented vehicle around a 50-mile loop in Cleveland Ohio. They found that drivers took longer glances at digital billboards than at conventional billboards.
2) In a 2009 study, Young researched the effect of billboards on the driver attention. This study was conducted on a simulator. Drivers experienced urban, rural and freeway environments, with and without billboards. The presence of billboards was found to impair lateral control of the vehicles.
3) Another study by Edquist in a simulator in 2011 found increased delay in the time taken to change lanes in response to the presence of billboards, although not to a greater extent for DMS's.
4) The negative impact of roadside advertising on lateral control has also been reported by Bendak and Al-Saleh in a 2010 study. This was also a simulator study. They concluded that, while the frequency of crashes in Young's study (presented above) was too low for statistical analysis, it is worth noting that there were three times as many crashes in the presence of billboards compared to driving conditions where billboards were absent. Interestingly, they also found that participants displayed significantly poorer recall of traffic control in the freeway and rural driving conditions, compared to urban driving conditions, suggesting that participants were spending more time processing advertisements in these less demanding driving scenarios, at the expense of attending to information that is important for safe driving.
5) In 2009, Chattington conducted a simulator study comparing the effect of static roadside advertising and moving video advertisements. Their team found that video advertising was significantly more distracting than static advertising, as indicated by more and longer glances towards the advertising. In addition, video advertising was found to reduce the ability to maintain a constant speed and lane position to a greater extent than static advertising.
6) In 2005, Smiley investigated the impact of video advertising in the Toronto area on driving performance in a series of studies, including a before and after installation comparison of crash rates. While Smiley found no statistically significant effect on crash rates overall, he noted that sample sizes were not large enough to detect any effect that might accrue from the presence of the billboards. The descriptive statistics in this study, however, are consistent with a relative increase in collisions, of all the various types, at the approaches to the video advertising sites.

Conclusion

The VMS graphic signs are deployed in many parts of the world, including the Province of Ontario in Canada. They have combined best practices from around the world with regional research and public input to create signs for the travelling public. These signs were developed based on public sessions, design charrettes, field observation of VMS's, and extensive human factor testing. Now they are widely deployed in the whole province. Full color images and symbols enable drivers to easily recognize important road safety information, safely react to traffic conditions and choose better routes, improving overall traffic flow.

The conclusion we derive from the study by TTI is that a graphic display improves the ability of drivers to identify the lanes available to drive in through a problem area. This identification may have a direct impact on both lane choice and route diversion driving decisions. The delivery of incident descriptor information (e.g., crash or work zone ahead) through the use of graphic symbols improves the comprehension levels of non-native language drivers (e.g., a driver whose primary language is not English). The viewing time required for comprehension by a non-native language driver may be shortened as a result of the use of graphics and symbols. The use of graphics makes it possible to effectively illustrate unusual operational scenarios, such as HOV lanes or adjacent toll lanes, to a driver through the graphical representation of the roadway geometry, logos, shields, etc. In a nutshell, the use of GRIP's improves the efficiency of information transfer to the driver.

As far as the distraction caused by the video displays, the studies that have been conducted show convincingly that roadside advertising is distracting and that it may lead to poorer vehicle control. However, the evidence is only suggestive of, although clearly consistent with, the notion that this could in turn results in crashes. Studies providing direct evidence that roadside advertising plays a significant role in these distraction-based crashes are currently not available.

It is also worth noting that, on the basis of Klauer's study in 2006, while looking at an external object increased the crash risk by nearly four times, less than 1% of all crashes and near crashes were from this source of distraction. A substantial proportion of these external objects would not have been advertising signs. Thus, while it is not possible to tell from the reported results, it is reasonable to conclude that far less than 1% of all crashes and near crashes involved distraction from roadside advertising.

While the Klauer 2006 study may not be representative of all driving events, it does suggest that the contribution of roadside advertising to crashes is likely to be relatively minor. On the other hand, from a Safe System perspective it would be difficult to justify adding any infrastructure to the road environment that could result in increased distraction for drivers. The exception to this may be in the case of very monotonous roads where drivers are likely to suffer the effects of passive fatigue.