KU: STE48360

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

Technical Report 48360-1

The Civil, Environmental, and Architectural Engineering Department
The University of Kansas
Lawrence, Kansas

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
48360-1		

4. Title and Subtitle	5. Report Date
Evaluation of Technology-Enhanced Flagger Devices: Focus Group and Survey Studies in Kansas	April 2009
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Steven D. Schrock, Chen Fei See, Jamila Saadi, Wai Kiong "Oswald" Chong, Yong Bai	
9. Performing Organization Name and Address	**10. Work Unit No. (TRAIS)**
The University of Kansas 1530 W. 15th Street Lawrence, KS 66045-7609	**11. Contract or Grant No.** SWZDI Contract #09773
12. Sponsoring Organization Name and Address	**13. Type of Report and Period Covered**
Smart Work Zone Deployment Initiative 2711 S. Loop Dr., Suite 4700 Ames, IA 50010-8664	Final Report, July 2007 - March 2009 **14. Sponsoring Agency Code**

15. Supplementary Notes

Project Title: Evaluation of Technology-Enhanced Flagger Devices

Visit http://www.ctre.iastate.edu/smartwz for color PDF files of this and other research reports sponsored by the Smart Work Zone Deployment Initiative.

16. Abstract

Flagger-controlled work zones, by their very nature tend to utilize fewer traffic control measures than other work zones. Often these work zones are in place for only a short duration of time, so adding signing or positive protection beyond the minimum guidance directed by the MUTCD is rarely done. In these situations, the flagger is the key to effective traffic control, and so his/her visibility and conspicuity are critical to keeping motorists and workers safe. 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. 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 and workability of these devices, while synthesizing the effects of these technology-enhanced devices based on flagger focus groups and driver survey responses.

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. Interestingly, the standard 24" STOP/SLOW paddle and the standard fluorescent yellow safety vest with orange striping emerged to be favorites among focus group participants over other technology-enhanced equipment displayed. Additionally, 72 percent of participants agreed that red and/or amber LED lighting attached to cones appeared to have the best potential for large visibility gains, versatility of applications, and ease of use. For the motorist surveys, only 28 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 percent of in-favor drivers stated that it commanded their attention or fulfilled a need, whereas 86 percent of those not in-favor indicated that they either did not see it or thought it was hard to see. Also, more than half (54 percent) 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. Overall, only 26 percent of drivers stated that they drove differently because of the flashing STOP/SLOW paddles.

17. Key Words	18. Distribution Statement
flaggers—technology-enhanced devices—focus groups—surveys	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	54	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Report 48360-1
KUCR Project STE48360
Project Title: Evaluation of Technology-Enhanced Flagger Devices

Sponsored by:
The Smart Work Zone Deployment Initiative
a Federal Highway Administration pooled fund study
administered by the Iowa Department of Transportation
SWZDI Contract #09773
April 2009

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DISCLAIMER

This research was performed in cooperation with the Smart Work Zone Deployment initiative, a Federal Highway Administration (FHWA) pooled fund study administered by the Iowa Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Smart Work Zone Deployment Initiative, the Iowa Department of Transportation, or the FHWA. This report does not constitute a standard, specification, or regulation. The engineer in charge of the study was Dr. Steven D. Schrock, Kansas P.E. #18989.

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 the data collection efforts of undergraduate research assistant Samuel Klein.

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1. INTRODUCTION

In the United States, over 1000 fatalities occur every year in the construction sector (*1*). In 2007 alone, approximately 94 of these fatalities were highway, street and bridge construction related, whereas 30 percent (or 28 fatalities) of these incidents were due to construction workers struck by vehicle (*2*). Specifically, highway maintenance workers consisted of approximately 13 percent of these fatalities in the year 2007 and 50 percent of these fatalities were reported as workers struck by vehicles (*2*). Previous studies revealed that driver inattention and excessive speed are among the contributing factors most frequent reported for work zone crashes (*3*,*4*).

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 MUTCD is rarely done. Figure 1 shows an example of a flagger-controlled work zone described. Based on prior findings, approximately 6 percent of the examined fatalities from years 1980 to 1992 were either flaggers or surveyors (*5*). 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, as shown in Figure 2.

FIGURE 1 Flagger-Controlled Work Zone.

FIGURE 2 Flashing STOP/SLOW Paddle.

Many studies document the usability, advantages and disadvantages of various new devices or technology as soon as they are available in the market (*6*,*7*). 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 by 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 its 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 devices, 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.

WORK PLAN

This research was conducted in two phases. Phase I (Tasks 1-2) involved an examination of the state of the literature and the state of the art regarding the use of technology-assisted flagger devices. Phase II (Tasks 3-5) involved a series of focus groups of transportation maintenance and emergency services personnel to gauge and evaluate each of the technology-assisted flagger device chosen in Phase I. The work plan consisted of the following 6 tasks:

Task 1: Literature Review
Task 2: Determination of Technology-Enhanced Flagger Devices
Task 3: Focus Group Evaluations
Task 4: Field Surveys
Task 5: Report Preparation

The literature review is presented in Chapter 2; determination of technology-enhanced flagger devices are presented in Chapter 3; focus group evaluations of technology-enhanced flagger devices are discussed in Chapter 4; the field surveys is presented in Chapter 5; and findings and discussions of future research are presented in Chapter 6.

2. LITERATURE REVIEW

FLASHING STOP/SLOW PADDLES

Flashing STOP/SLOW paddles are approved devices in Section 6E.03 of the MUTCD (*8*). The main purpose of this option is to improve conspicuity by incorporating flashing lights on both background faces. Nonetheless, the following requirements are cited in the MUTCD (*8*):

- Two white or red lights, one centered vertically above and one centered vertically below the STOP legend; and/or two white or yellow lights, one centered vertically above and one centered vertically below the SLOW legend; or
- Two white or red lights, one centered horizontally on each side of the STOP legend; and/or two white or yellow lights, one centered horizontally on each side of the SLOW legend; or
- One white or red light centered below the STOP legend; and/or one white or yellow light centered below the SLOW legend; or
- A series of eight or more small white or red lights no larger than 6 mm (0.25 in) in diameter along the outer edge of the paddle, arranged in an octagonal pattern at the eight corners of the border of the STOP face; and/or a series of eight or more small white or yellow lights no larger than 6 mm (0.25 in) in diameter along the outer edge of the paddle, arranged in a diamond pattern along the border of the SLOW face; or
- A series of white lights forming the shapes of the letters in the legend.

Morena (*9*) 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.

AUTOMATED FLAGGER ASSISTANCE DEVICES

Other technology-based devices also exist on the market beyond hand-held devices. The MUTCD classified the Autoflagger, J4 Flagger Workstation and RC Flagman as automated flagger assistance devices (AFADs), a portable device that helps flaggers in short-term lane closures on a highway (*10*). The Autoflagger is a device that consists of 36-inch STOP/SLOW signs on a trailer that is 13.9 feet long and 8 feet wide, supplemented with a 12-inch red LED signal light with strobe above the stop sign and two amber lights with strobes on each side of the

FIGURE 3 Autoflagger (*6*) (Used with permission).

LOW sign. Figure 3 shows the Autoflagger described. The Autoflagger is also equipped with an emergency horn that can be activated to alert construction workers. The wireless remote control function is another advantage of this device; the operator can observe and control the Autoflagger from a safer and strategic distance other than the edge of the roadway.

The Remote Control (RC) Flagman was originally developed in Ontario, Canada (*11*). Since its introduction, many state agencies and construction companies in the U.S. have obtained this new innovation to help save cost and protecting their employees (*12*). The RC Flagman consists of two 12-inch signal heads, red and yellow in color mounted vertically on a trailer. The device can be augmented with gate arm, solar panel, cellular emergency response and hardwire communication link. The basic functions of a RC Flagman include radio remote control, flash memory for cycle-time settings, conflict monitoring, and towing and emergency ready capabilities. The basic instructions of RC Flagman, which are similar to traffic signal regulations, made the task to understand and comply easy for the driving public. The flashing yellow on the signal head indicates that the traffic is allowed to proceed, whereas the steady amber and red lights signify that ready to stop and stop, respectively. After the red light, the gate arm with fluorescent orange and white retroreflective sheeting (if supplemented) is lowered to indicate a closed lane.

In recent years, many new techniques or devices were proposed for implementation to improve flagger safety in work zones. In Texas, Trout and Ullman (*6*) 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 (*7*) 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 paddle, radar drone, 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.

