**STUDY OF THE HUMAN/ITS ITERFACE ISSUES ON THE
DESIGN OF TRAFFIC INFORMATION BULLETIN BOARD
AND TRAFFIC CONTROL SIGNAL DISPLAYS**

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**October 2002**

**URITC PROJECT NO. 536113**

PREPARED FOR

UNIVERSITY OF RHODE ISLAND
TRANSPORTATION CENTER

| 1. Report No URITC FY 99-13 | 2. Government Accession No. N/A | 3. Recipient's Catalog No. N/A |
|---|---|---|
| 4. Title and Subtitle Study of the Human/ITS Interface Issues on the Design of Traffic Information Bulletin Board and Traffic Control Signal Displays | | 5. Report Date October, 2002 |
| | | 6. Performing Organization Code N/A |
| 7. Authors(s) David M. Shao & Jhy-Hone Wang | | 8. Performing Organization Report No. N/A |
| 9. Performing Organization Name and Address David M. Shao & Jhy-Hone Wang Department of Industrial & Manufacturing Engineering University of Rhode Island Kingston, RI 02881 | | 10. Work Unit No. (TRAIS) N/A |
| | | 11. Contract or Grant No. URI-536113 |
| | | 13. Type of Report and Period Covered Draft final |
| 12. Sponsoring Agency Name and Address University of RI Transportation Center University of Rhode Island Kingston, RI 02881 | | 14. Sponsoring Agency Code N/A |
| 15. Supplementary Notes N/A | | |

16. Abstract

The success of automation for intelligent transportation systems is ultimately contingent upon the Interface between the users (humans) and the system (ITS). The issues of variable message signs (VMS) and traffic signal device (TSD) design were studied in this project. Well designed variable message signs and high traffic signal device will get better driver response. Those messages or signals will serve the intended purposes to help the ITS system function effectively. In this project, computer simulations and experimental design were conducted to determine the significant factors such as size, color, and shape, which might affect the drivers' response. In addition to the commonly used circular-shaped traffic signals, other shaped signals were also included in this study. Variable message signs (VMS) are programmable message bulletin boards that are used to provide information about changing condition on highways to improve operations, reduce accidents, and inform drivers. This project studied the variable message signs used in present transportation system and explored potential improvements through designed experiments. It evaluated the impacts on several factors on the design and display of VMS as the effectiveness of VMS depends upon its color scheme, format, size, wording, etc.

| 17. Key Words ITS, Traffic Control Signal, Variable Message Sign, Driver Reliability, Driver Response, Human Factors, Experimental design. | 18. Distribution Statement No Restrictions. This document is available to the public through The University of Rhode Island Transportation Center, 85 Briar Lane, Kingston, RI 02881 | | |
|---|---|---|---|
| 19. Security Classification. (of this report) Unclassified | 20. Security Class. (of this page) Unclassified | 21. No. of Pages 15 | 22. Price N/A |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized (art. 5/94)

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Two subjects, variable message signs and traffic control signals, were studied in this project. This report hence consists of two parts, the first is on variable message signs and the second part is on traffic control signals.

## Variable Message Signs (VMS)

## 1. Introductions and Background

Variable message signs (VMS) are employed by intelligent transportation systems (ITS) to provide drivers with real time information and instruction. They are designed to have one or more messages displayed at a time and messages could be changed by a system monitor through remote control or through automatic controls that could "sense" the conditions that require special message. Variable message signs, with more sophisticated technologies, are gaining widespread use to inform motorists of various situations particularly along more congested traffic corridors. In addition, portable message signs are used in some areas to furnish information for nonrecurring incidents such as major traffic collisions or highway maintenance and repair [1].

Most variable message signs use a matrix format upon which characters and symbols are formed by showing appropriate patterns of matrix elements. There are four general types of signs: (1) Warning signs, to caution motorists of road conditions; (2) Regulatory signs, to inform traffic of regulations governing movements, parking, speeds, weights, etc.; (3) Guide signs to show route designations, destinations, directions, distances, services, points of interest, and other geographical, recreational, or cultural information; and (4) Construction signs, to caution motorists in advance of and through construction and maintenance activities (may include warning, regulatory and guide signs) [1]. The information to support traffic management using VMS can come from a variety of traffic monitoring and surveillance systems.

