Evaluation of Vehicle Mounted Attenuator (VMA) Markings Using a Driving Simulator for Mobile Work Zones for Different Times of the Day

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ABSTRACT
Four Vehicle Mounted Attenuators (VMAs) used by the Departments of Transportation (DOTs) in mobile work zones were evaluated for the effectiveness of striping pattern and color combination for different times of day using subjects in a driving simulator. Twenty-four subjects, male and female, participated in the driving simulator experiment in which they drove through virtual highway work zones. Lane change distance was used as the variable to determine the driver reaction to the four VMA markings during day, dusk and night conditions. The result indicated that the red and white checkered board pattern is more effective during the day and dusk conditions whereas orange and white vertical striped pattern is more effective during night conditions. The finding from this objective evaluation was consistent with the result from the subjective evaluation where the subjects were asked to rate several features of each VMA markings including visibility, ability to cause drivers to move out of the closed lane, effectiveness of color combination, ability to grab attention, color contrast, and most preferred pattern.

Key words: Vehicle Mounted Attenuator (VMA), driving simulator, work zone, driver behavior, Traffic Control Devices (TCD)

1. INTRODUCTION
VMA'S are crash cushions mounted at back of construction trucks. They have been used successfully for many years in reducing the severity of rear-end collision impacts in work zones. The Manual on Uniform Traffic Control Devices (MUTCD) (1) and American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide (2) contain general guidelines on the specifications of VMAs. However neither of these references include recommendations for striping patterns and/or colors for these devices. The existing design incorporates predominant colors yellow or orange and striping pattern is the inverted ‘V’ design on a white or black background, but other options have also been used. Some states have experimented with vertical striping and/or a checkerboard pattern using red and white colors. Figure 1 presents these striping patterns and colors combinations.

This study evaluates public perception of the effectiveness of various striping patterns and color combinations for VMA’s.

The methodology to evaluate VMAs comprises of using subjects for both objective evaluation of driving behavior and subjective evaluation through an online survey.

![Lime green and black inverted ‘V’](image1)
![Red and white checker board](image2)
![Yellow and black inverted ‘V’](image3)
![Orange and white vertical striped](image4)

Figure 1. Vehicle Mounted Attenuator (VMA) Patterns

The results of this study would be beneficial to state DOTs in selecting the most effective colors and striping patterns for VMAs, thereby improving the safety and operations in work zones especially on high speed, high volume roadways. To evaluate driver perception and behavior, the following approaches can be adopted: field study, laboratory study, i.e. using a driving simulator, and traffic modeling. Field data collection is expensive time consuming and only a limited number of traffic control devices (TCDs) can be tested. Microscopic traffic simulation models do not incorporate detailed driver behavior such as vision, hearing, identification distance, etc. and therefore, cannot be used for evaluating color and pattern designs of TCDs. Driving simulator studies are advantageous compared to field testing as it allows the study of risky driving situations that may not be possible to replicate during field tests. Driving simulator studies can be efficient and low-cost, and specific data can be collected. Driving simulator studies are efficient as they can be repeated and different scenarios can also be simulated. Additionally, subjects can be tested in a laboratory under safe conditions and their reaction can be observed using multiple TCDs, and researchers are not exposed to unsafe road conditions. Work zone safety is a high
priority issue for transportation agencies and the construction industry because of continuing increase in work zone fatalities. Fatalities in work zones have increased in the U.S. by nearly 41% between 1995 and 2004, from 665 to 936 (3). Additionally, safety must be improved with the intention of reducing transportation fatalities. There are two approaches: the first approach focuses on passive safety, i.e., to protect the vehicle occupants in the event of a road crash, and the second approach focuses on preventing crashes from occurring. The present study addresses the latter approach.

2. LITERATURE REVIEW
Construction and maintenance work on streets and highways is unsafe, even more so on high speed highways. The focus on safety in construction operations has received a lot of attention in the last several years. Efforts to improve safety have increased substantially after a fatal accident in 1975 in Washington D.C. (4). However, there is an increasing trend in rate of crashes, probably attributing to increase in highway construction activities. Preventing crashes and reducing the severity of crashes require methods aimed to anticipate the driver’s reactions to a specific situation.

