WORK ZONE POSITIVE PROTECTION POLICY GUIDANCE: SYNTHESIS OF DEVICES AND STATE OF PRACTICE

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ABSTRACT
The United States experiences over 700 fatalities and over 37,000 injuries each year in temporary construction and maintenance work zones. The Federal Highway Administration (FHWA) has implemented Temporary Traffic Control Devices 23 CFR 630 Subpart K, which specified that each state highway agency amend their work zone safety and mobility plan by 2008 to include a description for positive protection in work zones and implementation guidelines for federal funded highway projects. This research study first investigated temporal trends in national and Kansas work zone related crash trends, specifically crashes involving striking a construction vehicle or fixed object. Additionally, current work zone Test Level Three and Two (TL-3 and TL-2) approved positive protection devices were summarized including longitudinal barriers, mobile barriers, vehicle arresting systems and end protection systems. Next, a nationwide survey of state highway agencies was conducted to summarize current guidance relating to positive protection or changes in guidance to comply with Temporary Traffic Control Devices 23 CFR 630 Subpart K. Finally, the research study provided preliminary work zone positive protection guidance for the Kansas Department of Transportation based on the findings of the survey and currently commercially available products.
BACKGROUND
The United States experiences over 700 fatalities and over 37,000 injuries each year in temporary construction and maintenance work zones (1,2). The Federal Highway Administration (FHWA) has implemented Temporary Traffic Control Devices 23 CFR 630 Subpart K, which specified that each state highway agency amend their work zone safety and mobility plan by 2008 to include a description for positive protection in work zones and implementation guidelines for federal funded highway projects (3). The Federal Highway Administration (FHWA) in 2003 defined positive protection as “a device which contains and redirects vehicles in accordance with the National Cooperative Highway Research Program (NCHRP) Report 350, preventing their intrusion into the work space” (4). Positive protection devices used in work zones include portable concrete barriers with end crash cushions, sand or water filled barriers, truck-mounted attenuators, and vehicle arresting systems.

This research study first investigated temporal trends in national and Kansas work zone related crash trends, specifically crashes involving striking a construction vehicle or fixed object. Additionally, current work zone Test Level Three and two (TL-3 and TL-2) approved positive protection devices were summarized including longitudinal barriers, mobile barriers, vehicle arresting systems and end protection systems. Next, a nationwide survey of state highway agencies was conducted to summarize current guidance relating to positive protection or changes in guidance to comply with Temporary Traffic Control Devices 23 CFR 630 Subpart K (3). Finally, the research study provided suggested work zone positive protection guidance for the Kansas Department of Transportation based on the findings of the survey and currently available products.

Highway agencies have recognized work zone crashes are a serious and a growing concern with an increased demand for infrastructure repair in the United States. The National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) maintains current fatal crash counts for the United States. The database can be searched based on the presence of a work zone or not, and then can be further broken down by cause of the crash. Table 1 summarizes two sources of related information which include the number of nationwide fatal crash inside and outside of work zones, and the number of fatal crashes in Kansas work zones between 2001 and 2012.

<table>
<thead>
<tr>
<th>Year</th>
<th>Not in a work zone</th>
<th>In a Work Zone</th>
<th>Total</th>
<th>Number of Fatalities in Kansas Work Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>2001</td>
<td>41,207</td>
<td>97.7%</td>
<td>989</td>
<td>2.3%</td>
</tr>
<tr>
<td>2002</td>
<td>41,819</td>
<td>97.2%</td>
<td>1,186</td>
<td>2.8%</td>
</tr>
<tr>
<td>2003</td>
<td>41,789</td>
<td>97.4%</td>
<td>1,095</td>
<td>2.6%</td>
</tr>
<tr>
<td>2004</td>
<td>41,773</td>
<td>97.5%</td>
<td>1,063</td>
<td>2.5%</td>
</tr>
<tr>
<td>2005</td>
<td>42,452</td>
<td>97.6%</td>
<td>1,058</td>
<td>2.4%</td>
</tr>
<tr>
<td>2006</td>
<td>41,704</td>
<td>97.6%</td>
<td>1,004</td>
<td>2.4%</td>
</tr>
<tr>
<td>2007</td>
<td>40,428</td>
<td>98.0%</td>
<td>831</td>
<td>2.0%</td>
</tr>
<tr>
<td>2008</td>
<td>36,707</td>
<td>98.1%</td>
<td>716</td>
<td>1.9%</td>
</tr>
<tr>
<td>2009</td>
<td>33,141</td>
<td>98.0%</td>
<td>667</td>
<td>2.0%</td>
</tr>
<tr>
<td>2010</td>
<td>32,393</td>
<td>98.2%</td>
<td>586</td>
<td>1.8%</td>
</tr>
<tr>
<td>2011</td>
<td>31,750</td>
<td>98.2%</td>
<td>587</td>
<td>1.8%</td>
</tr>
<tr>
<td>2012</td>
<td>33,014</td>
<td>98.4%</td>
<td>547</td>
<td>1.6%</td>
</tr>
</tbody>
</table>
As shown in Table 1, between 1.9 and 2.8 percent of the total number of fatal vehicle crashes in the United States occurs in work zones. Although these percentages are low, it remains constant over the twelve-year study period as the total number of highway fatalities decrease. Additionally, it can be seen that the number of fatal vehicle crashes in Kansas are decreasing overall and are generally following national fatal crash temporal trends (5).