The success of intelligent transportation systems is ultimately contingent upon the proper design of VMS and its presentation. As this method becomes widely used in highway management, it is important that drivers be able to read and comprehend these messages to make timely responses. The effective delivery of information to the drivers is critical especially in high-volume, high risk and construction/repair zones. This project focuses on the design and display of variable message signs. It intends to find out the roles of VMS in a variety of conditions and identify the driver information requirement for the specific objectives of the VMS. It intends to help design the appropriate messages to meet drivers' needs and assess the impacts of various factors that could effect the display of certain messages. Some past studies on existing VMS systems are briefed below.

A study conducted at Northern Virginia assessed motorist attitudes toward VMS and the effect of demographic characteristics on those attitudes [2]. In response to a question regarding how often VMS influenced their driving, half the survey respondents replied "often", two-fifths said "occasionally," and the remainder stated "not at all." In other words, half the respondents depended regularly on VMS, which was consistent with attitudes expressed in the focus groups.

According to the investigation of effects of VMS conducted in Paris [3], it was found that VMS could affect vehicle diversion significantly, especially during congested times. VMS had more influence on drivers during morning peak hours, the longer the queue length posted in VMS, the more drivers diverted. Based on the survey results in Finland [4], 91% of the drivers recalled the posted speed limits, 66% recalled the slippery road sign and 34% recalled the temperature display, indicating that the drivers could recall the VMS better than regular fixed signs. Surveys of driver's attitudes toward VMS in Virginia [5] found no significant correlation between driver's attitude and demographic variables such as age, education, income, and gender. When asked how often they were influenced by VMS, half of the people surveyed responded with "often", two-fifths "occasionally", and others "not at all". A study of speed monitoring displays with radar in work zones at South Dakota indicated that they were effective in reducing the speed of the traffic entering the work zone. The mean speed was 4 to 5 mi./hr bwer after the speed monitoring displays were installed. When VMS were used for special events in Dallas, 71-85% drivers used the recommended route [6]. Reasons given by the 15-29% that did not divert were: 1) didn't see or understand the message; 2) anticipated unsatisfactory traffic conditions on the alternate route or uncertain of the adequate guidance along the route; 3) were unfamiliar with the alternate route or uncertain of the adequate guidance along the route; and 4) lacked confidence in the information. Armstrong and Upchurch [7] conducted a field study in Phoenix, Arizona on the legibility distance, target value, and viewing comfort of a variety of VMS measured by observers. They concluded that the number of words in a message should vary with the VMS technology, the lighting conditions, and the prevailing traffic speed. Variable message signs using different character fonts or dimensions should undergo a legibility analysis prior to implementation.

Early researchers recommended that messages be exposed to drivers at a rate not to exceed one word of information per second. At a prevailing speed of 55 mph, the message should not exceed eight words (excluding prepositions and assuming a typical legibility distance of 650 ft.). With lengthy messages or adverse and fluctuating environmental conditions, drivers may have to reduce their speeds to read the message. Studies have also shown that VMS used on U.S. freeways should have a character size of at least 457 mm (18 inches) to handle message requirements for most applications and audiences. Letter heights between 254 and 457 mm (10 and 18 inches) are recommended for roads other than freeways.

How well a VMS can be seen depends on two factors, the visual capabilities of the drivers and photometry qualities of the sign [8]. How effective a VMS is depends largely on how much time a driver has to read it. The available time is determined by travel speed, the distance from the sign when it is first noticed, and the legibility distance from the sign when it is first noticed. Drivers must recognize a VMS and its messages before they can respond to it, and a sign's foreground and background color and its brightness are significant to its overall visibility. On a bright, sunny day, the display must be significantly brighter for contrast. This potential contrast problem is acute when the sun's rays are directly behind or in front of the sign [9].

All the studies mentioned above focused on existing VMS systems. Not much was done in assessing the design and display of VMS and their impacts on driver's response. The effects of VMS should be predicted or evaluated before its actual implementation. Many factors in VMS design and display could affect its effectiveness. The influence of these factors on the

responsiveness and accuracy of driver's comprehension need to be studied systematically. These factors include size of the sign (board size and font size), location (height and viewing angle), color (background and foreground), display (words, sequence and format), etc. Proper selections of these factors and their levels are very important; inaccurate or poorly formatted messages may confuse drivers or not allow them enough time to read and understand all the words in the message. Another concern is the number of VMS's placed in succession. Since an excessive number of signs might distract drivers and reduce the effectiveness of the essential traffic information displayed, it is also necessary to asses drivers' capacities to assimilate a variety of signs presented simultaneously or in quick succession. In addition, demographic differences in driver's gender and age might also affect their response time and accuracy to VMS and thus need to be studied.

