Evaluation of Technology-Enhanced Flagger Devices: Focus Group and Survey Studies in Kansas

Chen Fei See  
Transportation Research Institute  
University of Kansas  
2160 Learned Hall  
1530 West 15th Street  
Lawrence, Kansas 66045-7609  
cfsee@ku.edu

Steven D. Schrock  
Department of Civil, Environmental, and Architectural Engineering  
University of Kansas  
2159B Learned Hall  
1530 West 15th Street  
Lawrence, Kansas 66045-7609  
schrock@ku.edu

Wai Kiong “Oswald” Chong  
Department of Civil, Environmental, and Architectural Engineering  
University of Kansas  
2134C Learned Hall  
1530 West 15th Street  
Lawrence, Kansas 66045-7609  
oswald@ku.edu

Yong Bai  
Department of Civil, Environmental, and Architectural Engineering  
University of Kansas  
2135B Learned Hall  
1530 West 15th Street  
Lawrence, Kansas 66045-7609  
ybai@ku.edu

Jamila Saadi  
Department of Civil, Environmental, and Architectural Engineering  
University of Kansas  
2160 Learned Hall  
1530 West 15th Street  
Lawrence, Kansas 66045-7609  
tunis123@ku.edu

ABSTRACT

Flagger-controlled work zones are often in place for only a short duration, so adding protection beyond the minimum guidance is rarely done. Several vendors have begun marketing devices equipped with various technologies. While a wide variety of studies have been undertaken to evaluate the technology-enhanced flagger devices, there has been little effort to examine these devices on the basis of perceived usefulness to field personnel and understanding by motorists. This study was aimed at obtaining responses from field personnel regarding the perceived usefulness of these devices, while synthesizing the effects of these devices based on flagger focus groups and driver survey responses.

The focus groups results revealed that weight of devices, conspicuity of flaggers, and awareness of drivers were among the influential criteria for field personnel to opt for a flashing STOP/SLOW paddle. Additionally, 72% of participants agreed that 4 in. red/amber light appeared to have best potential for visibility gains and versatility of applications. From the surveys, only 28% of drivers indicated that they saw the STOP sign or flagger in work zones. When asked about the displayed STOP sign, 74% of in favor drivers stated that it commanded their attention or fulfilled a need, whereas 86% of those not in favor indicated that they either did not see it or thought it was hard to see. More than half of the surveyed drivers did not think that the flashing paddles indicated a more important situation. Only 26% of drivers stated that they drove differently because of the flashing paddles.

Key words: flaggers—focus groups—temporary traffic control—work zone safety
INTRODUCTION

In the United States, over 1,000 fatalities occur every year in the construction sector (Bureau of Labor Statistics Undated [a]). In 2007 alone, approximately 94 of these fatalities were highway-, street-, and bridge construction-related, whereas 30% (or 28 fatalities) of these incidents were due to construction workers struck by vehicle (Bureau of Labor Statistics Undated [b]). Specifically, highway maintenance workers consisted of approximately 13% of these fatalities in the year 2007 and 50% of these fatalities were reported as workers struck by vehicles (Bureau of Labor Statistics Undated [b]). Previous studies revealed that driver inattention and excessive speed are among the contributing factors most frequently reported for work zone crashes (Chambless et al. 2002; Mohan and Gautam 2002).

In a flagger-controlled work zone, the flagger is the key to effective traffic control, and thus, his/her visibility and conspicuity are critical in keeping motorists and workers safe. Nonetheless, these short-duration work zones often utilize fewer traffic control measures than other work zones, so adding signing or positive protection beyond the minimum guidance directed by the Manual on Uniform Traffic Control Devices is rarely done. Based on prior findings, approximately 6% of the examined fatalities from years 1980 to 1992 were either flaggers or surveyors (Ore and Fosbroke 1997). In an effort to increase flaggers’ visibility and conspicuity, several vendors have begun marketing STOP/SLOW paddles, personal protective equipment, and other ancillary devices equipped with various technologies typically including embedded LED lighting.