OTHER DEVICES

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) (*7*). The paddle 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. Next, the wiring of the radar that 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 (*6*). 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 beam, and pneumatic tubes. The microwave and infrared models can be setup simply by mounting it 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 (*6*). False alarms were the major concerns that 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 can be triggered by movement of the drums, rain, or even dust. The ease of use for all three models were rated as low by various agencies as the required setup time were longer than anticipated, and on top of that these devices were neither lasting nor reliable. However, researchers believed 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.

3. DETERMINATION OF TECHNOLOGY-ENHANCED FLAGGER DEVICES

The second task of the research involved the identification of technology-enhanced flagger devices with potential to increase driver compliance and/or flagger safety in work zones. These devices were identified by conducting a review of the literature and focus groups. On the basis of the results, the following technology-enhanced flagger devices were identified as the innovations that would be helpful in increasing driver compliance and/or flagger safety:

- flashing STOP/SLOW paddle,
- blinking safety vest,
- LED lights with cone clip,
- safety flashing light, and
- portable changeable message sign (CMS).

In this chapter, a detailed discussion of each technology-enhanced flagger device is reported. Additionally, one or more standard flagger devices of the same category were also included. This measure was to ensure that a comprehensive comparison test was conducted. The summary on each device consists of the following components:

- a general description of the standard and technology-enhanced flagger devices,
- perceived advantages and disadvantages of each device or technology,
- the results of the technology examination, and
- the comparison test between the selected technology-enhanced flagger devices.

Rather than list the products using their brand names, each product has been given a letter designation in this report. Additionally, the brand names and the manufacturers were never mentioned during the focus groups or during the driver surveys in order to minimize any brand preference bias among the participants.

STOP/SLOW PADDLE PRODUCT EVALUATIONS

Paddle A

Paddle A is a standard 24” x 24” STOP/SLOW paddle that made out of aluminum. This slender STOP sign is light in weight (2.65 pounds) and retro-reflective on both sides of the paddle. It comes with a 5-feet (hollow) plastic pole that connects the STOP paddle with two screws. Figure 4 shows the standard STOP/SLOW paddle described. This product has been available on the market for a long period of time. Preliminary examinations showed that this light-weight paddle seemed durable and was easy to store. Nonetheless, the engineer grade sheeting (ASTM Type I or II) did not seem to be able to provide the scratch resistance needed for tough usage in the field. This standard STOP/SLOW paddle costs approximately $50.

FIGURE 4 Standard STOP/SLOW paddle (Paddle A).

Paddle B

Paddle B is a 24” x 24” blinking STOP/SLOW paddle that made out of plastic. This blinking STOP paddle consists of engineer grade sheeting (ASTM type I or II), eight LED lights, one edge-protection rubber frame and one battery compartment. Figure 5 shows the blinking STOP/SLOW paddle described. It also comes with two 26-inch PVC poles and a threaded PVC connector that connects both of the poles. When needed, the STOP sign can be quickly assembled by connecting the PVC poles together through the threads. After completion, the paddle can be connected to the PVC pole through a plastic connector that holds the paddle. Also, the package includes three AA NiMH batteries, plus an AC outlet charger and a DC cigarette lighter charger. In terms of handiness, this blinking STOP sign seemed to provide all of the equipment needed in most scenarios. In addition, the design of this paddle allows different uses. For instance, when fully assembled the STOP/SLOW paddle can be used for contractors, DOT personnel or emergency responders for traffic control purposes. When detached from the pole the stand-alone paddle can be used for crossing guard in school zones to direct traffic.

Prior to the technology examination, a comprehensive test was conducted to examine the pros and cons of this device including the usability and durability. From the test, the assembling time for this device was observed to be two to four minutes, whereas the dismantling time was recorded to be less than a minute. Furthermore, observations showed that the paddle can be extended to its highest at 91 inches or 7 feet 8 inches. However, by removing one of the PVC pole sections, the sign was recorded at 63 inches or 5 feet 3 inches tall. While the blinking paddle weighs 6.5 pounds when fully assembled, examination showed that this wobbly paddle did not seem to be able to provide the stability needed for flaggers to conduct the flagging operation especially during strong wind conditions.

For the technology examination, various functions of the device were tested in an effort to examine its usability. The results of the examination showed that this STOP sign allows two different blinking modes. Users can either choose to light up the LEDs on the side with "STOP", or "SLOW" on the other side, or both sides of the paddle at the same time. In addition, the intensity of the LEDs can be adjusted accordingly by selecting the "single" or "triple" mode. Observations showed that the battery compartment, AC outlet charger and DC cigarette lighter charger allowed the convenience of recharging the paddle at any instance. Nonetheless, in order to obtain the optimum level of blinking time, it is advised to fully charge the paddle within the 8-24 hours window recommended by the manufacturer. Additionally, circumstantial observations showed that the STOP sign allows for power preservation when the paddle is rotated 90 degrees or more from vertical. So when the flaggers needed to take a break, the power preservation mode can be simply activated by placing the top section of the paddle on the ground, effectively extending useful battery life. This blinking STOP/SLOW paddle costs approximately $350.

FIGURE 5 Blinking STOP/SLOW paddle with corner LED lighting (Paddle B).

Paddle C

Paddle C is a 24" x 24" flashing STOP/SLOW paddle with the words "STOP" and "SLOW" blinking in a given time interval set by the manufacturer. As shown in Figure 6, this plastic-made STOP paddle consists of approximately 51 ultra-bright LED lights on each side, one edge-protection rubber frame and one battery compartment. Furthermore, an extendable telescopic pole was purchased in order to connect this flashing paddle. Preliminary examination showed that this telescopic pole is relatively heavier than the conventional PVC staff. However, the pole can be extended from six feet to as high as ten feet above the ground. Initial observations showed that this flashing paddle is relatively heavy (6.87 pounds) as compared to the other three paddles. In addition, the paddle has the “STOP” and “SLOW” sections extended out from the main paddle, while protected by an edge-protection rubber frame around the paddle.

Like Paddle B, users can either choose to light up the LEDs on the side with “STOP”, or “SLOW” on the other side, or both sides of the paddle at the same time. All of these modes can be either powered by four size D batteries, or via AC or DC power using the optional power adapter. Out of the four STOP/SLOW paddles, Paddle C provided the most lights, and examination showed that the words “STOP” and “SLOW” were clearly spelled out at night and in low visibility conditions. The manufacturer claimed that the lights can capture the attention of drivers from as far as one mile away, whereas vendors advertised that the sign is not easily washed out unlike standard reflective signs.

For the technology examination, the results of the test revealed that in any position (upside down or sideway), the paddle continued to flash the LED lights when switched on, unlike Paddle B where there is a power preservation mode. In addition, online research showed that a wire rim sign guard can be purchased externally to protect the extended sections from tough usage. This flashing STOP/SLOW paddle costs approximately $350 excluding the telescopic pole ($50).

FIGURE 6 Flashing STOP/SLOW paddle (Paddle C).

Paddle D

Paddle D is a 24” x 24” flashing STOP/SLOW paddle that flashes alternately through two flashing LED-arrays located above and below the “STOP” and “SLOW” words. Figure 7 shows the flashing STOP/SLOW paddle described. Initial examination showed that this plastic-made paddle can only be operated using four size C batteries and no external AC or DC power can be connected to it. Based on the vendors’ advertisement, this paddle is available in three different sheeting: engineer grade (ASTM type I), hi-intensity (ASTM type III) and diamond grade (ASTM type VII, VIII, X or IX). In order to be consistent and to prevent bias, only the engineer grade sheeting paddle was tested in both the lab and the field. Similar to Paddles A and B, the reflective sheeting did not seem to be able to provide the scratch resistant needed for tough usage in the field.

FIGURE 7 Flashing STOP/SLOW paddle (Paddle D).

Furthermore, observations showed that there was no option to adjust the flashing LED arrays on each side of the paddle, unlike Paddles B and C where users can choose to light up the LEDs on the side with “STOP”, “SLOW”, or both sides of the paddle at the same time. The only usability issue observed during the test was the size of the battery compartment.

As aforementioned, Paddle D requires four size C batteries in order to power the STOP sign. However, observation found that the size of the batteries compartment, which is also the handle, was only marginally bigger than the size C batteries making it difficult for users to replace the batteries, which would be a negative aspect to long-term use. Overall, the flashing components, the size and the weight (4.26 pounds) of Paddle D seemed to be adequate for flaggers to conduct the flagging operation. This flashing STOP/SLOW paddle costs approximately $240 including the PVC staff.