## 2.   Experimental Approach

This project studied VMS design and display issues using a systematic design of experiment approach. It examined the various factors and their impacts on human /ITS interface using different variable message signs.  It used a computer-generated environment to simulate a virtual driving experience. Various variable message signs were introduced in a random but controlled manner. Two groups of factors including controllable factors and blocking factors came into play in the experiment. Controllable factors included font size, background color, foreground color, and number of message lines. Blocking factors considered here were gender and age of drivers. Subjects were required to make proper responses to each stimulus and their response time and accuracy were recorded for analysis. A series of  blocked factorial experiments were conducted to fully investigate these factors and their interactions. Assessments using real VMS will be considered in the future.   A description of this study and its preliminary findings is briefed below.

In this study, a sequence of computer generated VMS were projected onto a large screen to simulate a drivers view. Computer generated signs start showing up on the screen very small and slowly get larger to simulate the driver's approach to the sign. Once the subject recognizes the sign, he/she hits a certain key on the computer. The subject's response time and accuracy were recorded in a Microsoft Access file for later analysis. Figure 1 depicts the experimental layout.
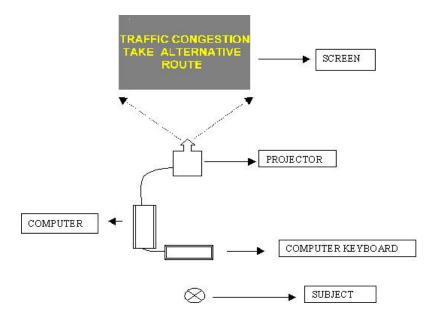
Figure 1. Experimental Setup

Three different messages: "Road work ahead, reduce speed", "Foggy area ahead, turn on the head light" and "Traffic congestion, take alternative route" were displayed with a different combination of foreground color (red and yellow), background color (black and blue) and message lines (two and three). Examples of those messages are shown in Figure 2. Twelve subjects from different age and gender groups participated in the experiment. Each subject went through 24 runs -3 messages x 2 foreground colors x 2 background colors x 2 message lines. The messages were projected onto a screen and subjects saw the messages gradually increasing in size and finally disappearing. Appropriate actions were required to signal the subject's comprehension. To record the subject's response, special keys on the keyboard were used and the subjects were made aware of the key to hit for a particular type of message. Response time and accuracy were recorded and analyzed. Since the experiment is in its initial stages, a three-factor factorial design with two blocking factors was employed to identify the significant factors. The results of this experiment follow.



Figure 2. Example of two and three lined messages.

## 3. Results and Discussions

Based on a statistical analysis of the results, it was found that the foreground color, message lines, age and gender all significantly affect the subject's response time. As noted in Table 1, a full blocked–factorial experiment model was employed in this analysis. The  model can be stated as:

*Y = Overall mean + F + B + L+ A +G + F\*B + F\*L + B\*L+ F\*B\*L + Error*

Where   *F* is the foreground color,
*B* is the background color,
*L* is the number of message lines,
*A* is age, and *G* is gender.

Table 1. Analysis of Variance of the Full Model

```
Source                 DF     Seq SS     Adj SS     Adj MS       F       P
Background (F)          1     0.5506     0.2025     0.2025     0.41   0.521
Foreground (B)          1     3.8280     2.5159     2.5159     5.13   0.024
Message Lines (L)       1    32.4203    30.9999    30.9999    63.17   0.000
B * F                   1     0.3881     0.4891     0.4891     1.00   0.319
B * L                   1     0.2290     0.2173     0.2173     0.44   0.506
F * L                   1     0.0258     0.0356     0.0356     0.07   0.788
B * F * L               1     0.5416     0.5986     0.5986     1.22   0.270
Age (A)                 1     6.4749     6.4778     6.4778    13.20   0.000
Gender (G)              1     8.8733     8.8733     8.8733    18.08   0.000
Error                 278   136.4263   136.4263     0.4907
Total                 287   189.7579
```

From Table 1, we find that P values for foreground color, message lines, age, and gender are all less than 0.05 and hence the factors are significant. Neither the background color nor the interaction between the different factors shows any significance. Main effects plots on those significant factors are provided on Figure 3.
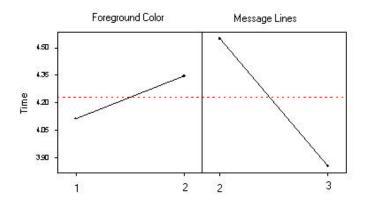


Figure 3. Main Effect Plots

From these plots, we found that the foreground color 1, yellow, took less response time than foreground color 2, red. We also found that three-lined message took much less response time than the two-lined messages.