Many studies document the usability, advantages, and disadvantages of various new devices or technology as soon as they are available in the market (Trout and Ullman 1997; Fontaine and Hawkins 2001). It is important to understand the functionality and feasibility of these devices and how they will improve the safety of workers in the work place. Devices or technologies such as radar drones, intrusion alarms, and flashing LED lights have been receiving the attention of the industry for over a decade. Nevertheless, the effectiveness of these technology-enhanced devices tends to be evaluated on the basis of observational tests, speed tests, or even their availability. While the effectiveness of these devices is important, understanding of motorists and the underlying reasons for specific precaution measures, such as slowing down or stopping earlier, are also critical. There are many factors that can influence the drivers to decrease their speeds or take precaution measures. However, only the drivers themselves can explain what was actually happening. Aimed at obtaining the true effectiveness of each selected technology-enhanced flagger device, this study used the responses from field personnel regarding the perceived usefulness and workability of these devices, while synthesizing the effects of these technology-enhanced devices based on driver survey responses.

LITERATURE REVIEW

Morena (2002) evaluated five different flashing STOP/SLOW paddles for a group of federal, state, and local highway workers in Wisconsin. Specifically, these STOP/SLOW paddles, including a halogen lights paddle, were tested in bright sunlight at 285 feet from the observers. The results of the tests revealed that only the halogen lights paddle commanded the attention of drivers from as far as 285 feet or greater. Additionally, a contractor from Princeton, Wisconsin, commented that these flashing STOP/SLOW paddles should be used in all areas where there is high traffic volume and low visibility. The interviewee added these highly visible paddles can help to increase the conspicuity of flaggers, while improving the safety of workers in work zones. The only drawback observed in these flashing paddles was the cost. The author revealed that the extra cost of these flashing STOP/SLOW paddles was priced from $175 to as high as $530 for the halogen paddle. In essence, the question regarding the worthiness of the flashing STOP/SLOW paddles investment lay upon individual work needs and site conditions.
In recent years, many new techniques or devices were proposed for implementation to improve flagger safety in work zones. In Texas, Trout and Ullman evaluated ten new devices or technologies to improve worker safety in work zones: opposing traffic lane dividers, drum wraps, direction indicator barriers, radar drones, water-filled barriers, blinking reflectors, portable curbs, portable rumble strips, intrusion alarms, and queue length detectors. In a newer report, Fontaine and Hawkins cataloged and added several devices that produced positive impacts in short-term work zones: fluorescent yellow-green worker vests and hard hat covers, portable variable message signs, speed display trailers, fluorescent orange signs, radar-activated flagger paddles, radar drones, retroreflective magnetic strips for work vehicles, portable rumble strips, and worker strobe lights. In both of these reports, radar drones repeatedly appeared as the device that had the potential to improve work zone traffic control. This device helped decrease vehicle speeds by emitting a K-band radar signal, which can be detected up to a mile through the radar detectors. The radar drones can incessantly emit radar signals by powering it through the car cigarette lighter until turned off. However, no significant reductions in average speeds of the approaching and traveling vehicles were found in the study. Fontaine and Hawkins added that radar drones may be suitable for rural work zones as it provides limited benefits in speed reductions.

The radar-activated flagger paddle was another device that was found to be useful in improving flaggers’ safety. This prototype device was developed and modified exclusively by the Texas Transportation Institute (TTI). The paddle was comprised of a plastic STOP sign that was modified by incorporating detectors and LEDs in the sign face areas to detect vehicles traveling above the preset speed range. The device was observed to have a few usability problems. First, the unit was top-heavy due to the location of the battery within the sign face. Second, the wiring of the radar that was exposed to the elements was found to be very fragile. The research concluded with recommendations to further improve and examine the effectiveness of this device.