A field study carried out on the best practice of VMA in New Zealand (5) reported that placing an advance warning system 1312 feet before a VMA performed better than any other practice resulting in 27.7% fewer drivers not reacting until the last 984 feet. Recognition distances increased at night when the traffic volumes were lower as compared to recognition distances during the day with higher traffic volumes.

Research on the effectiveness of VMAs indicated that they save about $23,000 per crash (3) and reduce damage to the maintenance truck. The study showed that the injury rate is higher for maintenance vehicles that are not equipped with VMAs. Additionally, the cost of crashes where no VMAs were used was considerably higher than those when a VMA was impacted.

A study that focuses on traffic control devices was conducted by the Texas DOT (6) to introduce innovative features to improve work zone operations. The techniques used included a survey of drivers, input from maintenance crews, and recorded citizen band radio conversations. To evaluate the visibility of various colors of worker garments like fluorescent orange and fluorescent yellow-green with and without mesh, luminance values were recorded from a distance of 500 feet away from the work zone.

Other studies have been the comprised of different colors in work zones. A study (7) evaluated the presence of fluorescent yellow-green background with an orange color sign and found that it improved the contrast between the orange color of the sign and the orange color of the DOT truck. It conducted the drivers’ survey on the visibility of the sign with and without the fluorescent background. Additionally, traffic volumes on the left and right lanes were collected using a trailer. Analysis of the collected data revealed that there was a significant decrease in traffic volume in the lane where the truck was present after using the traffic sign with fluorescent yellow-green background. A similar study (8) was conducted to test the visibility of orange, fluorescent orange, yellow, white and red colors. Driver recognition distances were collected. From the analysis of data, fluorescent colors were proved to have higher color perception accuracy and recognition distances during day time but not during the night time. A study (9) suggested that fluorescent traffic signs have no added advantage compared to non-fluorescent signs and it provided the proof by conducting an eye-tracking sensitivity measuring experiment.

No specific guidelines were found from the existing literature for selecting colors or striping patterns for use with VMAs. This research project described in the present paper is a first step towards evaluating the public perception of VMA patterns used by state DOTs in mobile work zones.

3. METHODOLOGY
To evaluate the driver perception and behavior during different times of day, a driving simulator was used and a survey of state DOTs on their use of VMAs was conducted. The driving simulator study involved both subjective and objective evaluation of the VMAs for day time, dusk and also night time driving conditions. This section describes the experimental setup, the methodology used in performing the evaluations, and the details of the questionnaires used.

3.1. Missouri S&T Driving Simulator
A driving simulator at Missouri University of Science and Technology used for this study, shown in Figure 2, consists of a mockup passenger car, three LCD projectors, a projection screen, and three networked computers with Ethernet connection. The mockup car is a Ford Ranger pick-up truck with a speedometer and other related components. Optical and rotary sensors are used to measure the steering operation, speed, acceleration/deceleration, and braking. The screen has an arc width of 25 feet and a height of 6.6 feet.

Figure 2. Missouri S&T Driving Simulator

For the driving simulator, a work zone environment was developed according to the MUTCD specifications for a partial
lane closure on a divided highway. As per these guidelines, different sign spacings, taper lengths, and optional buffer length channelizer spacings for different speed limits, sign heights, and work zone lengths should be used for urban and rural highways. Also as per these guidelines, the minimum distance between the protective vehicle and the work vehicle should be 150 feet.

3.2. Work Zone Setup and Configuration

Three work zone scenarios, each resembling a 4-lane rural highway divided by a median during day time, dusk and night time conditions, respectively were developed. Each of these scenarios consisted of four consecutive work zones. The highway length was approximately eight miles in total length. The first work zone started after 1.5 miles of highway, each 0.5 miles in length, and 1.5 miles apart. After the last work zone, 0.1 miles was provided before the scenario ended. The construction zone was set up with traffic control devices and three construction vehicles on the closed lane with 170 foot distance between the vehicles. Each of these construction vehicles was equipped with a VMA striping pattern and color combination at the back of the truck.