RED/AMBER FLASHING LIGHTS

4-Inch Red/Amber Light

Figure 8 shows a red and amber flashing LED lights (approximately 6" x 3.75"). Each of this LED light consists of 18 LED lights (arranged in three rows), one red or amber face cover, and two 2.25" x 1.5" magnets. In order to be connected to the traffic cones, manufacturers provided the "L" shaped metal brace. Each metal brace comprises of a 2.5" diameter hole on the shorter section and 4" x 4.5" metal surface on the longer section. This LED lights utilizes four AA batteries to power the two lighting sequences: steady-on and blinking mode. Without the metal brace, each LED light weighs approximately 0.69 pounds when fully assembled. With the magnets, this versatile device was found to be handy for many different occupational uses. For instance, the lights can be used for engineers or surveyors to attach to their trucks or trailers when they stopped on the side of freeways. This traffic control kit, which includes six LED lights, six cone clips, and a carrying case, can be purchased at approximately $230.

FIGURE 8 LED lights with cone clip (4-inch Red/Amber Light).

2-inch Red Light

Figure 9 shows a 3" x 1.5" red flashing light. This product has been available on the market for a long period of time. This plastic-made LED lights consists of 5 LED lights (arranged in a row), one red face cover, and a handy clip. Initial observation showed that this safety light utilizes a single AA battery to operate the light. Furthermore, it has clip on the back of the light allowing it to be clipped on any suitable device or material or on a person. For the technology examination, the results showed that this safety light has seven different flashing or blinking modes, each one displays a different light pattern to allow different usage. This $16 red light weighs approximately 0.18 pounds.

FIGURE 9 Safety flashing light (2-inch Red Light).

STANDARD AND BLINKING SAFETY VESTS

Vest E

Vest E is a Class II fluorescent yellow safety vest with reflective striping. This product has been available on the market for a long period of time. Figure 10 shows the safety vest described. This conventional safety vest is made out of highly durable polyester material, allowing it to withstand tough usage. Online research showed that the polyester materials do not require any special care before and after use. Additionally, research revealed that Vest E is machine washable with at least 25 washes.

Initial evaluations found that the Velcro front design of this safety vest allows easy dressing and removal. Furthermore, Vest E also has several small pockets inside the vest, allowing for small items storage such as pens and papers. This standard safety vest costs approximately $30.

Vest F

Vest F is a Class II fluorescent yellow safety vest with reflective and orange striping. This product has been available on the market for a long period of time. Figure 11 shows the safety vest described. Similarly, this conventional safety vest is made out of highly durable polyester material, allowing it to withstand tough usage. Examination showed that this polyester material does not require any special care before and after use. Similarly, online research revealed that Vest F is machine washable.

FIGURE 10 Fluorescent yellow safety vest with reflective striping (Vest E).

FIGURE 11 Fluorescent yellow safety vest with reflective and orange striping (Vest F).

Initial evaluations also found that the Velcro front design of this safety vest allows easy dressing and removal. Similar like Vest E, Vest F also has several small pockets inside the vest, allowing for small items storage such as pens and papers. This standard safety vest costs approximately $35.

Vest G

Vest G is a fluorescent yellow mesh safety vest with LED lights and reflective striping. This blinking safety vest consists of twelve LED lights on both of the front and back of the vest, three plastic protected reflective striping, and a small battery compartment case. Figure 12 shows the safety vest described.

FIGURE 12 Fluorescent yellow mesh safety vest with LED lights and reflective striping (Vest G).

Initial examination found that the air-mesh material is suitable for spring and summer seasons, where most construction works are generally undertaken. In addition, examination found that the battery compartment is protected by a waterproof case to prevent water from slipping in. However, based on the vendor's specifications this vest will require special care as the vest is not recommended for machine washing. The vendor explained that while the blinking safety vest may be waterproof, the LEDs may not be able to withstand the forces in a washing machine. The research team did wash this vest in a standard washing machine on gentle cycle, and after only three washes all but three of the fourteen LEDs stopped working. Similar like Vest E and F, the Velcro front design of this safety vest allows easy dressing and removal. This safety vest costs approximately $50.

Vest H

Vest H is a fluorescent-yellow safety vest with LED lights, reflective and orange striping. This blinking safety vest consists of twelve LED lights on both of the front and back of the vest, a zipper front, two adjustable Velcro striping, and a small battery compartment case. Figure 13 shows the safety vest described.

FIGURE 13 Fluorescent-yellow safety vest with LED lights, reflective and orange striping (Vest H).

Initial examination found that the battery compartment is protected by a waterproof case to prevent water from entering the compartment. However, observation revealed that this $50 blinking vest will require special care as the vest is not recommended for regular washing. Similarly, while this blinking safety vest may be waterproof, examination showed that the LEDs may not be able to withstand the forces in a washing machine. Unlike Vest E, F and G, this blinking safety vest has a zipper front and two Velcro strips down the waist area to allow easy dressing and removal. This blinking safety vest costs approximately $50.

PORTABLE CHANGEABLE MESSAGE SIGN

Changeable Message Sign (CMS)

Figure 14 shows a 30” x 28” x 3.25” portable rapid messenger. This product is a new technology that was available on the market recently. This 42 pounds sign consists of high intensity LEDs,

FIGURE 14 Portable rapid messenger (CMS) (*13*).

and two 30" x 28" panels that connected through several sturdy hinges. Other specifications of this device include 200 pixels per square feet resolution, and 30 degrees viewing angle. In addition, online research showed that this full-matrix variable message sign can provides three lines of 7-inch characters, two lines of 10-inch characters, or one line of 24-inch characters up to a maximum of twelve, eight and four characters, respectively. Furthermore, research showed that this portable sign also has full graphics capability to allow for different usage. This system costs approximately $8000. This device has Bluetooth capability, where users can connect and program the message they want through their laptops or Personal Digital Assistants. While this variable message sign has wireless capabilities, users can also opt for conventional methods, i.e. adjust the buttons on the unit to alter the messages.

Although no physical evaluation was performed to examine this device due to its expensive cost, online research showed that this device required special care, even though it has protective feet, powder-coat finish and strong structural elements. Additionally, online examination revealed that the external brackets of this sign allow for different usage. Users can either place the sign on a trailer, post or hitch mount utilizing the universal brackets provided. For the power source, the sign can be recharged via DC power using the cigarette lighter charger. In addition, a solar panel available in 20W, 60W or 120W capacities can also be attached to the portable message sign to provide power for the configuration needs.

TECHNOLOGY EXAMINATIONS

Figure 15 shows the results of the comparison test for each of the technology-enhanced flagger devices described. As shown in this figure, various functions of these devices were tested to its limit in an effort to examine its usability and feasibility in work zones. The results of this comparison test revealed that 2-inch red light (536 hours), Vest H (502 hours), 4-inch red/amber light (473 hours), and Paddle D (289 hours) provided the longest effective working time than other technology device tested. Overall, each of these devices surpassed the anticipated 24-hour