The intrusion alarm was another device that was proposed by Trout and Ullman to improve work zone safety. This device was intended to detect vehicles that breached into the buffer area in a work zone. The alarm of this device will sound almost instantly to warn construction crews regarding the potential danger if intruders were detected. There are three types of intrusion alarms available in the market: microwave transmissions, infrared light beams, and pneumatic tubes. The microwave and infrared models can be set up simply by mounting them on the traffic cones or traffic drums, whereas the pneumatic tube systems require the tubes to lie flat on the roadway. All three intrusion alarm models had not been receiving positive reviews; many issues regarding the functions and workability of this device were revealed. False alarms were the major concerns that were repeatedly reported in all three models. The alarm system of the infrared unit was found to be overly sensitive and resulted in many false alarms, whereas the pneumatic tube systems were found to be ineffective in warning the workers. Similar issues were observed in the microwave models, where false alarms could be triggered by movement of the drums, rain, or even dust. The ease of use for all three models was rated as low by various agencies as the required setup time was longer than anticipated, and on top of that, these devices were neither lasting nor reliable. However, researchers believe that there may be still room for intrusion alarms to improve by providing training programs to construction workers regarding the pros and cons of each device under certain conditions.

**FOCUS GROUP EVALUATIONS**

Focus group meetings were conducted in order to gain a better understanding of the views and opinions of the highway contractor flaggers, department of transportation maintenance personnel, and emergency services personnel, such as police and firefighters, regarding the current state of technology available for flaggers, any experiences with previous technologies that they may have tried, and the innovations that they found helpful in promoting increased driver compliance and/or worker safety. Focus groups have advantages over other survey methods in that they are able to cover a topic in more depth, and due to the
open-ended nature of the discussions, the potential exists for innovative concepts to be suggested by participants (University of Texas Undated).

Three focus groups were conducted in Kansas in order to provide a diverse group of participants. Focus groups were conducted in LRM Industries, Inc., Lawrence Fire Department, and Douglas County Public Works. Four techniques were used during the focus group discussions:

- **Listing.** Participants in each focus group were asked to list the training and equipment they received or used in order to perform in temporary traffic control work zones.
- **Evaluating.** After each participant listed the equipment they used, participants evaluated eight different technology-enhanced flagger devices and three standard traffic control equipment.
- **Ranking.** The participants were also asked to rank the equipment in their category based on the usability, conspicuity, durability, preference, and importance. The ranking was to assess the relative preference and importance of the equipment.
- **Building desirable technology-enhanced flagger device.** At the end of each focus group, participants were asked to create a flagger device that they think would be helpful in assisting the flaggers in flagging operations.

As the final step of the focus group discussions, participants were guided to answer each selected question before an open-ended discussion. This measure was intended to obtain consistency in the data, while providing participants an opportunity to relate their duties to the technology-enhanced devices before any discussions. Additionally, the measure also helped minimize any biases that may arise during the discussions. During each questionnaire session, focus group participants were asked to rank the pros and cons as well as the perceived usability, conspicuity, durability, and preferred technology-enhanced flagger device. This part served as the important data collection section, which will be used to compare against the results of the motorist surveys.

The panel evaluation sessions comprised of four parts. The first part was an orientation to understand participant backgrounds, responsibilities, and devices that they have while performing the flagging operations. The second, third, and fourth part consisted of the following:

- Important criteria of technology-enhanced flagger devices
- Perceived usefulness and effectiveness of the technology-enhanced flagger devices
- Flagger device-creating sessions

Once the participants had undergone a brief orientation, the first question that was asked in the focus group session was to rank the pros and cons of the flashing STOP/SLOW paddle as opposed to a standard paddle on a scale from most important of 1 to least important of 5. In an effort to maintain the accuracy and consistency in the data, only the scores of focus group participants that indicated they used the STOP/SLOW paddle in traffic control operations were included for analysis (e.g., firefighters and police were not included in this analysis). Participants revealed that the following issues were most important to them regarding the use of the STOP/SLOW paddles:

- Weight
- Conspicuity of flaggers
- Alerting drivers sooner
Table 1 shows the results described. On the basis of the results, conspicuity and mobility of flaggers emerged to be top priorities for participants in these focus groups. Overall, the safety of flaggers and longevity of the flagging operations were found to be the most important criteria.

Table 1. Results for question four: “What are the advantages/disadvantages of the flashing STOP/SLOW paddle compared to a standard paddle?”