The work zone configuration was developed according to the specifications of the MUTCD, and consultation with the Missouri Department of Transportation (MoDOT). In order to replicate the real environment, traffic control devices such as cones, barriers and traffic signs were placed on the highway. The first 1.5 miles of the freeway had a speed limit of 70 mph, which was conveyed by a regulatory speed limit sign at the start of the section. Traffic signs were placed along the right side of the roadway as shown in Figure 3 at a spacing of 500 feet starting with a ‘Road Work Ahead’ warning sign located 1.5 miles before the start of the work zone. The remaining four signs were placed in the following order: ‘Speed Limit 45 mph’, ‘Right Lane Closed Ahead’, ‘Speed Limit 45 mph’ and then again ‘Right Lane Closed Ahead’. The construction zone was 1300 feet in length with barriers on both sides of the work zone, i.e., on the shoulder and the lane marking. The construction zone consisted of a shadow vehicle with a VMA, a work vehicle with a VMA, and a construction vehicle.

3.3. Participants

Participants in this study were undergraduate students enrolled in a Transportation Engineering course in the fall 2008 semester at Missouri S&T. Thirty-nine students volunteered to participate in the experiment. In the first step, the subjects were screened using a questionnaire which had questions related to their driving experience, health, and vision. The subjects who satisfied the requirements of the experiment were accepted for participation. Two subjects who did not have a driver’s license were not allowed to participate in the experiment, the remaining 37 subjects met the requirements, but only 24 subjects participated in the experiment. The participants were comprised of 21 males and 2 females with an average age of 22 years. All 24 subjects were considered for the subjective evaluation; whereas for the objective evaluation, data from 23 subjects was analyzed while discarding the data of one of the subjects.

Out of the 24 subjects who participated in the study, 19 have been driving between 5 and 15 yrs, and 5 have been driving between 1 and 5 years. Out of the 24 participants who drove frequently during daytime, 21 of them drove daily during dusk and nighttime. All the participants had previously experienced VMAs on highway work zones.

3.4. Experiment

After the pre-screening questionnaire was completed by the subjects, experiments were conducted using the driving simulator. To study driver behavior, subjects were first given a brief introduction about the experiment. To familiarize the subjects with the driving simulator, the environment and the instructions, subjects first drove through a trial environment similar to the experiment. Typically, each participant drove for about eight minutes during the trial run. After the trial run, each subject drove through the three scenarios day time, dusk and night. The scenarios and the four work zones setups within each time scenario were arranged randomly. The driving simulation runs were recorded and the driving data from the various sensors was collected for analysis.

3.5. Pre- and Post Experiment Questionnaire

On the day of the driving experiment, before participating in the driving simulator, each subject was asked to fill a Pre-Experiment Questionnaire related to the experiment requirements such as no consumption of alcohol in the past 24 hours, to ensure that the drivers were alert and not under the influence of alcohol. None of the subjects indicated that they had consumed alcohol in the past 24 hours.

After the experiment, each subject was asked to complete a Post-Experiment Questionnaire. The Post-Experiment Questionnaire served as the basis for the subjective evaluation of the VMA colors and the striping patterns based on the subject’s driving experience using the simulator. Subjects were asked to rate the design patterns based on different criteria, which included visibility, ability to capture attention, color contrast, and ability of the driver to move out of the closed lane.

Questions were also related to rating of each color combination based on its recognition in the construction zone and also rating of each color combination based on its discernability. Subjects were also asked to provide their input about the most liked and least liked features of individual striping patterns.
4. Results and Discussion
4.1 Objective Evaluation
To determine the relative effectiveness of a VMA pattern, lane change distance was used. Lane change distance (LCD) was selected because most of the DOTs reported using it from the DOT survey (1), in addition to the crash data, as the measure to determine the effectiveness of VMAs in work zones. During the driving simulation experiments, vehicle positions and speeds were measured at sub-second intervals for all the subjects. Table 1 summarizes the results of the LCD measured for the different VMA markings during daytime, dusk and nighttime driving conditions.

