Applied Research and Innovation Branch

Automated Placement and Retrieval of Traffic Cones

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16. Abstract

This research report documents the findings of an investigation into automated temporary traffic control device (TTCD) deployment and retrieval technologies. The researchers used a literature review to gather product relevant product information from manufacturers and vendors. The survey of transportation agency contacts was used to identify automated TTCD deployment and retrieval technologies and agency experiences. The researchers found that some automated TTCD deployment and retrieval products may reduce one or more types of worker risk while increasing other types of risk. A fully automated product has the potential for the greatest risk reduction overall, but also has a much higher cost than less complex systems. Partially automated systems may reduce opportunities for worker injury due to TTCD lifting and lowering mechanisms, but they may also introduce increased opportunities for workers to fall from their platforms. Systems with no automation offer the least benefit, but also have lower costs.

Implementation

Steps to implementation include:

(1) CDOT will need to determine which TTCD setup and removal systems best fit into their risk-balancing practices by reviewing the types of injuries that CDOT maintenance forces have experienced and comparing them to the types of injuries that each TTCD setup and removal system can reduce or eliminate.

(2) If CDOT is interested in a fully-automated system, consideration should be given to performing a peer exchange with the Minnesota DOT, which has recently procured and is now using such a device. CDOT should contact their Federal Highway Administration (FHWA) Division to explore the funding potential for such a peer exchange.

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EXECUTIVE SUMMARY

The placement and retrieval of lane closures is one of the most hazardous activities that maintenance crews perform on a daily basis. It generally requires two workers, one driving the vehicle and one standing in a well on the back of the truck. During deployment, the worker on the back of the truck is leaning out, placing the cones, and has minimal protection from the other vehicles on the roadway. When picking up the lane closure, the truck backs up the highway while the worker on the back leans out and retrieves the cones. The act of backing up a closed lane can be hazardous. Leaning out from the vehicle placing and retrieving a 15 to 30 lb cone can contribute to worker injuries, such as sprains and strains. This potentially increases workers' compensation claims and injury lost time.

Colorado Department of Transportation (CDOT) contracted with the Texas A&M Transportation Institute (TTI) to investigate the available automated cone placement and retrieval devices and recommend best practices for automated traffic cone placement and retrieval. To accomplish this, the research team used several research tools to collect information on automated and manual temporary traffic control device (TTCD) deployment and retrieval technologies, including: a literature review, a survey of relevant transportation agency practices, and a survey of product vendors and manufacturers.

Initially, the researchers hoped to find several fully automated systems for which attributes could be compared, but only one fully automated product was available on the market. Others were only partially automated, had no automation, or could only be used to move TTCD across a lane from a staged location. In many cases, transportation agencies developed and fabricated their own in-house systems. The researchers created a matrix that itemizes the expected cost and relevant risk-reducing characteristics of each system that was commercially available at the time of this writing. The researchers could not recommend any one product over the others, but do recommend that CDOT perform a relative risk tradeoff assessment to determine if purchasing any of the systems would be appropriate.

The results of this research can be used by CDOT to improve maintenance crew practices, reduce workers' compensation claims, and reduce lost time accidents. All of these objectives contribute to increased safety of CDOT crews, which is the primary benefit of this research.

Implementation Statement

The results of this research included the following recommendations:

(1) CDOT will need to determine which TTCD setup and removal systems best fit into their risk-balancing practices reviewing the types of injuries that CDOT maintenance forces have experienced and comparing them to the types of injuries that each TTCD setup and removal system can reduce or eliminate.

(2) If CDOT is interested in a fully-automated system, consideration should be given to performing a peer exchange with the Minnesota DOT, which has recently procured and is now using such a device. CDOT should contact their Federal Highway Administration (FHWA) Division to explore the funding potential for such a peer exchange.

Ultimately, if the implementation of automated or semi-automated TTCD setup and removal systems results in reducing or eliminating an injury to one worker, tens of thousands of dollars could be saved. If the one worker fatality is eliminated, millions of dollars could be saved.

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CHAPTER 1 INTRODUCTION

The setup and removal of temporary traffic control devices (TTCD) is a task performed by maintenance crews on a daily basis. These workers are at risk of bodily injury any time they perform work within the public right of way. The primary types of injury that can occur include: 1) strains or sprains from lifting and/or lowering channelizing devices between the truck and pavement, 2) falling from a truck platform, and 3) being struck by an errant vehicle.

In an effort to reduce injury risks, many agencies have considered using automated TTCD setup and removal equipment/products. These products may include lifting and/or lowering mechanisms that move the TTCD for the worker, fall restraints such as tethers or cages, and/or configurations that remove the worker from the pavement entirely (to reduce injury severity during an errant vehicle event).