<table>
<thead>
<tr>
<th>Advantages/Disadvantages</th>
<th>Average Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weight</td>
<td>1.63</td>
</tr>
<tr>
<td>2. Increase conspicuity of flaggers</td>
<td>1.75</td>
</tr>
<tr>
<td>3. Alert aging and inattentive drivers sooner</td>
<td>2.00</td>
</tr>
<tr>
<td>4. Command respect</td>
<td>2.13</td>
</tr>
<tr>
<td>5. Mobility</td>
<td>2.13</td>
</tr>
<tr>
<td>6. Positive accident prevention tool in work zones</td>
<td>2.13</td>
</tr>
<tr>
<td>7. Battery life</td>
<td>2.25</td>
</tr>
<tr>
<td>8. Works great at dawn, dusk or night</td>
<td>2.25</td>
</tr>
<tr>
<td>9. Positive protection for flaggers</td>
<td>2.50</td>
</tr>
<tr>
<td>10. Cost</td>
<td>2.63</td>
</tr>
</tbody>
</table>

Note: Based on the following scale:
1 = most important, 2 = very important, 3 = important, 4 = somewhat important, 5 = least important

At two focus groups, participants were asked which STOP/SLOW paddles were the most desired devices that they would use in a flagging operation (police and firefighters were not asked this question). Most respondents ranked the standard 24 in. STOP/SLOW paddle the highest in categories of usability (1.17), durability (1.42), and preferred (1.17), whereas in the category of conspicuity, Paddle C received the highest votes with an average score of 1.83. Table 2 shows the results described.

Table 2. Results for question five: “How would you rank these four STOP/SLOW paddles?”

<table>
<thead>
<tr>
<th></th>
<th>Paddle A</th>
<th>Paddle B</th>
<th>Paddle C</th>
<th>Paddle D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability</td>
<td>1.17</td>
<td>3.00</td>
<td>3.08</td>
<td>2.83</td>
</tr>
<tr>
<td>Conspicuity</td>
<td>2.92</td>
<td>2.83</td>
<td>1.83</td>
<td>2.75</td>
</tr>
<tr>
<td>Durability</td>
<td>1.42</td>
<td>2.92</td>
<td>3.33</td>
<td>2.92</td>
</tr>
<tr>
<td>Preferred</td>
<td>1.17</td>
<td>3.33</td>
<td>3.25</td>
<td>2.75</td>
</tr>
</tbody>
</table>

Note: Based on the following scale:
1 = most desired, 2 = very much desired, 3 = desired, 4 = somewhat desired, 5 = least desired

The open-ended discussions included issues such as the perceived usability, effectiveness, and advantages or disadvantages of each STOP/SLOW paddle. Responses to these discussions yielded similar results that flashing STOP/SLOW paddles were perceived to help increase the conspicuity of flaggers. However, the basic usability and durability issues such as inadequate weight and fragile electronic components were concerns mentioned by focus group participants. A few participants in each focus group explained that during strong wind and high-volume conditions, the weight and “top-heaviness” of some of the paddles have a direct effect on their productivity and worker fatigue. While heavy paddles may hinder the
workability of flaggers, one participant pointed out light-weight paddles are not perfect either. The participant stated that during strong wind conditions, “wobbly” paddles may be hard to control.

In one device-building session, one flagger suggested the STOP/SLOW paddle be equipped with a built-in radio. The participant revealed that normally they would hold the STOP sign in one hand and the radio on another, while looking out for the opposing traffic. By incorporating the radio into the paddle, they can communicate effortlessly with the flagger on the other end, while control the traffic with this new technology.

Following the question-answer and discussion for question five, researchers addressed the standard and technology-enhanced safety vest usability and effectiveness in work zones. As shown in Table 3, the standard fluorescent yellow vest with reflective and orange striping (vest B) was ranked the highest in all four categories of usability (1.50), conspicuity (1.71), durability (1.50), and preferred (1.43). Participant comments revealed that blinking LEDs safety vests did not obtain the popularity as expected from the subjects. Participants pointed out that the battery-powered safety vests did not seem to have the usability and durability advantages over the conventional safety vests. Additionally, the LEDs and wiring components of the safety vests triggered a few participants to inquire about the washability and water resistance capability of these technology-enhanced vests. These comments were the impetus for the research team to actually wash the vests. Observations showed that many of the LEDs were rendered unusable after three washes.