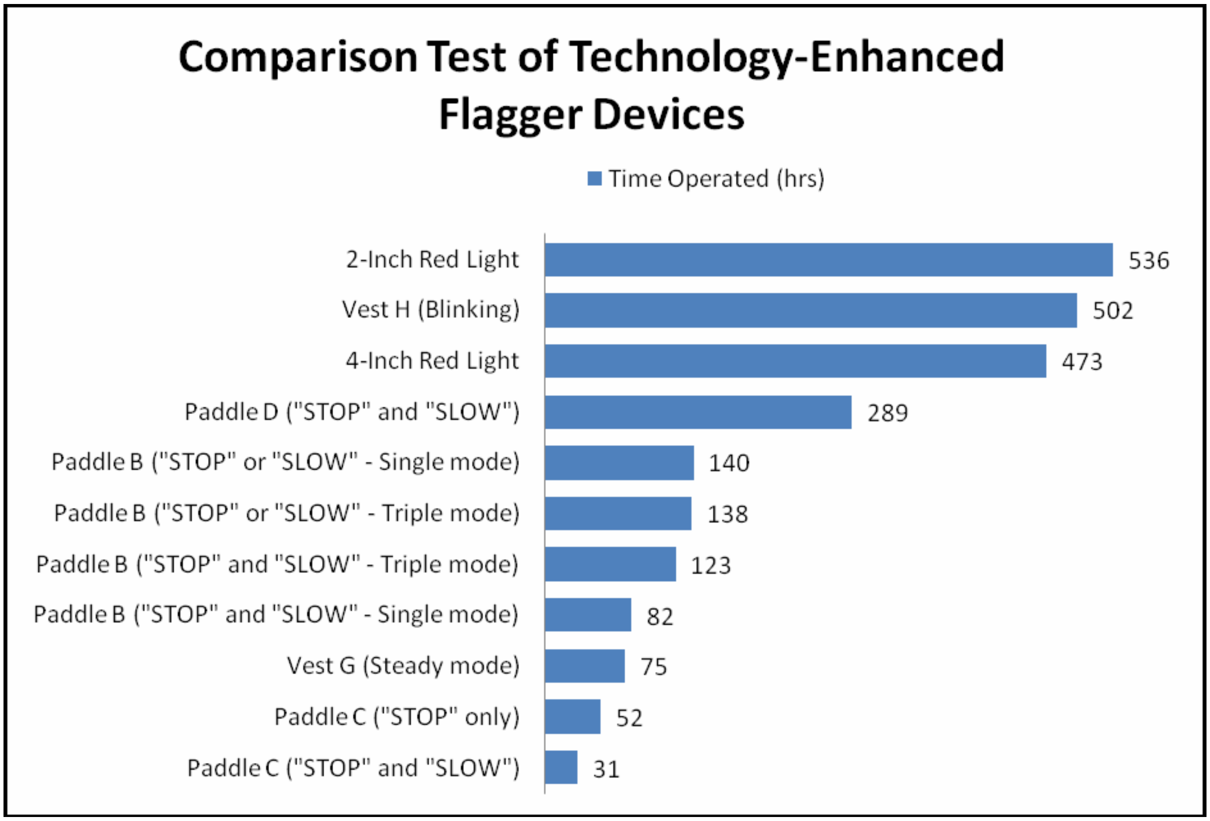

FIGURE 15 Comparison test of the technology-enhanced flagger devices.

window for recharging or batteries replacement purposes. Nonetheless, it is believed that the actual operating time in the field may vary especially during cold weather conditions, as the batteries may drain faster than expected. For the purpose of this study, only the fresh alkaline batteries were used to conduct the tests for those devices that did not have internal rechargeable batteries. Although the power source for each of these devices may be different, the comparison tests were conducted consistently with the best possible power source in an effort to prevent bias.

4. 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 existed for innovative concepts to be suggested by participants (*14*).

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 provide 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. Figure 16 shows the focus group discussions and panel evaluations described.

The panel evaluation sessions comprised of four parts. The first part was an orientation to understand their 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, and
- Flagger device creating sessions.

FIGURE 16 Focus group discussions and panel evaluations in Douglas County Public Works office.

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 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, and
- 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?"

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

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-inch 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?"

	Paddle A	Paddle B	Paddle C	Paddle D
Usability	1.17	3.00	3.08	2.83
Conspicuity	2.92	2.83	1.83	2.75
Durability	1.42	2.92	3.33	2.92
Preferred	1.17	3.33	3.25	2.75

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 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-answering and discussion for question five, researchers addressed the standard and technology-enhanced safety vests 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: 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 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; as noted in the previous chapter many of the LEDs were rendered unusable after three washes.

TABLE 3 Results of Question Six: “How Would You Rank These Four Safety Vests?”

	Vest A	Vest B	Vest C	Vest D
Usability	2.07	1.50	2.43	2.57
Conspicuity	2.57	1.71	2.07	2.79
Durability	1.93	1.50	2.57	2.00
Preferred	2.43	1.43	2.29	2.93

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-inch red/amber light, a 2-inch red light, and also 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-inch red/amber light was a popular device in all three focus groups with 72 percent of participants indicated that they would use it in a flagging operation, whereas 22 percent of the participants revealed that they either have 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-inch red/amber light can help alert drivers sooner while increasing the conspicuity of flaggers in work zones. Interestingly, one subject revealed that the 4-inch 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. While the 4-inch 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-inch red light did not receive the positive response (33 percent) as the 4-inch 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" STOP/SLOW paddle, creating 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 indicated that they will use the device and 56 percent 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-Inch Red/Amber Light, 2-Inch Red Light, and Flashing Headlight) Improve Flagger Effectiveness/Safety?"

Device	Would Use	Would Not Use	No Response/ No Opinion	Total
4-inch red/amber light	72%	6%	22%	100%
2-inch red light	33%	28%	39%	100%
Flashing headlight	0%	56%	44%	100%

Although portable changeable message signs 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 suffice 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-inch and 2-inch lights, as well as the flashing vests) may turn into drivers' target 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-inch red/amber light or 2-inch red light seemed to provide the flexibility, assurance and budget they need to perform their duties.

5. 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); and
- 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 which 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 include 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 needed 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. A copy of the survey questionnaire is enclosed in Appendix A.

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. Figure 17 shows the progress of the survey described.

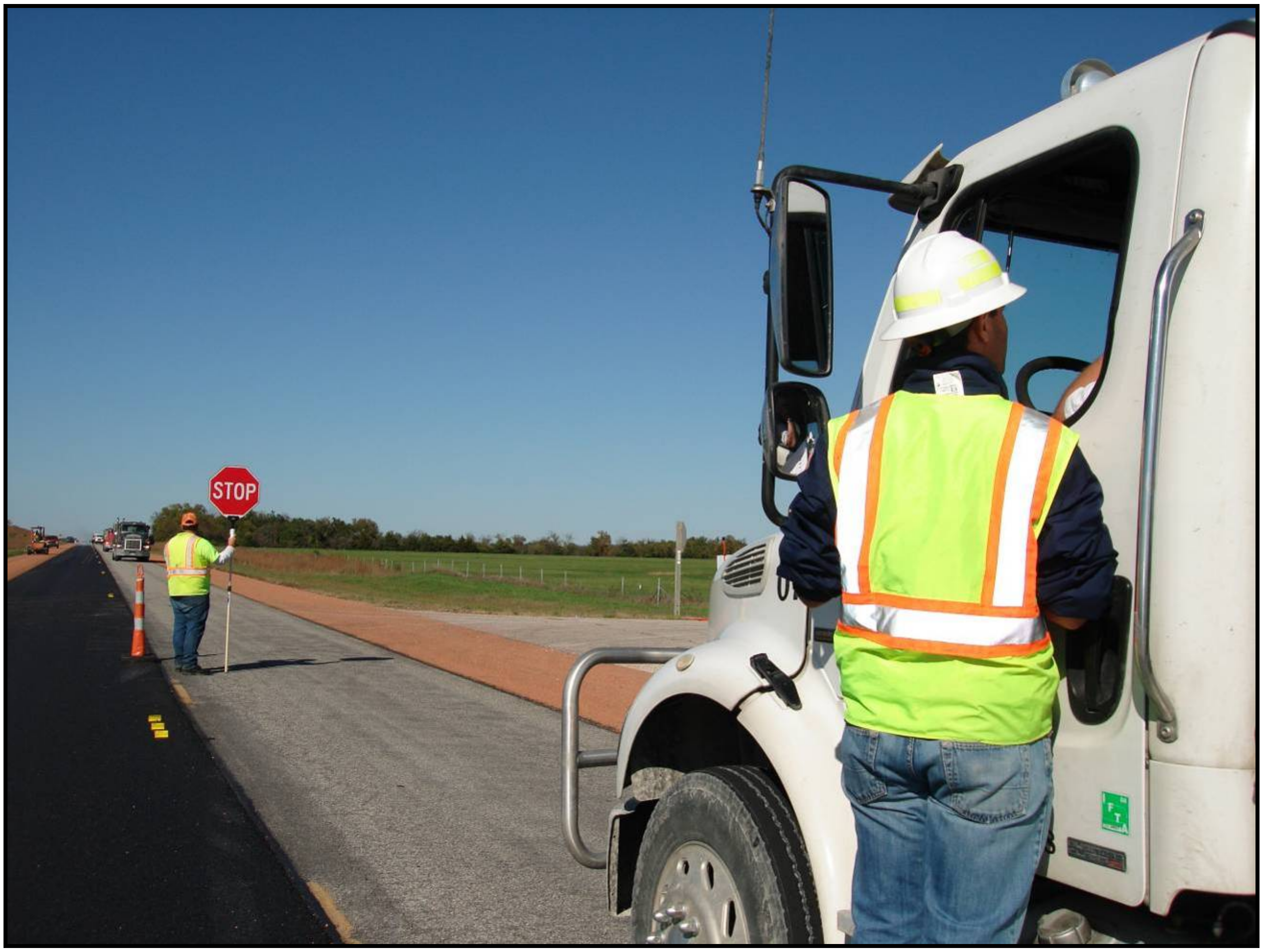

FIGURE 17 Field survey in Iola, Kansas.

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 18 shows the layout of the proposed steps described.

Figure 19 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 percent of respondents in these categories stating that they noticed them.

Figure 20 shows the overall responses to Question three: “What did you see?” Most of the drivers (70 percent) responded that they paid attention to the advance warning signs, whereas 36 percent of respondents replied that they saw the construction cones and new pavement. For the STOP sign and flagger, each of these categories received 15 percent and 12 percent, respectively. Overall, the conspicuity of STOP sign and flagger when combined together collected a total of 27 percent 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 21 shows the distribution of responses to question three described.