Lane change distance was measured as the distance from the point where the driver starts to steer left to achieve maximum steering needed to move out of the closed lane before the start of the construction zone. The assumption made is that the driver’s response is visual outlook of the VMA pattern.

Daytime conditions
The relationship between the four patterns during day conditions is presented in Figure 4 which illustrates the differences in their performances. As shown in Figure 4, 4.3% of the drivers did not recognize the construction zone until they were 200-300 feet from the VMA with the lime green and black inverted ‘V’ pattern. Also, 50% of the drivers reacted to the red and white checkered board pattern and the orange and white vertical striped pattern at a greater distance compared to the lime green and black inverted ‘V’ pattern and the yellow and black inverted ‘V’ pattern. It can, therefore, be, observed that the driver’s performance for the VMA with the orange and white vertical striped pattern and the red and white checkered board pattern were better than the lime green and black inverted ‘V’ pattern and the yellow and black inverted ‘V’ pattern for day conditions.

<table>
<thead>
<tr>
<th>Type of VMA patterns</th>
<th>Daytime (feet)</th>
<th>Dusk (feet)</th>
<th>Nighttime (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime green and black inverted ‘V’</td>
<td>897</td>
<td>1018</td>
<td>568</td>
</tr>
<tr>
<td>Red and white checker board</td>
<td>1046</td>
<td>1155</td>
<td>603</td>
</tr>
<tr>
<td>Yellow and black inverted ‘V’</td>
<td>829</td>
<td>934</td>
<td>597</td>
</tr>
<tr>
<td>Orange and white vertical striped</td>
<td>1051</td>
<td>1050</td>
<td>632</td>
</tr>
</tbody>
</table>
Also from Table 1, an average lane change distance of 1046 feet and 1051 feet from the VMA was observed for the red and white checkered board pattern and the orange and white vertical striped pattern respectively, whereas a distance of 829 feet was observed for the yellow and black inverted ‘V’ pattern. The data indicated that drivers on average made a lane change farthest from the work zone when the orange and white vertical striped pattern and red and white checkered board pattern were used on a VMA. Also, the yellow and black inverted ‘V’ pattern was most ineffective during day condition with the least lane change distance.

The orange and white vertical striped pattern and the red and white checkered board pattern are therefore effective patterns to be used at the rear of a VMA in day conditions.

Dusk Conditions

The driver’s performance for dusk conditions for the four patterns considered, all of the drivers reacted to all four patterns at a distance of more than 400 feet. This can be attributed to better color contrast with the surroundings which increases the visibility of the patterns during dusk conditions. As shown in Figure 5, 50% of the drivers reacted to the red and white checkered board pattern and the orange and white vertical striped pattern at greater distance compared to the lime green and black inverted ‘V’ pattern and the yellow and black inverted ‘V’ pattern. Similar to the day conditions, it can be observed that the driver’s performance for the VMA with the orange and white vertical striped pattern and the red and white checkered board pattern were better than the lime green and black inverted ‘V’ pattern and the yellow and black inverted ‘V’ pattern during dusk conditions.

From Table 1, the highest average LCD of 1155 feet from the VMA was observed for the red and white checkered board pattern and an average LCD of 1018 feet and 1050 feet for the lime green and black inverted ‘V’ pattern and the orange and white vertical striped pattern respectively. The driver’s reaction for the VMA with yellow and black inverted ‘V’ pattern was 934 feet which is the least among the four patterns during dusk conditions. Also, it is interesting to note that the LCD for dusk conditions is much higher than the LCD for day conditions which might be because of better color contrast as explained earlier.

The red and white checkered board pattern is therefore effective pattern to be used at the rear of a VMA in dusk conditions.

Night Time Conditions

The driver’s performance in the night conditions for the four patterns considered for the present study is illustrated in Figure 6. It was observed that 6 (26%) drivers reacted between 400 – 500 feet from the VMA with lime green and black inverted ‘V’ pattern, compared to 4 (17.4%) for the remaining VMA’s with the other three patterns studied. Also, 50% of the drivers reacted to the orange and white vertical striped pattern at a greater distance compared to the other patterns.