Table 3. Results of question six: “How would you rank these four safety vests?”

<table>
<thead>
<tr>
<th></th>
<th>Vest A</th>
<th>Vest B</th>
<th>Vest C</th>
<th>Vest D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability</td>
<td>2.07</td>
<td>1.50</td>
<td>2.43</td>
<td>2.57</td>
</tr>
<tr>
<td>Conspicuity</td>
<td>2.57</td>
<td>1.71</td>
<td>2.07</td>
<td>2.79</td>
</tr>
<tr>
<td>Durability</td>
<td>1.93</td>
<td>1.50</td>
<td>2.57</td>
<td>2.00</td>
</tr>
<tr>
<td>Preferred</td>
<td>2.43</td>
<td>1.43</td>
<td>2.29</td>
<td>2.93</td>
</tr>
</tbody>
</table>

Note: Based on the following scale:
1 = most desired, 2 = very much desired, 3 = desired, 4 = somewhat desired, 5 = least desired

Interestingly, one focus group participant revealed that safety vest with zipper (or vest D) seems to be a better design than the traditional Velcro option as it helps mitigate the safety vest readjustment issue for flaggers. In one of the focus group discussions, one veteran flagger explained that the standard fluorescent yellow (or lime color) safety vest, i.e., vest A, is the most preferred color as it prevents the color from fading. However, most of the participants agreed that the combination of the fluorescent yellow vests with reflective and orange striping (vest B) was perceived to be the best among all of the safety vests presented.

Prior to the device-building session, participants were asked to answer their “intent to use” for three other technology-enhanced devices: a 4 in. red/amber light, a 2 in. red light, and a flashing headlight device that could be worn on the head, much like a miner’s light. Due to the functionality differences in each of these devices, participants were instructed to explain their “intent to use” instead of comparing and ranking them. The 4 in. red/amber light was a popular device in all three focus groups with 72% of participants indicating that they would use it in a flagging operation, whereas 22% of the participants revealed that they either had no opinions regarding this device or found it not applicable to them. The response from the discussion yielded interesting results.
Overall, participants perceived that the 4 in. red/amber light can help alert drivers sooner, while increasing the conspicuity of flaggers in work zones. Interestingly, one subject revealed that the 4 in. red/amber light that flashes in red was more effective in getting drivers to stop than those in amber color. Additionally, the same participant pointed out that the device can be more effective in alerting drivers by flashing the word “STOP” instead of just flashing in red or amber color. While the 4 in. red/amber light received positive results, the open-ended discussions from another focus group revealed that this device may be useful in isolated areas to increase conspicuity of workers.

Although the 2 in. red light did not receive the positive response (33%) as the 4 in. red/amber light, discussions showed that this LED light may be a good supplementary device to improve flaggers’ safety. One veteran flagger demonstrated that by clipping the flashing light to a standard 24 in. STOP/SLOW paddle, they could create a possible low-cost alternative to the higher-priced LED STOP/SLOW paddle devices evaluated. While it increases the conspicuity of flaggers, this $20 flashing light, which is water resistant, can be used in many different working conditions. The flashing headlight in both questionnaire and discussion sessions received poor response with no subject indicating that they will use the device and 56% of participants stated that they will not use the light in a flagging operation. Table 4 shows the results described.

Table 4. Results of question seven: “How could the supplemental devices (4 in. red/amber light, 2 in. red light, and flashing headlight) improve flagger effectiveness/safety?”

<table>
<thead>
<tr>
<th>Device</th>
<th>Would Use</th>
<th>Would Not Use</th>
<th>No Response/No Opinion</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 in. red/amber light</td>
<td>72%</td>
<td>6%</td>
<td>22%</td>
<td>100%</td>
</tr>
<tr>
<td>2 in. red light</td>
<td>33%</td>
<td>28%</td>
<td>39%</td>
<td>100%</td>
</tr>
<tr>
<td>Flashing headlight</td>
<td>0%</td>
<td>56%</td>
<td>44%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Although portable, changeable message signs (CMS) were not presented at the focus group discussions, one focus group revealed that this CMS may reduce flagger conspicuity if used in the vicinity of the flagger even though it is useful in getting drivers’ attention. One veteran flagger explained that they do not like any devices or vehicles around them that are distracting, except for traffic cones. While this portable CMS seemed durable, a few participants suggested that the device might not be able to withstand strong winds. One focus group participant suggested that the police vehicle is most effective in getting drivers to slow down in work zones. The flagger elaborated that the presence of police vehicle alone may be sufficient to alert drivers to decrease their speeds on sections of highways where needed.