To understand how work zone fatalities relate to the presence or absence of positive protection, additional search criteria were inputted into the FARS database. This included investigating such variables as whether the motor vehicle strikes a construction worker or stopped/operating construction vehicle. This may mean that positive protection or an arresting system was not present to capture or redirect an errant vehicle. Additionally, the variable “strikes a traffic barrier” was inputted which means an errant vehicle lost control or ran off the road and struck positive protection device or fixed object in the work zone. Table 2 summarizes the number of nationwide fatal crashes where a vehicle struck a construction worker either in or outside of a work zone between 2001 and 2009.

<table>
<thead>
<tr>
<th>Year</th>
<th>Not in a work zone</th>
<th>In a Work Zone</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td>2001</td>
<td>6</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>27.3%</td>
<td>72.7%</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>7</td>
<td>24</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>22.6%</td>
<td>77.4%</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>7</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>33.3%</td>
<td>66.7%</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>5</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>23.8%</td>
<td>76.2%</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>5</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>23.8%</td>
<td>76.2%</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>12.0%</td>
<td>88.0%</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>16.7%</td>
<td>83.3%</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>5</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>23.8%</td>
<td>76.2%</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>4</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>16.7%</td>
<td>83.3%</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 2, the number of fatal crashes in which a construction worker was struck both inside and outside of a work zone has remained relatively constant. However, it can be seen the number of fatal crashes occurring in work zones between 2006 and 2009 are higher than fatal crashes between 2001 and 2005.

Engineering technical publications such as the American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide (7) and Chapter 6 of the Manual on Uniform Traffic Control Devices (MUTCD) have listed permanent and temporary positive protection devices (8). Many highway agencies have noted that these manuals do not provide standardized guidelines for positive protection, and current federal rulings give generous freedom to state agencies to implement positive protection guidance and policy. This ruling has resulted in many highway agencies creating a designated state MUTCD or specific policy on the design and examples of use of specific positive protection devices in work zones. Many state highway agencies have noted that specific guidelines can be beneficial to the worker and driver, especially with unique features such as tunnels, bridges, or large transportation roadway networks. This research project provides a summary of common positive protection devices, a synthesis of state highway agency guidance and policy for the use of these common devices, and recommendations for the Kansas Department of Transportation to strengthen their safety and mobility policy to include specific language to address positive protection.
LITERATURE REVIEW
A large body of knowledge exists which have investigated causes of work zone related crashes. Garber and Zhao (9) and Mahoney et al. (10) found through a synthesis of work zone crash studies that rear-end collisions account for 35 to 52 percent of all work zone crashes. Similar results were reported by Nemeth and Migletz (11) which investigated 21 work zones sites spanning 384 miles in Ohio. A total of 151 crashes were observed over a two year period. Crashes were found to increase significantly as compared to before construction conditions. Rear-end and single-vehicle fixed-object crashes were found to be the most frequent. The authors also noted that excessive speed was listed in 88 of 151 crashes as a contributing factor. A before and after work zone crash study in New Mexico by Hall and Lorenz (12) found crash experience increased by 26 percent during construction at 177 sites and run-off-road and fixed object crashes to be the most common.