Since both the age and gender factors exhibit significance, the results were analyzed using a two–factor factorial model to further investigate these two factors. The model is:

$$Y = Overall\ mean + A + G + A*G + Error$$

where *A* is Age and *G* is gender.

The analysis of variance (ANOVA) results of the experience are shown in Table 2.

Table 2. ANOVA Table for the Age-Gender Model

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Age | 1 | 6.4770 | 6.4770 | 6.4770 | 10.91 | 0.001 |
| Gender | 1 | 8.8726 | 8.8726 | 8.8726 | 14.95 | 0.000 |
| Age*Gender | 1 | 5.8739 | 5.8739 | 5.8739 | 9.90 | 0.002 |
| Error | 284 | 168.5344 | 168.5344 | 0.5934 | | |
| Total | 287 | 189.7579 | | | | |

From the above table, we found that P values for age, gender and their interaction are all less than 0.05, and hence both factors are significant. The main effect and interaction plots are shown in Figure 4. From these plots, we found that younger subjects (less than 30 yrs old) and female subjects took less time to respond. The young female groups took the least amount of reaction time while the old-male group took the longest time. Out of 288 total responses, only 18 errors were recorded (approx. 6%) which suggests that most of the time the subjects were cautious enough to make the correct responses.
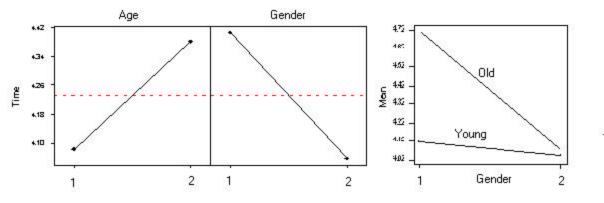


Figure 4. Main Effects and Interaction Plots of Age and Gender

## 4. Conclusions

In this project, we studied the factors that might affect the design and display of the variable message signs. Some factors like the foreground color, the background color, and the number of message lines were considered. In order to find improved VMS designs, all factors were experimented with in different combinations. Since the response time might also be affected by the age and gender of the subjects, different age and gender groups were selected. Experimental results were analyzed using MiniTAB and analysis of variance (ANOVA) procedures were employed to identify significant factors. Based on the analysis result, it found that the foreground color and the number of message lines significantly affect the response time. Examination of main effect plots and the ANOVA tables for the two models suggested that a better VMS could be composed using three-lined messages with yellow as the foreground color. The background color, black or blue, is unimportant. It also found that younger drivers showed better results and females proved to be more alert than males.

Variable message signs are serving as a critical element in the intelligent transportation system. They provide a direct communication between highway management system and human drivers. This research project is clearly one of the focus of ITS and linked with many other research project of ITS. The design of experiment approach employed in this project provides a reliable methodology that can help improve the quality and creditability of highway system management, and enhance the safety and comfort in driving. In general, it will promote a better understanding about the VMS in the human/ITS interface issues. In future studies, more factors like the inclusion of additional images, font size, contrast between background and foreground, viewing angle, etc. can be considered. Since the purpose of this study is to set up the foundation for a full-scale investigation, there is a tremendous opportunity to improve this investigation based on feedbacks given and experience learned. We anticipate this project to benefit the highway management system as a whole, stimulate more studies related to this topic, and help attain the mission of the URI Transportation Center.

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## Traffic Signal Device (TSD)

## 1. Introduction

The success of automation for intelligent transportation systems is ultimately contingent upon the interface between the users (humans) and the system (ITS). The issues of presenting information to the vehicle operator, the user interface in the vehicle and on highways, and the structure of signal presentation need to be investigated. A well-designed highway bulletin board will in general get better driver response. Those messages will serve the intended purposes to help the ITS system function effectively. In the second part of this report, the results of this project on the design of traffic control signal devices will be presented.