In the focus group with emergency responders (e.g., policemen and firefighters), participants revealed that firefighters are not expected to direct traffic at crash sites, even though they may arrive on the scene earlier than police officers. So, technology-enhanced devices generally do not apply to them. Nonetheless, they will assign one firefighter to block the traffic or use the flashing light wand at night to direct the traffic, if needed. While firefighters indicated they may still use certain technology-enhanced devices, police officers indicated otherwise. One police officer explained that police officers perceive that the red flashing lights (e.g., the 4 in. and 2 in. lights, as well as the flashing vests) may turn into drivers’ targets, especially drivers that are operating while intoxicated. Additionally, the police in the focus group believed that any blinking lights on their uniform would detract from their desired serious demeanor, which they use to command respect of the drivers. Therefore, police officers tend to use flares, flashlights, and hand...
signals to get drivers’ attention in emergency situations rather than flashing lights. While police officers revealed the disadvantages of red flashes; one firefighter pointed out that red is not as visible as amber.

Overall, participants understood that the flashing lights were incorporated to enhance the conspicuity of their presence in the work areas. However, electronic components, usability, and durability of these flagger devices appeared to be concerns that the subjects had when asked to relate the devices to their duties. Conventional equipment, such as the standard STOP/SLOW paddle and safety vest, seemed to have advantages over the technology-enhanced flagger devices (flashing STOP/SLOW paddles and blinking safety vests) presented. Nonetheless, participants in the first all-flagger focus groups revealed that they may purchase the flashing/blinking STOP/SLOW paddles and safety vests just for some night or evening work projects they occasionally worked. In addition, participants in all focus groups summarized (with the exception of the police) that supplementary devices such as the 4 in. red/amber light or 2 in. red light seemed to provide the flexibility, assurance, and budget they need to perform their duties.

FIELD SURVEYS

The final phase of this study was to conduct field surveys to examine the effectiveness of these technology-enhanced flagger devices on the basis of motorists’ responses. Field survey locations were searched within the 100-mile radius from the city of Lawrence. With the assistance of the Kansas Department of Transportation (KDOT) and various county engineers’ offices, the following were the three locations selected for field surveys:

- US-169 between Iola and Colony (Iola, Kansas)
- N 700th Road and E 1900th Road (Douglas County, Kansas)
- 31st Street between Louisiana and N 1275 Road (Lawrence, Kansas)

The setup of the flagging operation was also an important criterion that was considered when planning the survey instrument. Depending on the work to be completed by the workers, an ideal work zone for this research should be one mile long or longer, coordinated by two flaggers and a pilot car. However, field testing on 31st street revealed that the mobile work zone that moved intermittently could not provide the sufficient leeway needed to conduct the motorist surveys, and thus, this location was removed from further consideration.

Observations showed that flaggers on US-169 and 31st Street were equipped with similar safety gear, which included safety vests and hats. These workers explained that the clothing and equipment can help alert the drivers sooner and increase their conspicuity. The superintendent of the work zone on US-169 elaborated that while a queue of vehicles was instructed to stop, the traffic released from the opposite direction can better recognize the dress of the flagger stopping the opposing traffic and drive with caution. In order to prevent unnecessary procedures that may disturb the flagging operation, only the standard and flashing STOP/SLOW paddles were tested in these work zones.