Fitzsimmons et al. (13) and Maze et al. (14) summarized many commercially available products that can be implemented prior to and within the work zone to control vehicle speeds in the open travel lane. Along with the presence of a uniformed law officer, devices such as rumble strips, drone radar, automated enforcement, and Autoflagger were found to be effective in alerting drivers.

Appropriate guidelines and recommendations by state highway agencies and engineers are needed to protect work zone crews. Positive protection is one of many possible safety layers that can easily be implemented with practical step-by-step instructions provided by the manufacturer. Positive separation between work zones and traffic can lead to both societal and state highway agency benefits with the reduction in the number and severity of crashes in work zones.

Positive Protection in Work Zones
A key aspect to a safe work zone is the ability to separate workers inside the work zone from traffic which may be adjacent to the work area. Positive protection devices are designed to physically prevent vehicles and pedestrians traveling through work zones from entering space occupied by workers, equipment, materials, or roadside hazards. The following sections provide a summary of commonly used positive protection devices by state highway agencies in the United States as of 2013 that meet either test level 2 or 3 (TL-2 or TL-3) that are not considered experimental.

Portable Concrete Barrier
One of the most widely used longitudinal positive protection devices is the portable concrete barrier. Portable concrete barriers are segmented units, which are attached end-to-end by a load bearing connection. Segmentation of the positive protection devices allow for easy installation, positioning, and removal from the work zone area. Portable concrete barriers have several functions identified by the AASHTO Roadside Design Guide:

- Protect traffic from work areas such as excavation or material storage sites,
- Provide positive protection for workers,
- Separate two-way traffic,
- Protect construction such as falsework for bridges and other exposed objects, and
- Separate pedestrians from vehicular traffic.

A buffer space is typically needed behind a work zone barrier to accommodate potential deflection by the barrier system (15). The most common types of portable concrete barriers include New Jersey, F-shape, and single-slope safety shape barriers (16). However, other variations of these common designs can be found with varying height, length, width, and shape.
The impact performance of a barrier is influenced by a number of variables including barrier shape, height, segment length, joint rotation slack, joint moment capacity, joint tensile strength and friction between barrier and roadway surface (15). Portable concrete barriers are connected to each other through a variety of possible connections, most of which involve pins, plates, or rods.

As of 2011, the AASHTO Roadside Design Guide listed 15 different portable concrete barriers that met NCHRP 350 TL-3 guidelines. The approved portable concrete barriers’ deflection ranged from 6 inches to 76 which met or exceeded FHWA TL-3 guidelines. With small deflection values compared to other devices, portable concrete barriers provide the highest level of containment as compared to other positive protection devices. Minimal deflection values can be achieved by anchoring portable concrete barriers to the roadway or bridge deck using drift pins or anchor bolts. Research has also been conducted to investigate the use of four pin-and-stakes along each concrete barrier segment drilled diagonally through the pavement (17).

Noel et al. (18) identified that concrete barriers cannot easily be seen by drivers approaching work zones during the night and adverse weather conditions such as dust, fog, rain or snow. A study conducted by Mullowney (19) conducted a crash analysis of work zone crashes in which a vehicle struck a center barrier. A total of 258 crashes occurred in 1975 along a 70 mile segment, 113 crashes occurred at night and 52 occurred during wet pavement conditions at night. Research studies have investigated the effectiveness of various delineating devices for portable concrete barriers. The results of these studies have shown mixed results, however two research studies specifically mentioned vehicle headlight glare and the effectiveness of top and side-mounted delineator devices. Mullowney (20) over a 16 month study indicated that left handed curves restricted the visibility of side-mounted reflectors, and opposing headlight glare can reduce visibility of top-mounted reflectors and should be used in lighted areas. Similarly, Ugwoaba (21) studied a state of Washington highway and found devices on top of portable concrete barriers were greatly diminished with headlight glare and side-mounted delineators were much more effective.

**End Treatments**

The ends of a portable concrete barrier system need to be able to redirect an errant vehicle. The AASHTO Roadside Design Guide provides possible end treatments including the use of crashworthy cushions (7). Sand-filled barrels and a crumpling impact attenuator are two examples of crashworthy end treatments. It should be noted that many of the proprietary systems are one-time use devices and contractors need to be aware of vehicle hits for expedited repair or replacement.