Figure 22 and 23 show the overall distribution of question five. Overall, most drivers (65 percent) stated that they liked the displayed STOP sign they saw, whereas 14 percent of drivers indicated that they did not like the paddle and 21 percent had no preference. When asked about their opinions regarding the displayed STOP sign, 59 percent of in-favor drivers stated that it commanded their attention, whereas the next in order 14 percent 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 percent 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 feet 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” standard or flashing STOP/SLOW paddle) seemed to provide the respect and attention they need in order to direct the traffic compared to the 18” STOP/SLOW paddle they normally used.

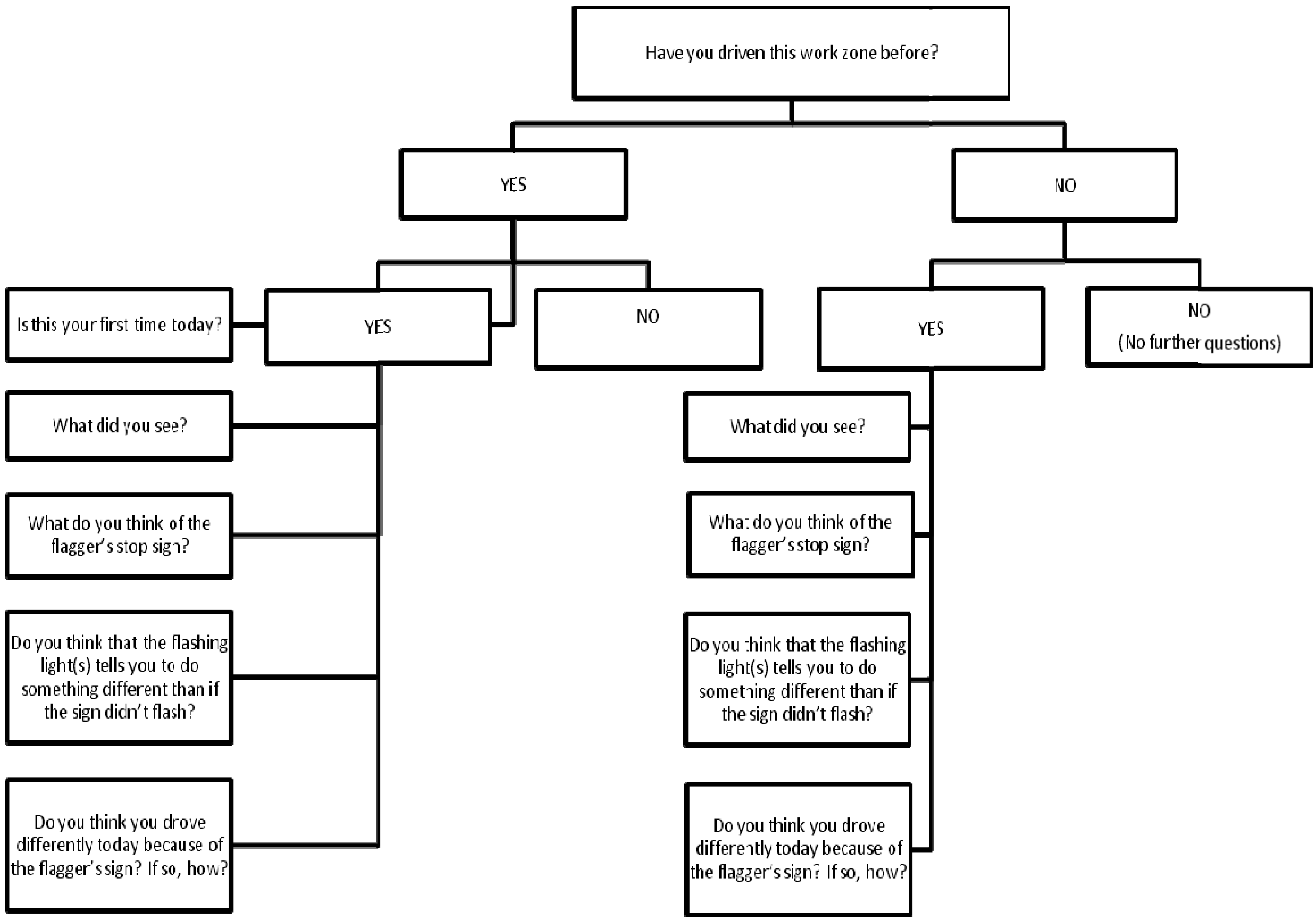

FIGURE 18 Survey questionnaire.

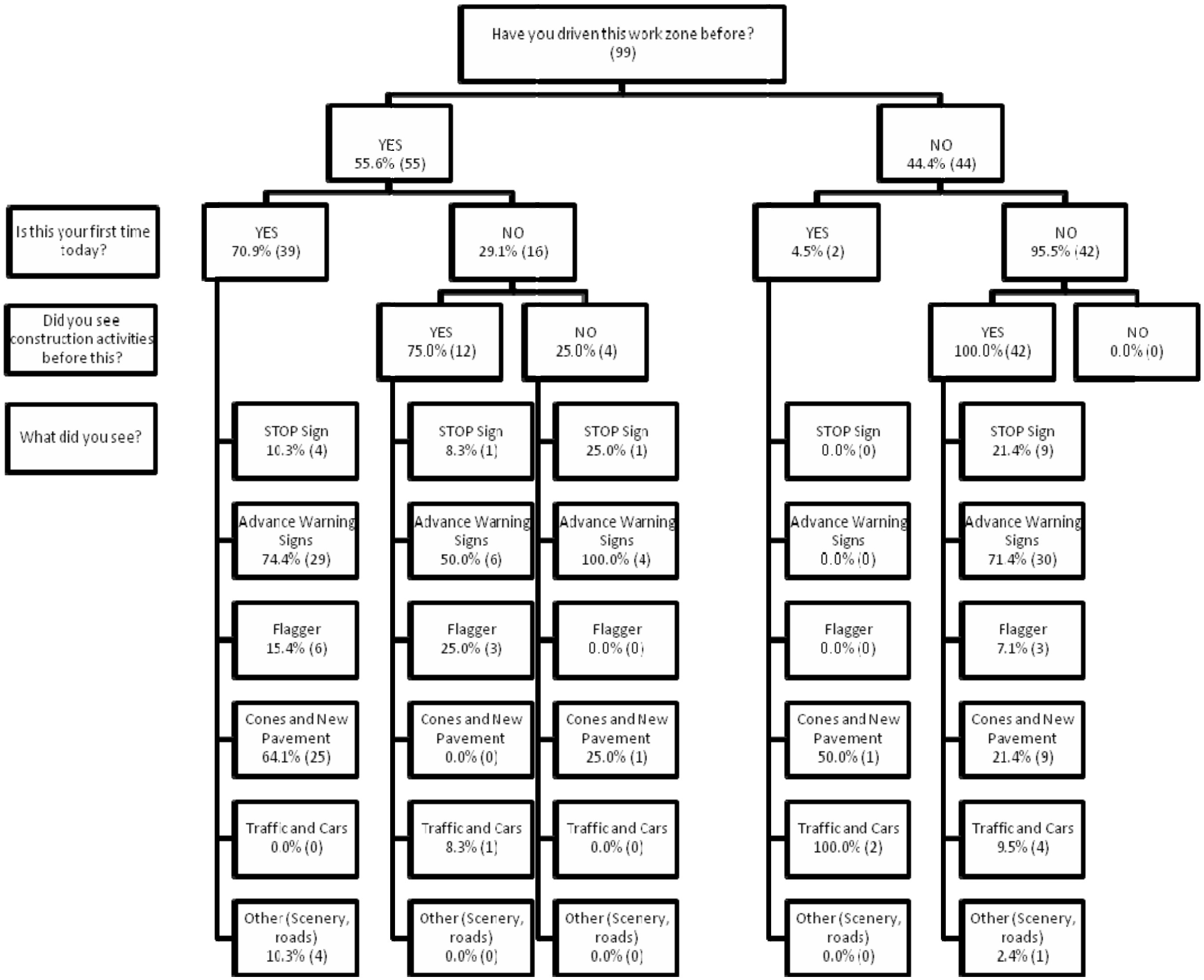

FIGURE 19 Response to question one: “Have you driven this work zone before?” two: “Is this your first time today?” three: “Did you see construction activities before this?” and four: “What did you see?”