Due to the nature of the construction work, the field surveys were conducted during clear daylight conditions. Contractors and authorities in KDOT revealed that nighttime flagging operation are infrequent and are only allowed when construction workers need to complete certain work at night; additionally, these night work locations are often police-controlled. Due to this issue, the selected technology-enhanced devices were only tested during daytime. By consolidating the surveys, a total of 99 motorists’ responses were collected for subsequent analysis. The survey questions used for this research were consistently performed throughout the study period unless otherwise indicated in the report.
Prior to initiating the surveys, vehicle type was recorded to classify each automobile sampled. On the basis of the results, 73 vehicles were recorded as passenger cars and the remaining 26 vehicles were classified as heavy trucks. Information such as gender, age, and education level were not collected for this study. As aforementioned, four different STOP/SLOW paddles, including a standard paddle, were tested on both ends of the flagger-controlled work zone. Additionally, only the first and second vehicles in a queue on both ends were selected to participate in this motorist survey. This was to ensure that the selected respondents reacted based on the presence of flagger or the STOP sign, and not because of the vehicles that stopped or slowed down in front of them. Preliminary trials revealed that each questionnaire needed to be completed within the 7-8 minutes time frame for the first and second vehicle in a queue before the flagger released the traffic. Secondary vehicles in queues that stopped behind a large truck were not surveyed. This measure was to ensure that the views of the selected drivers second in order were not obstructed by the first vehicle.

The survey questionnaire was conducted in four parts. The first section was to estimate whether drivers were local, same county residents, or other state residents. In addition, the questions were designed to ensure that there were no repeat respondents and each respondent was independent of the others. Anyone who had taken the survey earlier and was returning back through the work zone was not surveyed a second time. The second part was to examine the effects of the STOP/SLOW paddles along with other existing traffic control devices. In this section, survey respondents were asked to name all of the things they saw from the time they entered the work zone until they stopped by the flagger. For the third section, drivers were asked to state their opinions regarding the (flashing or standard) STOP/SLOW paddles handled by the flaggers. In the final sections of the questionnaire, drivers were instructed to state their responses and reactions to the flashing STOP/SLOW paddles displayed. For the second, third, and final sections, respondents can reply multiple answers.

Figure 1 shows the results of the distribution for question one: “Have you driven this work zone before?”, question two: “Is this your first time today?”, and question three: “Did you see construction activities before this?”. The first question was designed to separate two major drivers: local and different state. The second question was created to further divide the drivers into specific groups. It can be observed from this chart that advance warning signs were the leading choice in each of the categories, except for the group of first-time drivers who have not driven the work zone before. While the advance warning signs received attention from the drivers, the results of the STOP sign and flaggers indicated otherwise, with less than 27% of respondents in these categories stating that they noticed them.

For question three: “What did you see?”, most of the drivers (70%) responded that they paid attention to the advance warning signs, whereas 36% of respondents replied that they saw the construction cones and new pavement. For the STOP sign and flagger, each of these categories received 15% and 12%, respectively. Overall, the conspicuity of STOP sign and flagger when combined together collected a total of 27% of responses. Additionally, 13 drivers stated that they did not see the STOP sign until about 100 feet away or just noticed it when instructed to stop. The lack of conspicuity effect is one evident finding that can be observed from the results; however, the safety of the flaggers is the bigger concern when these workers are out performing the flagging operation in work zones.

Four different STOP/SLOW paddles, including a standard paddle, were tested in three work zones. Overall, the results of the computations revealed that there were few differences between the standard and flashing STOP/SLOW paddles when tested in work zones. The results were considered reasonable and conformed to expectations.

Figure 2 shows the overall distribution of question five. Overall, most drivers (65%) stated that they liked the displayed STOP sign they saw, whereas 14% of drivers indicated that they did not like the paddle and
21% had no preference. When asked about their opinions regarding the displayed STOP sign, 59% of in favor drivers stated that it commanded their attention, whereas the next in order 14% of in favor drivers indicated that it fulfilled a need. While most respondents replied that they were in favor of the displayed STOP sign, 86% of those that were not in favor indicated that they either did not see it or thought it was hard to see. Overall, most drivers liked the six foot STOP signs that were displayed to them. The flaggers revealed that while these flashing STOP/SLOW paddles were new, striking, and clean, the bigger size (24 in. standard or flashing STOP/SLOW paddle) seemed to provide the respect and attention they needed in order to direct the traffic compared to the 18” STOP/SLOW paddle they normally used.
Figure 1. Response to question one: “Have you driven this work zone before?” two: “Is this your first time today?” three: “Did you see construction activities before this?” and four: “What did you see?”
Figure 2. Distribution of responses to question five: “What do you think of the flagger’s STOP sign?” with respect to the STOP sign used.
Figure 3 shows the responses to question five: “What do you think of the flagger’s STOP sign?” with respect to the STOP signs used. From this chart, it can be observed that the overall responses for flashing STOP paddles were not significantly different than the STOP sign that flashes alternately above and below the STOP/SLOW words, which received the highest response. When asked about the indication of the flashing light(s), only 13% of the drivers who noticed the signs replied that the flash light(s) signified a more important situation. Interestingly, more than half (54%) of the surveyed drivers did not think that the flashing STOP/SLOW paddles indicated a more important situation than if the paddle did not flash.