Additionally, the AASHTO Roadside Design guide lists other candidate treatments including: burying the end of the barrier into the backslope, flaring the barrier away to edge of the clear zone, using a sloped end treatment, or a TL-2 barrier for the first part of the barrier system (7). It is strongly recommended that design engineers and contractors consider end treatments when designing a work zone.

**Ballast-Filled Barriers**

Ballast-filled barriers are large polyethylene containers that are typically filled with either sand or water. They are interlocked together to form a longitudinal barrier or channelizer barrier that can either redirect or provide guidance for vehicles through temporary work zones. Ballast-filled barriers are essentially used in the same capacity as a portable or moveable concrete barrier with between 6 to 22.6 feet of deflection (7, 22).

One advantage to ballast-filled barriers is the empty weight which enables workers to place, move, and tear-down the devices without specialized equipment. Although these devices are becoming more common in urban temporary work zones, a concern that must be considered is the potential for the water to freeze in the barrier. An internet search revealed that many online distributors recommend 12
pounds or 1.5 gallons of calcium chloride is added to each barrier if the temperature falls below freezing (23). Additionally, many states have implemented environmental protection policies that require water-filled barriers to be emptied and stored off-site (24).

Limited research is available as to the effectiveness of ballast-filled barriers beyond the FHWA TL-3 approval process research. However, many United States highway and contracting agencies have identified a need to warn of the risk of using appropriate ballast-filled barriers for temporary work zone protection. The AASHTO Roadside Design Guide notes that many plastic longitudinal plastic barriers are available commercially, but any ballast-filled barriers do not meet TL-3 guidelines and are not designed redirect errant vehicles. AASHTO reports that unapproved devices should not be confused by design engineers and contractors in the field as a substitute to a TL-3 approved device (7). To provide guidance for temporary work zones applications, a multi-agency supported guideline was produced in 2007 to recommend warning labels be adhered to each ballast-filled barrier warning that the device was to be used as a visual channelizing devices and not as a barrier (25).

As of 2011, the FHWA has approved four ballast-filled barriers to be in compliance with NCHRP-350 TL-2 and TL-3 guidelines. These barriers are the guardian safety barrier, the 2001M-BM, Sentry Water-Cable Barrier Wall, and the Triton Barrier TL-3. To meet TL-3 guidelines, the barriers needed structural reinforcement in addition to the weight of the plastic and water/sand. Each of the barriers listed are constructed using various reinforcement systems including external rails to internal cable or steel skeletons. Additionally, all of the barriers listed are approved to serve as their own end treatments.

Steel Moveable Barrier
An alternative to portable concrete barriers for short-term work zones are steel barriers. Steel barriers, similar to concrete barriers, are brought to the work zone site in sections ranging from 28 feet to 50 feet. This positive protection device can also be used with a concrete barrier system acting as a gate at the end of the work zone. Steel barriers can be towed behind a vehicle, moved easily using wheels or a fork lift, and can easily be taken off the roadway if the work zone has limited operations.

Limited data are available as to the effectiveness of steel barriers; however manufacturers advertise steel barriers as a higher initial cost with a longer lifespan (26). The decreased weight of the steel barrier also allows for higher deflection unless the system is anchored between the ends (24).

Movable Concrete Barrier
The Quickchange movable concrete barrier is a proprietary system designed and sold under Barrier Systems Incorporated that can be used for work zones or permanent applications. For long length and duration work zones, a movable concrete barrier system may offer a higher benefit to cost ratio over portable concrete barriers if directional flow, frequent openings and closings of lanes and changing work zone widths are needed.

Cottrell (27) describes the moveable barrier system as 39 inch long by 32 inch high by 24 inch wide concrete barrier sections weighing 1,400 pounds. Individual blocks are connected to each other by steel pins in hinges. A reversible barrier transfer machine lifts the sections off the road and repositions the sections 4 to 18 feet laterally at speeds of 5 mph (28).

A synthesis of literature conducted by Berg et al. (31) found limited research in the effectiveness of moveable barrier systems in work zones. However, five highway projects were cited and overall it was reported the moveable concrete barrier system reduced work zone congestion, enabled a faster construction schedules, and reduced user delay. Anderson and Ullman (29) stated a key advantage to the moveable barrier system is that it allows a smoother transition when closing or opening lanes around work
zones. However, Stanley (30) reported that a movable concrete barrier system in North Carolina was found to capture water on the roadway when repositioned, causing vehicles to hydroplane.