From Table 1, highest average LCD of 632 feet from the VMA was observed for the orange and white vertical striped pattern and an average LCD of 603 feet and 597 feet for the red and white checkered board pattern and the yellow and black inverted ‘V’ pattern respectively. The driver’s reaction for the VMA with lime green and black inverted ‘V’ pattern was the least with 568 feet among the four patterns during night conditions.

The orange and white vertical striped pattern was found to be the most effective pattern, whereas the lime green and black inverted ‘V’ pattern was the most ineffective pattern among the four patterns during night conditions.

![Figure 4. Cumulative Frequency curves for day conditions](image-url)
Figure 5. Cumulative Frequency curves for Dusk conditions

Figure 6. Cumulative Frequency curves for Night conditions
4.2 Subjective Evaluation

To complement the driving simulator experiment, the subjects were asked to complete a Post-Experiment Questionnaire for subjective evaluation of the VMA color combinations and their striped patterns. All the 24 participants participated in the subjective evaluation. The criteria used were visibility, ability to cause drivers to move out of the closed lane, effectiveness of color combination, ability to grab attention, color contrast, and most preferred pattern. The participants were asked to rate the four VMAs for each of the criteria and their responses were analyzed. For each criterion, the percentage of the sum of rating scores (1 to 4 given by each subject) for a particular pattern to the total sum of rating scores for all the four patterns were calculated. Table 2 presents the percentage data obtained for the four patterns based on the various criteria. Note that the percentages for the four patterns for each criterion (i.e. the four numbers in each row) add up to 100.

Table 2. Percentages of scores for the four patterns based on different criteria for day conditions

<table>
<thead>
<tr>
<th>Criterion/Type of VMA pattern</th>
<th>Lime green and black inverted ‘V’ pattern</th>
<th>Red and white checkerboard pattern</th>
<th>Yellow and black inverted ‘V’ pattern</th>
<th>Orange and white vertical striped pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause drivers to move out of the closed lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effectiveness of color combination in recognizing construction zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grabbing the attention of drivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color contrast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The reasons for choosing the various criteria in Table 2 are self-evident. For example, visibility was used as a criterion because it is one of the most important features of a VMA pattern, especially during different environmental and weather conditions and different times of the day. A pattern which is easily visible from a distance would make the driver aware of construction activity downstream and alert the driver, thus reducing the risk of a crash. The color contrast was used as a criterion in order that the study can propose the best possible color combination to contrast between the VMA colors and the construction equipment.

The lime green and black inverted ‘V’ pattern and red and white checkerboard pattern were reported to be better in all criteria compared to the other two patterns during day dusk and nighttime conditions.

Among 24 subjects, 11 (46%) preferred the red and white checkerboard pattern, 5 (21%) preferred the lime green and black inverted ‘V’ pattern and orange and white vertical striped pattern, 3 (12%) preferred the yellow and black inverted ‘V’ pattern. Thus, the red and white checkerboard pattern is the most preferred pattern among the four patterns for day, dusk and night conditions. The orange and white vertical striped pattern and lime green and black inverted ‘V’ pattern are the second most preferred patterns among the four patterns.

The post-experiment survey in conjunction with the driving simulator study revealed interesting results. In our initial discussion with MODOT, before the driving simulator study was conducted, it was conjectured that the inverted ‘V’ design provides the direction of lane change and suggests the driver to move out of the closed lane to an open lane. It was further conjectured that the checkerboard pattern indicates that the lane is closed but does not indicate the direction of lane change. However, when the subjects were surveyed regarding the information provided by the inverted ‘V’ pattern, 16 (67%) subjects did not perceive that the inverted ‘V’ design signifies the direction of lane change. On the checkerboard pattern, 15 (62%) subjects stated that it indicates reduction in speed, three (22%) stated that it indicates coming to a stop, and 4 (16%) stated that it does not signify any message.