Intelligent transportation system (ITS) is no doubt the latest technology researched and implemented by transportation planners and managers to improve highway performance. The U.S. DOT as well as state DOT's not only continue building roads and bridges, they start to add technologies and systems to help use the facilities more effectively [4]. With new ITS systems in place, it is projected that highway capacity can be substantially increased with less resources. It is also anticipated that commuters' daily commuting time can be shortened. Nevertheless, the success of the intelligent transportation system implementation is ultimately contingent upon a good interface between the system and its user (drivers, vehicle operators).

In real life, traffic signals are the most frequently encountered type of traffic control and safety device. The circular-shaped traffic signal has long been adopted universally. Early study [12] has demonstrated that a modified traffic control light design can be more effective in terms of human response time than the signal currently being used. However, its effectiveness relative to the non-circular shaped traffic signal in terms of human response time and degree of accuracy need further investigating.

When additional features, such as shape, are added to the color feature on the signal lenses, early preliminary research results clearly indicate that human response time is shorter than for regular lenses. Various lens shape sizes, background brightness, and background noises should be considered. Its effects on driver's response time and accuracy should be analyzed. It is anticipated that these added features would not only help normal and responsible drivers, it should also be, in particular, helpful to color blind and negligent drivers. In this project, we designed and carried out experiments to include these factors. The experiments were conducted under a variety of environmental conditions.

Traffic signal devices (TSD) are employed by intelligent transportation systems (ITS) to provide signals and directions to drivers. TSD is the most widely used in our transportation systems to avoid accidents and keep traffic flow smooth. According to the signal provided by the traffic signal device, vehicle operators stop, go, or take other actions. The response time of first found traffic light or traffic light change is very important. It can cause or prevent a traffic accident. Naturally, the subject's response time is the major data collected and analyzed in this study. We conducted studies on traffic signal devices to try to reveal the possible relation of the

response time of human beings to traffic devices with the features of the traffic devices. We also studied the effects of age and gender through blocked-factorial experiment.

Almost all the currently used TSD are circular-shape with three colors (red, yellow and green). Though TSD is generally effective for keeping traffic flowing smoothly most of the time, TSD with added features may improve effectiveness in terms of response time.    Non-circular shaped TSD maybe very helpful to color blind and negligent drivers.

This project studied TSD's design and display issues using a design of experiment approach. It used a computer-generated environment to simulate a virtual driving experience. Traffic signal light is introduced in a random but controlled manner. Two groups of factors including controllable factors and blocking factors came into play in the experiment. Controllable factors will be considered in the Test Model. Blocking factors will be discussed in the Experimental Approach. Experimental layout is depicted in Figure5.
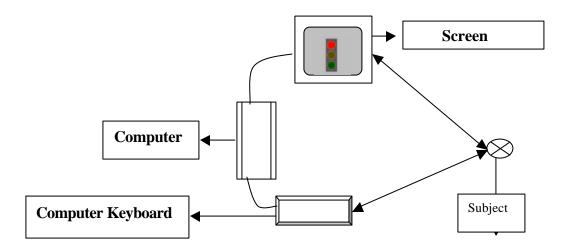


Figure 5. Layout of the Experiments

## 2. Test Model

In the experiments, controllable factors include shape (circle shape and non-circle shape), size (different distance will see different size of traffic light), driving conditions (day or night). The following controllable factors were considered in this study.

A). <u>Shape</u>:  The shape of the control sign is an important factor in the experiment design. Two types of signal shapes were considered and designed.  One type is the conventional circular-shaped which consists of three traffic signal lights and all three are circular in shape.  The second type is non-circular shaped consisting of a "red square" for the "stop light", a "yellow triangle"

for the "waiting buffer light", and a "green circle" for the "go light."  All lens shapes were carefully designed to be the same size in area as the conventional signs to eliminate possible bias in the results due to size differences in the signs (see A and B of Figure 6).
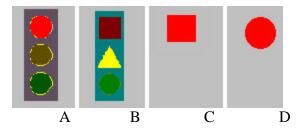