Cottrell (27) investigated movable barrier systems in Virginia from 1991 to 1992. Forty-two collisions involved striking the barrier in which no fatalities were reported and only 33 percent were found to have injuries. One collision involved a tractor-trailer which broke through the barrier system. Berg et al. (31) conducted a study to evaluate a moveable barrier system in a Utah urban corridor. The authors found that using the moveable barrier system reduced construction time by seven months, an estimated $1.7 to 2.5 million dollar savings in crash costs and travel time delay. A four-to-one benefit cost ratio with the potential of a ten to one benefit to cost ratio if variables such as reduced impact to businesses, lower air emissions, and other safety benefits were considered.

Mobile Barrier Trailer (Emerging Longitudinal Positive Protection Technology)
Mobile barriers are designed to provide positive protection for temporary, mobile, or maintenance work zone sites using a standard tractor-trailer configuration. The modified trailer provides a longitudinal barrier that provides a physical and visual wall between passing traffic and work crew personnel. Depending on the barrier type configuration, rear-end crash protection can be provided by attenuator cushions, and work zone lateral protection to divert errant vehicles can be performed by the rigid steel walls of the trailer.

Ullman et al. (32) developed a table based on previous literature and the needs of practitioners to implement highly-portable positive protection systems, in which the mobile barrier system is designed to compliment. The authors stated that a failure to meet minimum requirements would not allow work crews to utilize the device in all possible applications and would not provide safe separation from traffic.

Two types of mobile barrier systems are currently available. The first one is the Balsi Beam developed and crash tested by the California Department of Transportation, however this is not currently approved by the FHWA. The unit consists of a tractor trailer combination with the trailer converting into a 30-foot long work space between the rear axles of the tractor and the trailer with a collapsible and reversible steel beam barrier. The Balsi Beam was designed for localized activities, such as bridge deck repairs, bridge rail repairs, and bridge joint maintenance.

The other mobile barrier system is the Mobile Barrier Trailer (MBT-1) which was developed in 2007. The MBT-1 system can provide work crews with 42 to over 100 feet of protected work space between the tractor and trailer wheels. A study in Colorado (26) investigated the potential effectiveness of the application of the MBT-1 in work zones. The study focused particular attention on the benefits and limitations of lighting schemes associated with the MBT-1. The authors stated there were significant advantages to the MBT-1’s lighting schemes, programmable message board, NCHRP 350 TL-3 crash-tested barrier, and mobility. Since work zone signage and work area lighting systems are integrated with the MTB-1, the systems are always in optimal locations relative to the work activity.

A field test in New Jersey performed by Kamga and Washington (33) found that the MBT-1’s functional requirements were state-of-the-art for work zone positive protection against lateral intrusions by vehicles. The authors mentioned that the truck’s mobility both to the site and on the site was another attractive feature when considering the implementation of this equipment on a given road construction project, likely due to the decreased setup time compared to more traditional traffic control devices. They also found that using the MBT-1 at a temporary work zone required pre-planning as the unit needed to be manually converted from left and right side work zone operations. Finally, the authors noted one of the more preferred applications of the device was on straight roadway sections without ramps in the work zone.
Truck Mounted Impact Attenuators

Chapter nine of the AASHTO Roadside Design Guide describes how construction vehicles can be used as positive protection for work zones. The types of vehicles are discussed in the Roadside Design Guide include: truck-mounted impact attenuator (TMA) vehicles and advance warning trucks. A TMA vehicle is generally a large construction truck that is a vital component to a mobile temporary work zone. Michie and Bronstad (34) reported that 90 percent of these vehicles are dump trucks ranging from 22,000 to 38,000 pounds. Large vehicles provide substantial protection for work zones; however without a cushion attached to the truck, serious occupant injury can occur if a smaller vehicle strikes the rear of the truck.

Attenuators are constantly evolving with new technologies and plastics being produced and they can cost between $15,000 and $20,000 each (32). Michie and Bronstad (34) provide a comprehensive overview of the development of truck mounted attenuators in NCHRP Synthesis 182. Modern truck and trailer mounted attenuators must meet federal standards similar to those for positive protection devices such as concrete barriers by meeting NCHRP-350 TL-3 guidelines.