Colorado Department of Transportation (CDOT) contracted with the Texas A&M Transportation Institute (TTI) to investigate the available automated cone placement and retrieval systems and recommend best practices for automated traffic cone placement and retrieval. To accomplish this, the TTI research team used several research tools to collect information on automated and manual temporary traffic control device (TTCD) deployment and retrieval technologies. These research tools include a literature review, a survey of relevant transportation agency practices, and a survey of product vendors and manufacturers. The results were sorted into the following categories: fully automated systems (Chapter 2), partially automated systems (Chapter 3), systems with no automation (Chapter 4), TTCD pushing systems (Chapter 5), and systems developed by transportation agencies (Chapter 6). Chapter 7 provides the TTI research team's conclusions and recommendations.

CHAPTER 2 FULLY AUTOMATED TTCD SETUP AND REMOVAL SYSTEMS

These fully automated products were identified by the researchers:

- California Department of Transportation's (CalTrans's) Cone Machine.
- Traf-Tech ACT240.
- Centreville AutoCone 130 and AutoCone 500.

At the time of this writing, the Centreville AutoCone 500 is the only fully automated cone-placement and retrieval product known to be in use in the United States.

2.1. CalTrans Cone Machine

In the mid-1990s, researchers at CalTrans Advanced Highway Maintenance and Construction Technology Center (AHMCT) developed and tested one of the first automated cone placement and retrieval products (*1, 2*). The AHMCT Cone Machine (Figure 1) can set cones in the forward travel direction and retrieve them in either forward or reverse at speeds up to 10 mph. It requires only one worker to operate. The driver controls the placement and retrieval of cones from inside the truck cab. The machine was designed so that manual operation, as currently performed, would still be possible in the event of unusual circumstances. It was designed to handle generic 28-inch cones and can store about 80 cones on-board. The AHMCT Cone Machine was capable of retrieving upright or knocked-over cones on either the left or right side while traveling either in a forward or reverse direction (*3*). The AHMCT Cone Machine was developed for research purposes and was never used in the field by CalTrans workers (*4*). It was commercialized by a California company but is not currently available for purchase due to licensing issues. It is not known if these issues will be resolved any time in the near future (*5*).

Figure 1. CalTrans cone machine truck (*5*).

2.2. Traf-Tech ACT240

In 2005, the Traf-Tech Corporation produced a fully automated commercial cone machine. It could be operated by one person who also drove the truck. This machine (Figure 2) held 240 cones and was produced as the Automated Cone Truck (ACT240). It could automatically set the cones at 25-ft, 50-ft, or 100-ft spacing on the roadway traveling forward and could collect them traveling forward or in reverse. Other spacing increments could be set manually. However, the ACT240 had limited usefulness because it could only accommodate 28-inch cones. It was later modified to accommodate 36-inch cones. Original retail pricing was approximately $75,000 (*6*). Several older videos are available online (*7*). Field experiences with the ACT240 were somewhat negative. A Virginia-based traffic control provider purchased one of these machines and reported numerous problems with its performance and usefulness (*8*). Traf-Tech is no longer in business.

Figure 2. Traf-Tech automated cone truck (ACT240) (*6*).

2.3. Centreville AutoCone

Centreville Manufacturing, Inc. produces the AutoCone in both trailer-mounted and truck-mounted formats. The AutoCone 130 trailer was developed as a fully automatic cone placement and retrieval device and marketed by Centreville Trailer. It can be towed with a standard half-ton pickup truck and operated by the truck driver using the light switch and turn signals of the truck. As shown in Figure 3, the trailer consists of a large circular storage chamber that holds up to 136 36-inch cones. At the front of the trailer, there is a mechanical arm that dispenses cones to either side of the trailer and a retrieving chute that can pick up the cones and return them to the storage chamber (*10*). Several videos demonstrating the operation of this product can be found online (*11, 12*). At this time, the researchers have not identified any transportation agencies that have experience using the AutoCone 130.

Figure 3. Centreville AutoCone 130 (*9*).

Because deployment of lengthy work zones may require more than 130 cones, the need for a larger capacity storage chamber was evident. Centreville redesigned the AutoCone 130 and now also markets the truck-mounted AutoCone 500 (Figure 4). This unit can carry up to 500 28-inch cones, can place and retrieve cones from either side of the truck, and can do so in forward or reverse travel. The unit can be purchased in either truck-mounted or trailer-mounted formats (*13*). Pricing depends on the final configuration. A video demonstrating the operation of this product can be found online (*14*).