A          B          C          D

Figure 6. Conventional and Non-Circular Shaped TDS


B). Size: It was found that the actual traffic device in use in the area measured 13 inches by 39 inches.  The diameter of each traffic light is 12 inches.  Based on the distance from a vehicle to the traffic signal, the size of the TSD in the driver's view may vary.  From a further distance, the signal may appear smaller.  When the vehicle approaches closer to the light, it may appear larger in the operator's view.  As shown in  Figure 7 below, one can calculate the size of a traffic signal in a driver's view if the distance is known.  Accordingly, one can also calculate what the size of the signal should be in a simulated setting such as shown in Figure 5.  In this study, two sizes were simulated in the experiments.   One smaller size that is according to the resolving power of the eye  0'1'27", and one can get {arctg (23.25/10)-arctg (20/10)} which is equivalent the driver-light distance is 10 feet.   Then, signal size and driver-light distance may be computed accordingly.
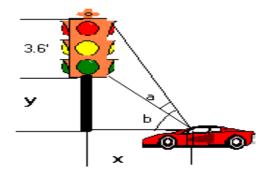


Figure 7.  Signal and Driver Position


C). Driving Condition:   The third factor considered in this study is the driving condition based on the time of day.  In the day time, all three traffic lights can be seen by the driver with only the one lighted shown in a brighter color and the other two not lighted. However, in the dark

evening or night, drivers normally can only see the lighted signal not the others.  In Figure 6, images A and B represent day time signals, and images C and D represent nigh time signals.

Considering the above three factors, needed images were designed for the experiments under all conditions.  Actually, in addition to the four images shown in Figure 6, the others are stand alone conventional circular yellow and green signs, and a yellow triangle and a green circle signal.  To simulate day time driving, image A in Figure 6 is used for conventional TSD but with only one of the signals shown bright color for stop, go and waiting buffer.  Similarly, image B as shown in Figure 6 is used for the special shaped TSD to take advantage of the added feature of TSD design.

## 3. Experimental Approach

Blocking factors considered here were the gender and age of drivers.  Initially, the factor "eye" which represents subjects with normal eyesight or colorblind were considered to be included in the experiments.  Unfortunately, it was extremely difficulty to identify colorblind people.  Through referral, the ones we identified either did not want to admit it or were unable to participate in the experiments. Hence "eye" factor was not included. According to the distribution of samples, we selected 50% female and the other half male. The age of samples was also divided into 50% young (30 years or younger) and 50% old.

Participants in the experiment were required to make proper responses to each stimulus and their response time and accuracy were recorded for analysis.  A series of blocked factorial experiments were conducted to fully investigate these factors and their interactions.

At the beginning of the experiment, a brief description was given to the participant on the objectives and the process of the project.  The operation of the keyboard and screen was explained to him/her.  They were instructed to enter basic information such as sex and age.  A few signals were generated to let the participants practice the operation of the simulation systems such that they could become familiar with the experimental process.  It was explained to them that various traffic signals would appear randomly, starting at a small size and zooming larger at certain speed.  This is to simulate the participants approaching the signal in a vehicle.

The speed of graph's zoom simulates a moving vehicle and was calculated as follows (see Figure 7).  Assuming the starting distance of TSD to vehicle is $\chi$ feet, then the eye angle of driver to watch TSD is $\{arctg(23.25/\chi)-arctg(20/\chi)\}$. We get the height of graph is $25*tg\{arctg(23.25/\chi)-arctg(20/\chi)\}$ inch. If the drive speed is 50 miles an hour or 73.32 feet per second [1], after s seconds, the height of graph is $25*tg\{ arctg(23.25 / (\chi-73.32*s) )- arctg(20 / (\chi-73.32*s))\}$.

The eight images representing eight different traffic lights were displayed to the participants. In addition, a replica of three was adopted for statistical analysis purpose.  This means that all together twenty-four images were generated randomly.  Twelve participants from different age and gender groups participated in the experiment. Each participant was required to view all twenty-four traffic light signals in random order.  During the test, the computer generated TSDs were projected onto a screen to simulate the drivers' approaching process.  Once the participant sees and recognizes the sign, he/she lits the space key as soon as possible.  The response time,

from when the traffic light appeared to when to the space key was hit was recorded. The accuracy of the response time is 1/100 second. All response times are recorded in the Access file and will later be transferred to another file for data analysis.

The Minitab software was used to perform statistical data analysis. For this project, a three-factor factorial design with two blocking factors was employed to identify the significant factors. The statistical analysis results are presented in the following section.

## 4. Analysis and Discussions

Based on the factors we set up our full model as fellow:

Y= Overall mean +D+S1+S2+A+G+D*S1+D*S2 +S1*S2+ D*S1*S2+ Error

where:  D is daylight,
S1 is shape,
S2 is size,
A is age and G is gender.