Common guidance on when to use a TMA vehicle and/or a truck mounted attenuator has been found for most state highway agencies. Most require a truck mounted attenuator on TMA vehicles for moving temporary work zones. However, guidance for most other applications is based on AASHTO Roadside Design Guide Table 9.3 which was originally based on research reported by Humphreys and Sullivan (35). Positive protection using a truck and an attenuator device is highly desirable for many for most work zone applications. However, under many conditions where construction crews are not exposed, it may be justified by an engineer or unique features of the work zone site.

Limited research is available on the effectiveness of truck mounted attenuators. Bryden (36) investigated New York work zone crashes for five years with a total of 461 crashes being identified. The author concluded that the truck mounted attenuators were highly effective in preventing 77 vehicles from entering the work area in which striking a truck mounted attenuator was the primary cause of the crash. Approximately one-third of these crashes resulted in vehicle occupant injury. The author also noted that the ratio of truck mounted attenuator strikes from the rear as compared to the side was four to one.

Truck mounted attenuators were also found to have a positive benefit cost ratio. A 1985 report prepared for the Texas legislature estimated a savings of $23,000 per accident in injury and damages were found as compared to a vehicle striking a stationary construction vehicle (35). Recent research regarding truck mounted attenuators has focused on visually enhancing the TMA vehicle. Smith et al. (37) developed new recommendations for truck mounted attenuation systems in New Zealand. The author recommended posting advance warning signs 400 meters (1,312 ft.) upstream of the TMA vehicle. Flashing strobe lights and retroreflective tape were shown to enhance the size and shape of the attenuator device. These recommendations were found to result in 27 percent fewer drivers merging in the last 300 meters prior to the truck. A complimenting study by Steele and Vavrik (38) found that the percent of vehicles that merged within 500 feet the truck mounted attenuator was 4.8 percent in a rural area and 12.2 percent in an urban area.

FEDERAL GUIDELINES

In 2004 the FHWA published the Work Zone Safety and Mobility Rule (Subpart J) which addressed the country’s changes in congestion, infrastructure, safety issues, and overall increase in work zones. The rule also charged state highway agencies (by 2007) to develop long-term plans to help with mobility in work zones and implementation of strategies to help manage current and future impacts during project delivery (39).

A supplement on the FHWA 2004 rule was implemented in 2007 called the Temporary Traffic Control Devices Rule (Subpart K). This rule was in response to section 1110 of the Safe, Accountable,
Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Subpart K addressed work zone topics such as expenditure of funds for uniformed law officers, positive protection measures, and installation of temporary traffic control during construction, utility, and maintenance operations (3). However, the ruling does not provide state highway agencies with requirements or recommended thresholds on positive protection usage. This gives great flexibility in developing guidelines and policies for unique characteristics that a state might have on the roadway system. The ruling also encourages state highway agencies to explore techniques to reduce the likelihood of an errant vehicle entering a work zone.

In 2012, the Moving Ahead for Progress in the 21st Century Act (MAP 21) was signed into law. Section 1405 of the bill “Highway Worker Safety” states that at a minimum, positive protection measure should be used in all work zones that offer no means of escape for workers unless an engineering study determines otherwise. Additionally, longitudinal barriers should be used for long-duration work zones (work zones in place longer than three days) with high travel speeds (> 45 mph) and within one lane-width from the edge of the travel way. This does not apply to work zones outside of urban areas and the traffic volume is less than 100 vehicles per hour. Finally, MAP 21 states positive protection devices used for work zones are paid for on a unit-pay basis.

STATE HIGHWAY AGENCY POSITIVE PROTECTION SURVEY

In the process of developing proposed work zone positive protection guidance for the Kansas Department of Transportation (KDOT), the research team conducted a survey of state highway agencies. A total of 27 agencies were sampled in 2012 that represent a good distribution of the U.S. An Internet search and follow-up phone calls with traffic operations offices provided key information on such questions as: (1) does the state have an updated safety and mobility plan or guidance that specifies positive protection? (2) What positive protection devices does the state give guidance for? And (3) What year did the guidance take affect and has it been subsequently revised? (40).