Figure 4. Centreville AutoCone 500 (*13*).

Recently, Minnesota Department of Transportation (MnDOT) purchased an AutoCone 500 and had the manufacturer install the equipment on a MnDOT-owned truck (a 1993 Ford F700) (Figure 5). MnDOT took delivery of the truck with the retrofitted AutoCone 500 in May 2016 for a cost of approximately $80,000, and maintenance crews have been using the equipment for approximately one year as of this writing (*15*).

Figure 5. MnDOT AutoCone 500 truck (*16*).

An interview with MnDOT staff revealed that there were some issues with cold weather operation of the AutoCone 500. A small diesel engine located above the truck cab runs the 24-volt generator that charges the batteries and runs the air compressor. The fuel tank for this engine is mounted along the truck frame down below, making it difficult to keep the fuel flowing up to

the engine. In addition, the compressor runs continuously during operation and that heat results in condensation in the air lines, which can freeze up in cold weather. MnDOT staff are considering swapping this system for a standalone compressor/generator similar to those found in mechanics' service trucks. At this time, it is not known if the manufacturer will incorporate this modification into the assembly of AutoCone 500 systems in the future.

MnDOT staff also found that, like any mechanical equipment, the operator will occasionally need to make some minor adjustments when operating this equipment. Having a few regular operators that are familiar with (and know how to adjust) the AutoCone 500 is beneficial. MnDOT staff have been very pleased with the manufacturer's ongoing responsiveness to their needs and willingness to provide generous phone support. At this time, MnDOT does not have plans to purchase additional AutoCone 500 units. MnDOT staff in the Owatonna Subarea office have offered to conduct an operational demonstration at their facility for staff from other agencies that may have an interest in this equipment (*17*).

CHAPTER 3 PARTIALLY AUTOMATED TTCD SETUP AND REMOVAL SYSTEMS

Partially automated systems are those that eliminate the lifting task for workers, but require at least one worker to stand on a platform to feed cones into the system and operate the lifting/lowering mechanism that moves the cones. Another worker must still drive the truck. The researchers identified two partially automated systems:

- J-Tech Dynamic Lift System (DLS).
- Roadrunner System.

3.1. J-Tech Dynamic Lift System

The J-Tech DLS (Figure 6) enables workers to deploy and retrieve vertical panels and is not designed for use with any other types of channelizing devices. While a hydraulic arm is used to raise and lower the platform supporting the vertical panel, a worker must still reach over a railing to slide the vertical panel from the platform to the pavement. This can be more easily seen in the online video for this product (*18*). The DLS system includes the J-Tech truck body, rear basket, hydraulic system, and platforms. The cost is approximately $40,000 to have the DLS system installed on a customer-supplied truck chassis. There is one Pennsylvania Turnpike Commission (PTC) contractor who is using this equipment on PTC jobs. There are no state departments of transportation or tollway agencies using the DLS, primarily because they are not willing to switch out their channelizing device inventory for vertical panels (*19*).

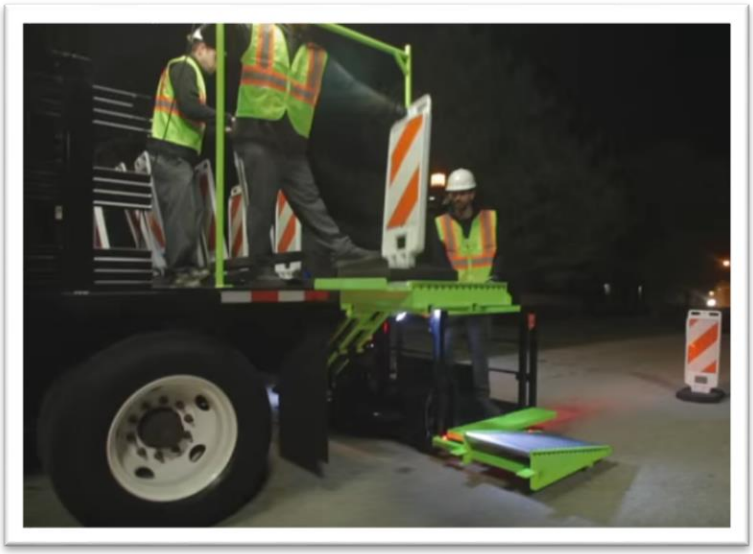

Figure 6. J-Tech DLS (*18*).