Table 3. Percentages of scores for the four patterns based on different criteria dusk Time

<table>
<thead>
<tr>
<th>Criterion/Type of VMA pattern</th>
<th>Lime green and black inverted ‘V’ pattern</th>
<th>Red and white checkerboard pattern</th>
<th>Yellow and black inverted ‘V’ pattern</th>
<th>Orange and white vertical striped pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause drivers to move out of the closed lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effectiveness of color combination in recognizing construction zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grabbing the attention of drivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color contrast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7
Table 4. Percentages of scores for the four patterns based on different criteria night Time

<table>
<thead>
<tr>
<th>Criterion/Type of VMA pattern</th>
<th>Lime green and black inverted ‘V’ pattern</th>
<th>Red and white checkerboard pattern</th>
<th>Yellow and black inverted ‘V’ pattern</th>
<th>Orange and white vertical striped pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>26</td>
<td>29</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Causing drivers to move out of the closed lane</td>
<td>27</td>
<td>28</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Effectiveness of color combination in recognizing construction zone</td>
<td>29</td>
<td>24</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>Grabbing the attention of drivers</td>
<td>27</td>
<td>25</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Color contrast</td>
<td>25</td>
<td>27</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

Subjects were also followed to indicate the most favored features of each pattern. Table 3 provides the summary of their responses for the four patterns. It is interesting to see that pattern design was more liked for the orange and white vertical striped pattern and the red and white checkerboard pattern. Color combination is the most liked feature for the lime green and black inverted ‘V’ pattern and orange white vertical striped pattern, while color contrast is similarly liked for the lime green & black inverted ‘V’ pattern and red and white checkerboard pattern.

Table 5. Most liked features of the patterns in terms of the percentage of total score

<table>
<thead>
<tr>
<th>Patterns</th>
<th>Pattern Design</th>
<th>Color Combination</th>
<th>Color Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime green and black inverted ‘V’ pattern</td>
<td>30</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Red and white checkerboard pattern</td>
<td>39</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Yellow and black inverted ‘V’ pattern</td>
<td>31</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>Orange and white vertical striped pattern</td>
<td>39</td>
<td>33</td>
<td>28</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS AND RECOMMENDATIONS

This paper presents a driving simulator study to evaluate the striping patterns and color combinations used with the Vehicle Mounted Attenuators (VMA) in mobile work zones. It was found from the objective evaluation, lane change distance used as the evaluation criteria, that the red and white checkered board pattern is the most effective among the four patterns during the day and dusk conditions, whereas the orange and white vertical striped pattern is more effective during night time conditions. This finding was confirmed by the subjective evaluations that surveyed the subjects of the driving simulator experiment and were asked them to rate each of the four patterns in terms of visibility, ability to cause drivers to move out of the closed lane, effectiveness of color combination, ability to grab attention, and color contrast. The subjective evaluation also indicated that the red and white checkered board pattern as the most preferred pattern. In the next phase of this study, more subjects from all age groups will be included in the experiment.

6. ACKNOWLEDGEMENTS

We acknowledge the support of the FHWA Pooled Fund Study at the Iowa State University, ISC and the Regional UTC.

7. REFERENCES


Accomplishments (March, 2008 – March 2009)

- DOTs were surveyed on the VMA practice in work zones. The DOT survey contacted 50 states, out of which 30 responded. The result indicated that the yellow and black inverted ‘V’ pattern is the most widely used as it is provided by most VMA suppliers.
- Four Vehicle Mounted Attenuators (VMAs) used by the Departments of Transportation (DOTs) in mobile work zones were evaluated for the effectiveness of striping pattern and color combination using subjects in a driving simulator for daytime.
- Twenty-three subjects, male and female, participated in the driving simulator experiment in which they drove through virtual highway work zones. Lane change distance and speed reduction identification distance were used as the variables to analyze the driving behavior of subjects. The result indicated that the yellow and black inverted ‘V’ pattern and the orange and white vertical striped pattern are more effective than the lime green and black inverted ‘V’ pattern and the red and white checkerboard pattern. The finding from this objective evaluation was consistent with the result from the subjective evaluation where the subjects were asked to rate several features of each VMA pattern including visibility, ability to cause drivers to move out of the closed lane, effectiveness of color combination, ability to grab attention, color contrast, and most preferred pattern.