During the process of finding survey information, the research team noted that in many cases when a positive protection guidance document or the state highway agency safety and mobility plan was found and downloaded, it was outdated. This resulted in a phone call to the state highway agency work zone safety specialist who provided the documents from the agency internal servers, not accessible to the public. In two cases, draft documents were provided to the research team in which the work zone safety specialist was unsure if the document was even approved by senior personnel.

The results of the survey indicated that eight state highway agencies were in the process of updating their safety and mobility plan, specifically addressing positive protection in work zones while 15 of the state highway agencies have posted revised safety and mobility plans on public areas of their websites. Many state highway agencies have dedicated manuals to specifically address work zone positive protection. These agencies included the Colorado, Hawaii, and North Carolina Departments of Transportation. It was found that states such as Arkansas, New Hampshire, and Virginia have extensive positive protection guidance including recommended distances, type, and best practices for varying types of work zone activities and positive protection devices. Some state highway agencies have gone as far as recommended certain types of proprietary devices for positive protection and their associated guidelines that can be used under unique or certain conditions. Finally, it was observed by the research team that over half of the surveyed state highway agencies have successfully worked together in information sharing on best practices for work zone positive protection and are reflected in their guidance with similar language, references, and noted device limitations.

PROPOSED PRELIMINARY POSITIVE PROTECTION GUIDANCE FOR THE STATE OF KANSAS
Working with KDOT, the research team developed draft work zone positive protection guidance. Guidance is divided into the following areas:

- Written guidance was developed for work zone positive protection that is expected to meet federal Temporary Traffic Control Devices 23 CFR 630 Subpart K. Guidance was divided into four sections. The background section provides a short description explaining why guidelines were developed and its intended goals for the State of Kansas. The second section provides a clear definition of what positive protection is for work zones. Exposure control measures define how work crew exposure to open traffic can be limited, reduced, or eliminated using the new decision flowchart. Finally, the other Traffic Control Measures section provides a list of other measures that can be used to control exposure and which are not considered positive protection devices.

- A decision flowchart, shown in Figure 1, was created to assist individuals under the supervision of an engineer in determining and documenting how to limit, reduce, or eliminate exposure in temporary work zones. Additionally, the flowchart provides decision points where work zone positive protection is required.

- A work zone exposure control measures was created as shown in Tables 3 and 4. These tables describe commonly used KDOT exposure control measures along with approved guidance for each measure that an engineer or an individual under the supervision of an engineer can reference.

One important aspect KDOT wanted in the development of guidance was to help an individual in charge with the decision process in determining if positive protection is needed for a temporary work zone. Additionally, the guidance was setup to provide professionals with existing documents approved by KDOT to limit, reduce or eliminate exposure at work zones through various methods before considering positive protection.

DISCUSSION AND LESSONED LEARNED
Crashes at work zones continue to be a serious safety concern in both the State of Kansas and the United States. Under certain work zone circumstances, particularly long duration and setups that provide limited escape options; the protection of work crews through the use of a solid barrier that can redirect, capture, or divert an errant is critical. The federal government also reinforces this understanding through the distribution of federal guidance in which state highway agencies must address for federally funded projects. This research project was designed to aid KDOT in meeting the requirements of Subpart K and more recently MAP 21.

The research team performed an extensive literature search on positive protection devices. It was found that the positive protection device industry is constantly evolving and continuing to improve effective safety devices. Products that were reported ranged from traditional positive protection devices such as portable concrete barriers to more recent developments such as plastic barriers. A survey of state highway agencies followed the literature search, which reported as to the status of each state’s progress in meeting the requirements of Subpart K. The survey revealed that there is a broad range of information ranging from extensive information addressing positive protection to other agencies that had updated existing documentation and specifications. Overall, most state highway agencies were within one to three years of developing a comprehensive set of guidelines for work zone positive protection.
FIGURE 1 Developed positive protection flow chart for temporary work zones.