Minitab software was used to perform all statistical analysis, including the analysis of variance. During the analysis process, six outlier data were deleted for they are far out of range. It probably was caused by operational error. Table 3 shows the results of the analysis. According to the statistical analysis of the results, one can find that the P Values of Daylight, Daylight* Shape, age and gender are less than .05 hence all significantly affect the driver's response time. The single signal seen at nighttime or size doesn't significantly affect the driver's response time.

Table 3. Analysis of Variance for TDS

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|--------|-----|---------|---------|---------|------|-------|
| Daylight(D) | 1 | 0.12534 | 0.11125 | 0.11125 | 5.02 | 0.026 |
| Shape (S1) | 1 | 0.00789 | 0.01092 | 0.01092 | 0.49 | 0.483 |
| Size (S2) | 1 | 0.04534 | 0.05396 | 0.05396 | 2.43 | 0.120 |
| D*S1 | 1 | 0.08222 | 0.08630 | 0.08630 | 3.89 | 0.049 |
| D*S2 | 1 | 0.00843 | 0.00849 | 0.00849 | 0.38 | 0.537 |
| S1*S2 | 1 | 0.01061 | 0.01255 | 0.01255 | 0.57 | 0.452 |
| D*S1*S2 | 1 | 0.02172 | 0.02266 | 0.02266 | 1.02 | 0.313 |
| Age(A) | 1 | 0.14966 | 0.15444 | 0.15444 | 6.97 | 0.009 |
| Gender(G) | 1 | 0.17283 | 0.17283 | 0.17283 | 7.80 | 0.006 |
| Error | 272 | 6.02943 | 6.02943 | 0.02217 | | |
| Total | 281 | 6.65348 | | | | |

In addition, one can find that in the evening or at night, the response time is less than that of the daytime. Furthermore, the response time required for the modified traffic signals is less than for the regular circular-shape traffic light.

As for the blocking factors, age and gender show significance. The two–factor factorial analysis model can be described as follows:

Y= Overall mean +A+G+A*G+Error

where: A is Age and G is gender

The analysis results are shown in Table 4. From the table, one can see that the P values for age, gender and their interaction are all less than 0.05, and hence both the factors are significant. Another interesting finding is that the younger subjects (less than 30 years old) and female subjects took less time in response. The young female groups had the least amount of reaction time while the old-male group had the longest reaction time.

Table 4. Analysis of Variance for Age and Gender

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|--------|-----|----------|----------|--------|-------|-------|
| Age | 1 | 6.4770 | 6.4770 | 6.4770 | 10.91 | 0.001 |
| Gender | 1 | 8.8726 | 8.8726 | 8.8726 | 14.95 | 0.000 |
| Age*Gender | 1 | 5.8739 | 5.8739 | 5.8739 | 9.90 | 0.002 |
| Error | 284 | 168.5344 | 168.5344 | 0.5934 | | |
| Total | 287 | 189.7579 | | | | |

## 5. Conclusions

In this project, some important factors which might affect the driver's response time to traffic signals were studied. Based on the analysis, it was found that factors such as daylight and daylight*shape significantly affect the response rate. Though the modified shape doesn't significantly affect the response time, it significantly affects the response time in the night. Examination of main effect plots and the ANOVA tables for the two models suggested that modified traffic light can improve the response time. It also found that younger drivers showed better results and females proved to be more alert than males.

The design of experiment approach employed in this project provides a reliable methodology that can help improve the quality and creditability of highway system management, and enhance the safety and comfort in driving. In general, it will promote a better understanding of the TSD. We anticipate this project to benefit the highway management system as a whole, stimulate more studies related to this topic, and help attain the mission of the URI Transportation Center.

Unfortunately, not enough people who are color-blind or color weak could be identified to participate in the experiment. Therefore, no conclusions can be drawn in this area for lack of data. However, the two participants who are colorblind have expressed that the special shaped

signal is a very helpful feature for them.  Most importantly, this study demonstrated that the non-circular traffic signal design could even be helpful to normal driver during night or evening. Shape in addition to color can contribute to less driver response time.

In future studies, we propose to spend more effort to identify more colorblind drivers to participate in the experiment.  Also, more factors such as the inclusion of additional images, background and different viewing angle, etc. can be considered.  Since the purpose of this preliminary study is not to draw conclusions, but to set up the foundation for a full-scale investigation, there is a tremendous opportunity to improve this investigation based on feed back given and experiences learned.  It is believed that future studies could benefit much from this study to achieve their objectives.

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