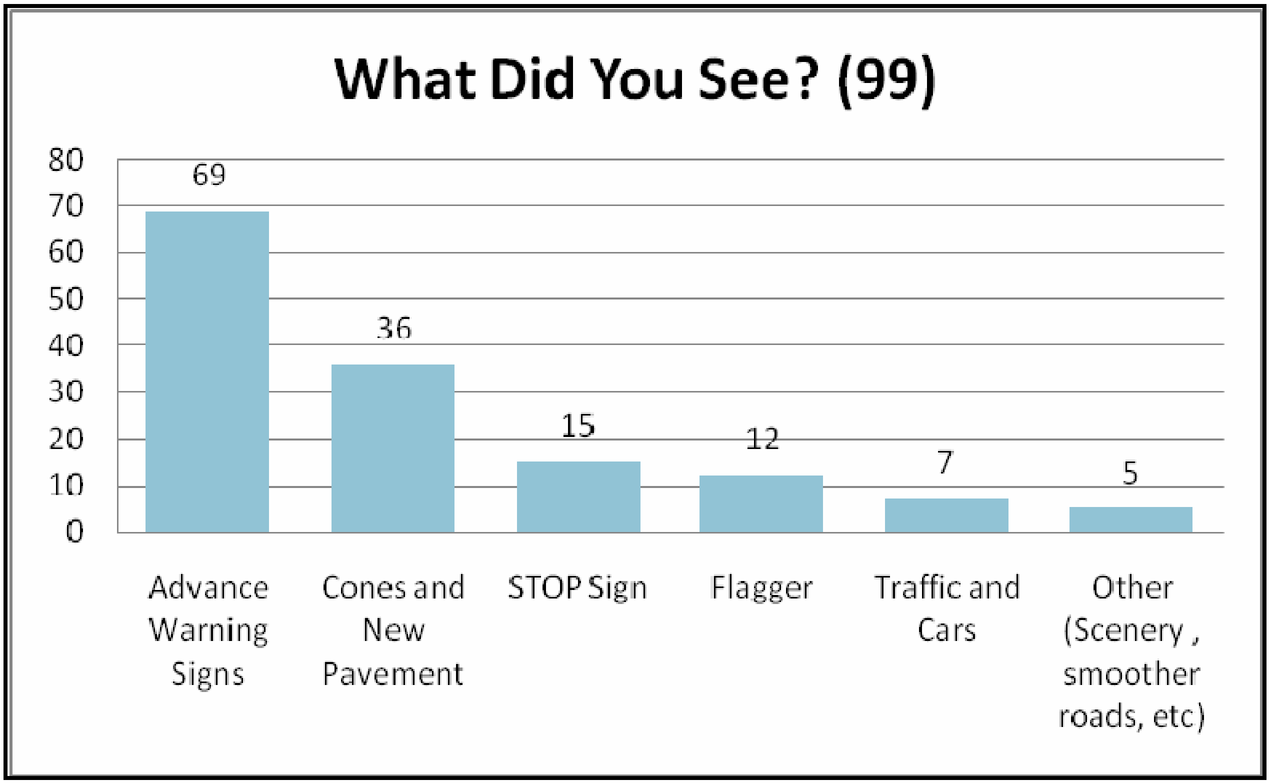

FIGURE 20 Response to question four: "What did you see?"

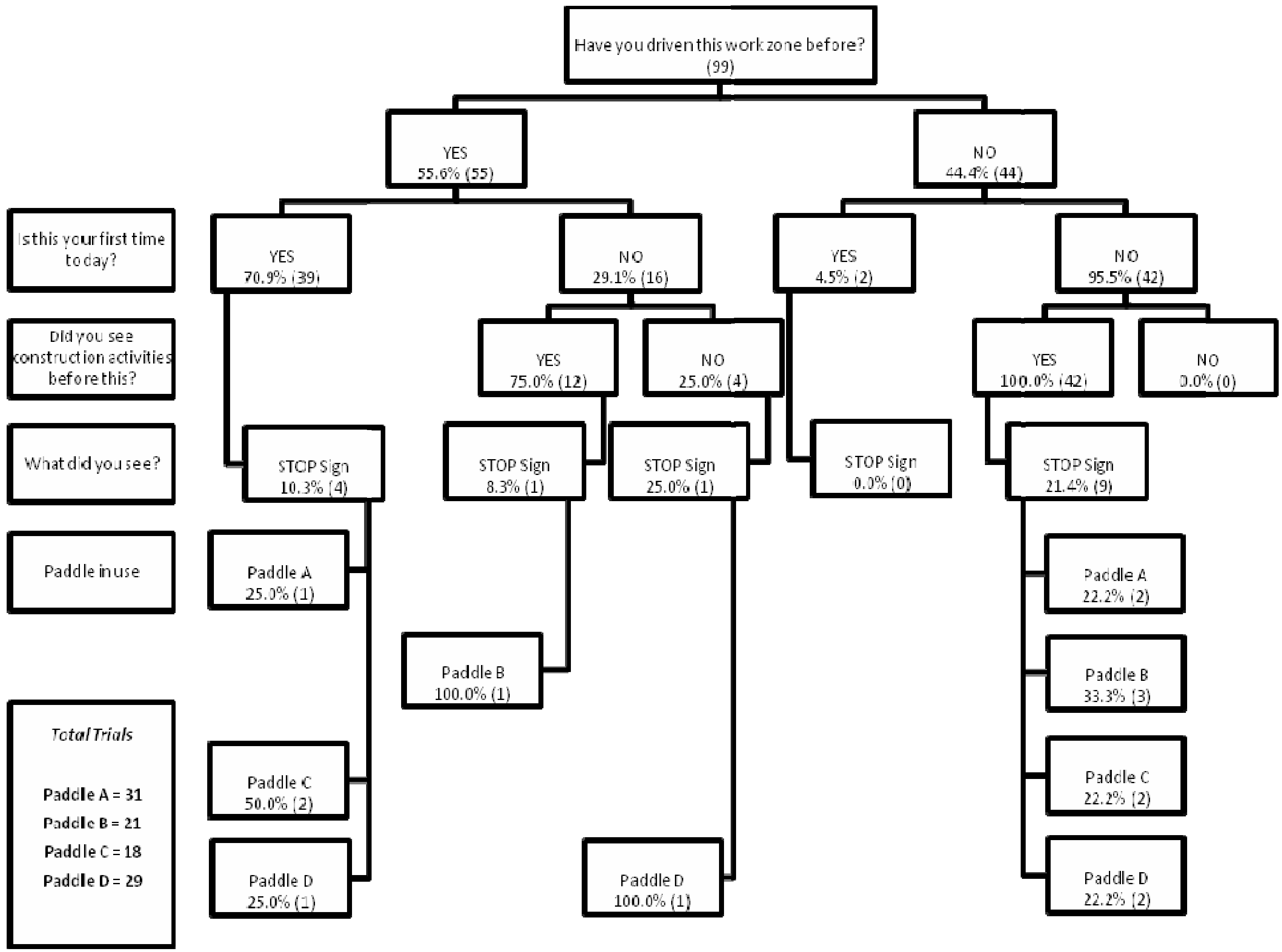

FIGURE 21 Distribution of responses to question four: "What did you see?" with respect to the STOP sign used.