Exposure = f(x) [Distance from traffic, Volume, Number of workers, Presence of positive protection device, speed, Time workers/work zone is in place, roadway work zone geometry, preexisting roadway crash experience]
<table>
<thead>
<tr>
<th>Positive Protection Device</th>
<th>Uses</th>
<th>Requirements and limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable Concrete Barriers (PCB)</td>
<td>Separates the work area from open traffic</td>
<td>Recommended for use on all roadways. Deflection of barrier is up to 3-feet. Pinning barriers to pavement will lessen deflection.</td>
</tr>
<tr>
<td>Ballast-Filled Portable Barriers</td>
<td>Separates the work area from open traffic</td>
<td>Recommended for use on low-speed (design speed of 45 mph or lower) roadways only. High deflection requires large longitudinal buffer area behind barrier. However, as of 2012, TL-3 approved ballast-filled barriers are available for high-speed facilities.</td>
</tr>
<tr>
<td>Steel Barriers</td>
<td>Separates the work area from open traffic</td>
<td>Recommended for use on all roadways. Deflection of barrier is usually less than 3-feet upon errant vehicle impact if anchored.</td>
</tr>
<tr>
<td>Moveable Barriers</td>
<td>Separates the work area from open traffic</td>
<td>Recommended for use on all paved roadways. Ideal for dynamic a work area that requires shielding for varying widths. Initial cost and on-going operation costs are higher than other barrier types.</td>
</tr>
<tr>
<td>Mobile Barriers</td>
<td>Provides longitudinal protection and portable crash cushion for mobile or short-term work zones</td>
<td>Recommended for mobile operations and smaller work areas where a tractor and modified trailer can be used as a longitudinal shield. Work area lateral distance and material/equipment delivery may be limited depending on the location of the project.</td>
</tr>
<tr>
<td>Truck Mounted Attenuators</td>
<td>Provides a portable cushion to shield the mobile or short-term work area</td>
<td>Recommended for mobile operations and smaller work areas where a truck can be used as a shield. Roll forward distance is necessary to allow system to perform as intended.</td>
</tr>
<tr>
<td>Vehicle Arresting Systems</td>
<td>Captures an errant vehicle prior to entering the work area</td>
<td>Recommended at the entrance of work areas where a flare cannot be created using a longitudinal barrier system. Arresting systems requires attachment to a longitudinal barrier system and a backup arresting net will be needed in the event that a vehicle is captured.</td>
</tr>
</tbody>
</table>

\*All barriers listed as Positive Protection Devices, except truck mounted attenuators require the use of a crashworthy end treatment\*

\*All devices listed, including their end treatments, shall be approved by the FHWA and KDOT prior to use*
### TABLE 4  Recommendations for Exposure Control Measures (Referred to as Table B in Figure 1)

<table>
<thead>
<tr>
<th>Measure to Remove / Reduce Exposure</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full road closure(s) / detour(s)</strong></td>
<td>Complete closure of the roadway. Only work vehicles and local traffic (where available) are allowed access.</td>
</tr>
<tr>
<td><strong>Highway Ramp closure(s)</strong></td>
<td>Similar to &quot;full road closure(s)&quot; except for either an on-ramp or off-ramp of a highway</td>
</tr>
<tr>
<td><strong>Median crossover(s)</strong></td>
<td>A &quot;break&quot; in the median to access contra-flowed lane(s)</td>
</tr>
<tr>
<td><strong>Full or partial diversion(s)</strong></td>
<td>Use of a temporary road to divert traffic around the work area.</td>
</tr>
<tr>
<td><strong>Performing work when traffic volumes are low</strong></td>
<td>Night closures and rescheduling the work hours when errant vehicle occurrences are less likely to occur.</td>
</tr>
<tr>
<td><strong>Accelerated Construction to reduce project time</strong></td>
<td>Reducing the project time to minimize worker exposure to traffic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KDOT Policy, Guidance, Standards, or Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDOT Detours, SOM 1.11.4</td>
</tr>
<tr>
<td>TE 702</td>
</tr>
<tr>
<td>TE 740 and TE 742</td>
</tr>
<tr>
<td>TE 736 and TE 737</td>
</tr>
<tr>
<td>Lane Closure Chart</td>
</tr>
</tbody>
</table>
Finally, this project provided KDOT with two important items to aid in fulfilling the requirements of Subpart K. The first was a flow chart, which is designed to assist a junior level engineer, decided if positive protection is needed and under what circumstances specific to Kansas. This flowchart was modeled after other state highway agencies, which reported positive feedback for this approach. The research team took the idea of helping a junior level engineer at KDOT to one more level by providing specific guidance within KDOT specifications and documentation for different exposure types. Overall, it was found that this approach was well received by KDOT officials and the proposed method developed here is being sent through the approval process to be adopted as a guideline.

ACKNOWLEDGEMENTS
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REFERENCES