In the last question, drivers were asked to state the precaution measures that they took when they observed the flashing STOP/SLOW paddles. Figure 4 shows the response to question six described. About one-quarter (26%) of the drivers indicated that they drove differently because of the flashing STOP signs, while 41% of the drivers replied that they did not adjust their driving. Surveyed drivers (26%) who responded to the presence of the flashing STOP/SLOW paddles indicated they either slowed down earlier,
drove slower, or drove more cautiously with the flashing STOP sign that flashes alternately above and below the STOP/SLOW words, and the blinking STOP/SLOW paddle received the highest response.

Figure 4. Do you think you drove differently because of the flagger’s sign?
FINDINGS AND DISCUSSION OF FUTURE RESEARCH

The findings of the analyses were organized by (1) focus groups evaluations and (2) field surveys. The following are the key findings from this synthesis effort:

Focus Group Evaluations

- The standard 24 in. STOP/SLOW paddle and the standard fluorescent yellow safety vest with reflective and orange striping emerged to be favorites among panel evaluation participants over other technology-enhanced equipment displayed.
- The results of the focus groups revealed that weight of devices, conspicuity of flaggers, and awareness of drivers were among the influential criteria for field personnel to opt for a flashing STOP/SLOW paddle over a standard paddle.
- Seventy-two percent of participants agreed that the 4 in. red/amber light appeared to have the best potential for large visibility gains, versatility of applications, and ease of use.
- The 2 in. red light did not receive 33% positive responses. Discussions showed that this LED light may be a good supplementary device to improve flaggers’ safety.
- Focus group participants generally understood that the flashing lights were incorporated to enhance their conspicuity in work areas; however, electronic components, usability, and durability of these technology-enhanced devices appeared to be concerns that the participants had when asked to relate the devices to their duties.

Field Surveys

- Twenty-eight percent of drivers indicated that they saw the STOP sign or flagger in work zones when enquired about the things that they observed.
- When asked about their opinions regarding the displayed STOP sign, 74% of in favor drivers stated that it commanded their attention or fulfilled a need, whereas 86% of those not in favor indicated that they either did not see it or thought it was hard to see.
- More than half (54%) of the surveyed drivers did not think that the flashing STOP/SLOW paddles indicated a more important situation than if the paddle did not flash.
- Twenty-six percent of drivers stated that they drove differently (e.g., more cautiously) because of the flashing STOP/SLOW paddles, while 41% of the drivers replied that they did not adjust their driving. So the message was interpreted as the same.

In conclusion, the use of focus groups of flaggers and emergency services personnel, combined with field surveys of drivers has revealed that technology-enhanced STOP/SLOW paddles have potential for increasing the conspicuity of flaggers, even under bright daylight conditions. Additionally, flaggers and emergency services personnel liked the potential of the 4 in. lights as a way to warn drivers that they are approaching workers in or near the roadway.
ACKNOWLEDGEMENTS

The authors would like to thank the Smart Work Zone Deployment Initiative (SWZDI) for their support of this project. We also thank the following individuals for their help in recruiting subjects for this research: Mr. Steve Glass of LRM Industries, Inc., Capt. James Saladin of Lawrence Fire Department, and Mr. Keith Browning and Mr. Mike Perkins of the Douglas County Public Works. Also, the authors thank the data collection efforts of graduate research assistant Mr. Robert Rescot and undergraduate research assistant Samuel Klein.

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