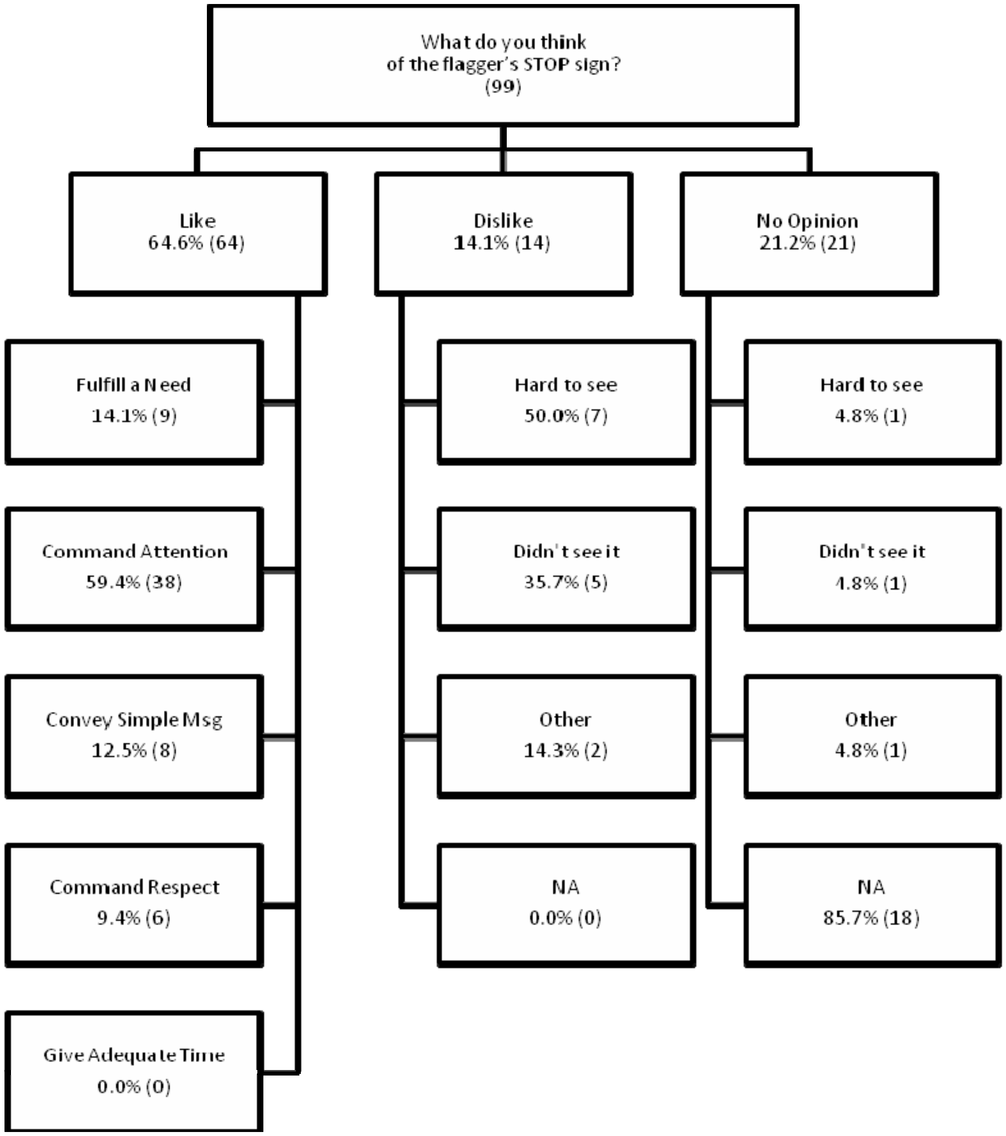

FIGURE 22 Response to question five: "What do you think of the flagger's STOP sign?"

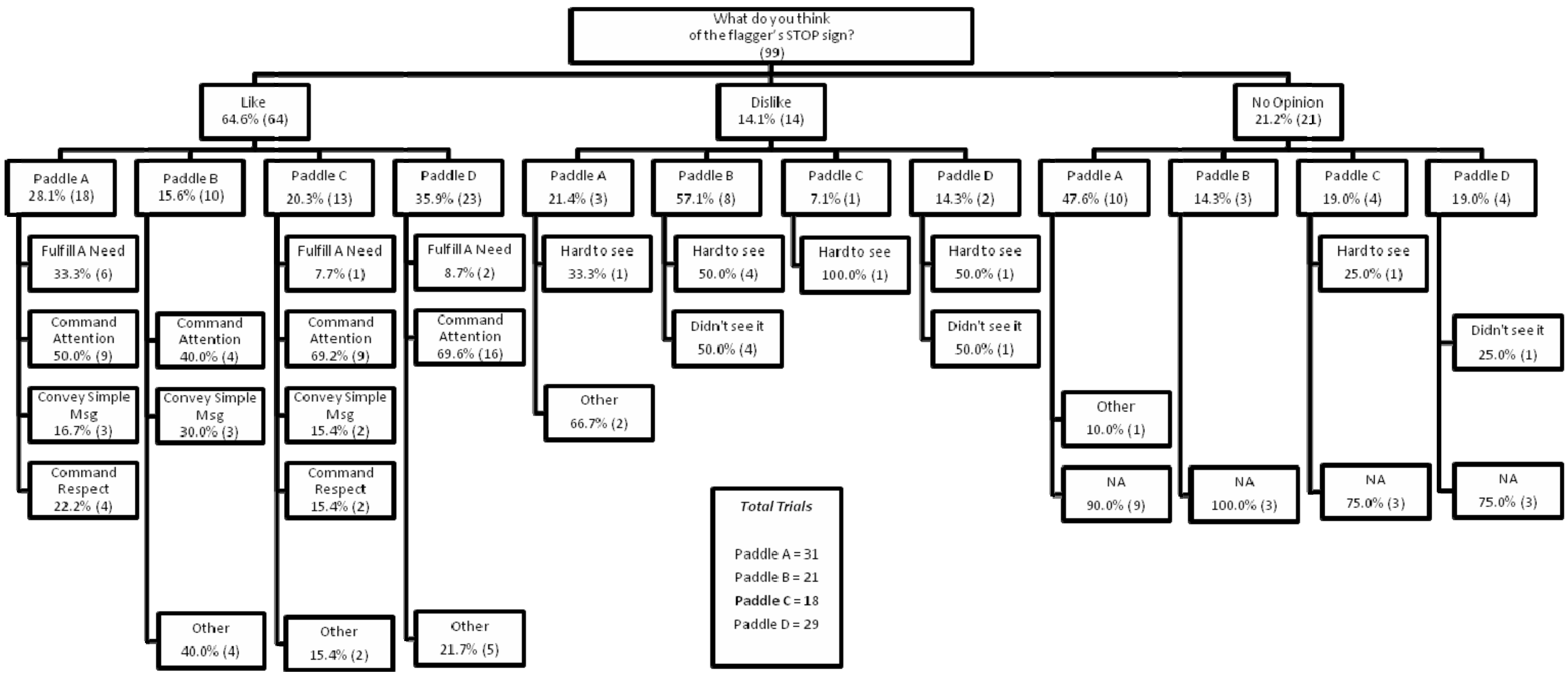

FIGURE 23 Distribution of responses to question five: "What do you think of the flagger's STOP sign?" with respect to the STOP sign used.

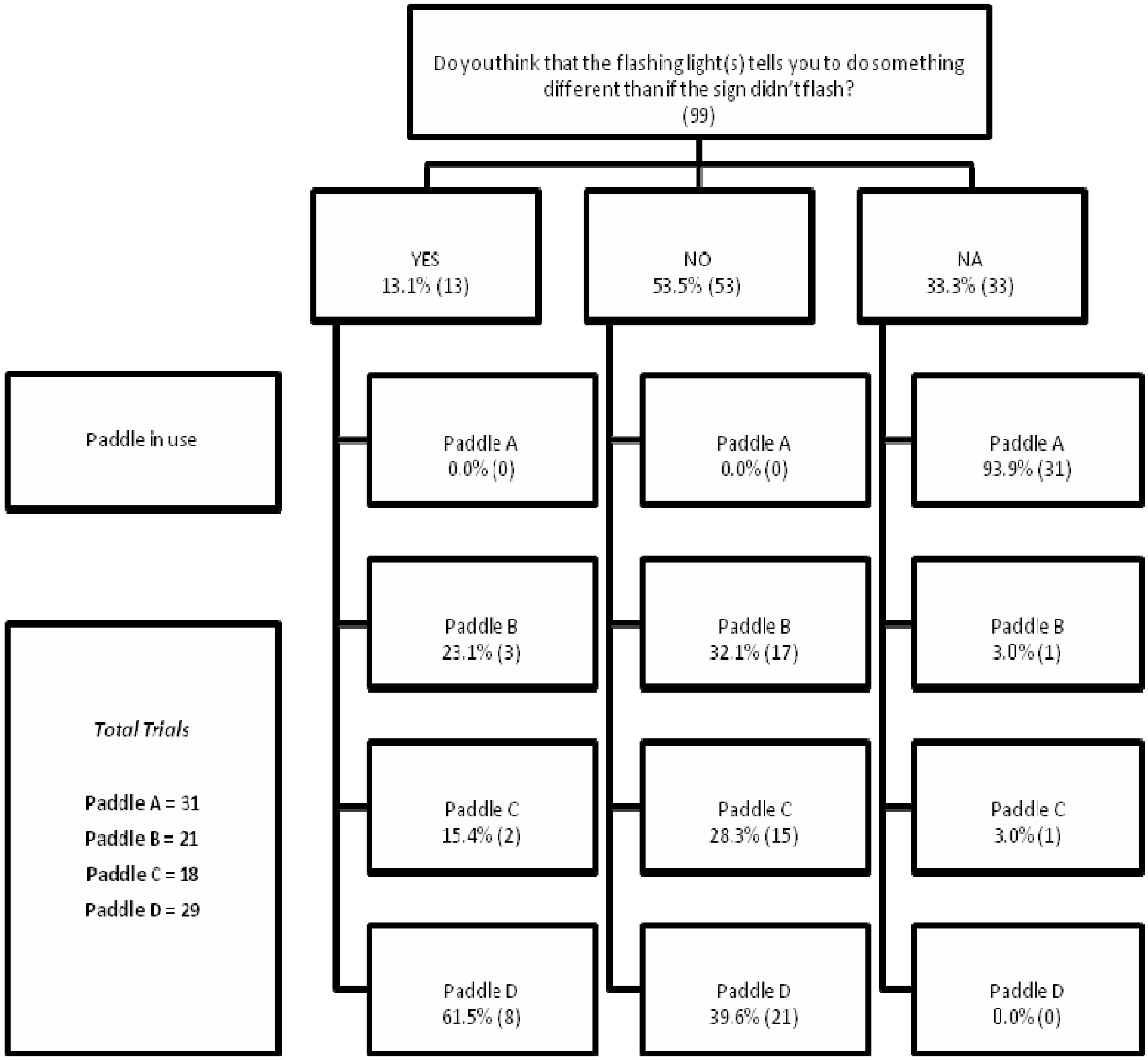

FIGURE 24 Distribution of overall responses to question five: "What do you think of the flagger's STOP sign?"

Figure 24 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 another with the flashing STOP sign that flashes alternately above and below the STOP/SLOW words received the highest response. When asked about the indication of the flashing light(s), only 13 percent of the drivers who noticed the signs replied that the flash light(s) signified a more important situation. Interestingly, more than half (54 percent) 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 25 shows the response to question six described. About one-quarter (26 percent) of the drivers indicated that they drove differently because of the flashing STOP signs, while 41 percent of the drivers replied that they did not adjust their driving. Surveyed drivers (26 percent) 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 blinking STOP/SLOW paddle received the highest response.

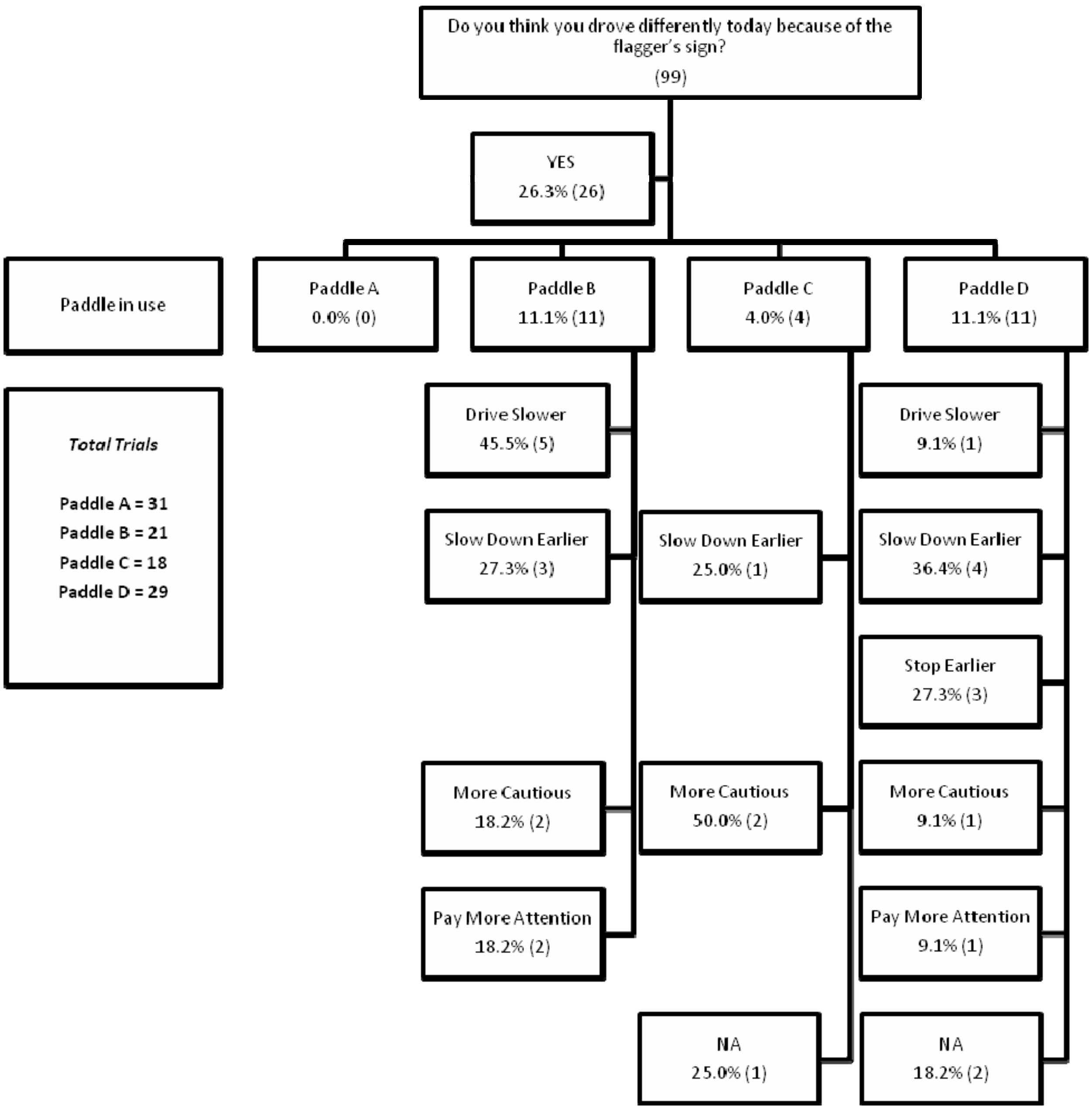

FIGURE 25 Do you think you drove differently because of the flagger's sign?

6. 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:

TECHNOLOGY EVALUATIONS

- The results of the technology examination and comparison test showed that the 2-inch red light (536 hours), Vest H (502 hours), 4-inch red/amber light (473 hours), and flashing STOP/SLOW paddle that flashes alternately above and below the "STOP" and "SLOW" words (289 hours) provided the longest blinking time than other technology device tested.
- Lab experiments showed that all of the technology-enhanced flagger devices tested lasted more than the 24-hour (full work day) window.
- While the flashing vests showed promise they are not water resistant and the lighting system failed after only three washes in a standard washing machine. As it is reasonable to expect that flaggers' apparel will become dirty from regular use this is a drawback to this product.

FOCUS GROUP EVALUATIONS

- The standard 24" 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-inch red/amber light appeared to have the best potential for large visibility gains, versatility of applications, and ease of use.
- The 2-inch red light did not receive 33 percent 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 percent of in-favor drivers stated that it commanded their attention or fulfilled a need, whereas 86 percent of those not in-favor indicated that they either did not see it or thought it was hard to see.

- More than half (54 percent) 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 percent 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” lights as a way to warn drivers that they are approaching workers in or near the roadway.

FUTURE RESEARCH NEEDS

The flaggers that participated in the focus groups felt that many of the items that were evaluated had promise for increasing conspicuity at night. Nighttime evaluations were beyond the scope of this research, but the research team believes that such an evaluation could show both the potential of these devices as well as help refine strategies for their use that maximize safety. Additionally, the research team is hopeful that flagger comments uncovered in this research, such as incorporating a radio device into the handle of a STOP/SLOW paddle, may lead product developers to continue to refine their products.

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APPENDIX A. DRIVER SURVEY GIVEN TO DRIVERS WHEN STOPPED AT FLAGGER-CONTROLLED WORK ZONES

The University of Kansas is conducting a research project studying flagger devices in temporary work zones. ***Are you willing to participate in this research project for the University of Kansas?***

Date:	Thursday,	October	16, 2008	
Time:	AM		PM	
Car Position:	1st ☐		2nd ☐	
Location:	NB ☐	SB ☐	EB ☐	WB ☐
Paddle Type:	 ☐	 ☐	 ☐	 ☐

1. Have you driven this work zone before?

YES	☐
NO	☐

→ If YES, is this your first time today?

YES ☐	NO ☐
↓	↓
Question 2	Thank You!

2. What did you see?

____

____

3. What do you think of the flagger's stop sign?

☐ **I like it, why do you like it?**	☐ **I don't like it, why do you don't like it?**
☐ It fulfills a need	☐ ________________________
☐ It commands attention	☐ ________________________
☐ It conveys a clear, simple message	☐ ________________________
☐ It commands respect of road users	☐ ________________________
☐ It gives adequate time for a proper response	☐ ________________________
☐ Other:______________________ ______________________ ________________	☐ ________________________
☐ **No opinion**	

4. Do you think that the flashing light(s) tells you to do something different than if the sign didn't flash?

____

5. Do you think you drove differently today because of the flagger's sign? If so, how?

YES ☐	NO ☐

____

Thank you for your time!