3.2. Roadrunner System

The Roadrunner System is based on a system initially developed by Illinois Tool Works. It is now produced and marketed by Epic Solutions and distributed by Royal Truck and Equipment. The system accepts cones up to 36-inches tall and consists of two parts: a cone setter and a cone retriever (Figure 7). The cone setter can be mounted in the stake pockets on either side of any flatbed truck. It requires one or two workers to operate (depending on the deployment speed) plus a driver for the truck. The workers place a cone in the cone stop at the top of the device and a separate handheld control is used to release each cone so it can slide down the rails and onto the pavement. A programmable timing package is also available. This allows the setter to dispense cones at an established rate, based on the speed of the vehicle. Videos on the manufacturer's webpage show how the setter operates (*20*).

The cone retriever requires only one person in the truck bed to operate the handheld controls and unload cones from the retriever unit (which can accumulate up to five cones at a time). The retriever tips each cone on its side, where it slips into a cage over a cone-shaped prong that rotates it into a vertical position and lifts it to the top of the cage. It can pick up cones in a forward or reverse direction, depending upon how it is mounted to the truck. Videos on the

manufacturer's webpage show how the setter and retriever operate (*21*). The cost for an installed Roadrunner System is approximately $35,000 (*22*).

Figure 7. Epic Solutions Roadrunner System (*20, 21*).

Traffic Engineering Services (TES), a contractor in Maryland, is using the Roadrunner System with 36-inch cones on one of their TTCD trucks. TES reported that they initially had some issues with the cones getting jammed in the retriever, but made some adjustments that resolved the problem. Now the cones rarely become jammed. TES has also been very pleased with the manufacturer's customer service. TES purchased the Roadrunner System as part of a truck package that included a new truck chassis, stake body, message board, and attenuator for approximately $120,000 (*23*).

CHAPTER 4 OTHER TTCD SETUP AND REMOVAL SYSTEMS

There are numerous other commercial products available to assist workers with placement and retrieval of TTCD. These systems have no automated or semi-automated device handling equipment installed and include:

- Centreville Roadway Safety Trailer.
- J-Tech Baskets.
- Royal Truck Cone/Safety Pattern Truck.
- S.P.A. Safety System Cone Truck.

4.1. Centreville Roadway Workzone Safety Trailer

The Centreville Roadway Workzone Safety Trailer is built on a 17-ft trailer base and can be towed with a standard pickup truck. It holds up to 30 drums and drum bases, over 100 cones, and 16 sign stands. The cost is about $15,000 (*24*).

Figure 8. Centreville Roadway Workzone Safety Trailer (*25*).

4.2. J-Tech Baskets

J-Tech manufactures and sells two types of baskets. The large, steel basket has a 4-ft by 8-ft floor and is permanently mounted to a large truck such as the one shown in Figure 9. A unique

feature of this product is that the basket can be hydraulically raised and lowered to approximately 3 inches above ground, which allows workers placing TTCD to be closer to the pavement. This setup requires at least three workers to operate, including the driver. The cost to have the stake body and large basket installed on a customer-supplied chassis is approximately $25,000 (*19*, *26*).

Figure 9. J-Tech large basket (*26*).

The smaller, aluminum basket (Figure 10) has a 3-ft by 6.5-ft floor and can be moved to different vehicles as needed. The basket height is adjustable and has two settings: travel height and working height. Workers can pull cones from the pickup truck bed and deploy them from the platform. This unit costs approximately $9,000 (*19*, *27*).

Figure 10. J-Tech small basket (*27*).

4.3. Royal Truck Cone Safety Pattern Truck

Royal Truck manufactures custom trucks for TTCD placement and retrieval with various optional equipment, such as truck-mounted attenuators, rear baskets, and lower side decks. Several Ohio Department of Transportation (ODOT) maintenance crews are currently using these trucks during maintenance operations. Figure 11 shows one of these trucks (*28*).

Figure 11. Royal Truck used by ODOT crews.

4.4. S.P.A. Safety Systems Cone Truck

S.P.A Safety Systems also manufactures custom cone trucks. The truck shown in Figure 12 has a 20-ft truck body and rear basket. Depending on the options selected, the truck sells for approximately $60,000 (*29*).

Figure 12. S.P.A. Safety System cone truck (*30*).

CHAPTER 5 TTCD PUSHING SYSTEMS

There are also several commercial products that shift TTCD across a lane. They do not place or remove TTCD. Instead, they simply move a line of channelizing devices laterally across the lane to open or close the lane. These devices include:

- Artec Innovation Sidewinder.
- Barrel Mover 5000.
- SCR Industries Barrel Picker Pro.
- Synergy Innovations Safety Shift.

5.1. Artec Innovation Sidewinder

The Artec Innovation Sidewinder (Figure 13) is a plow-type system that mounts to a customer's plow truck. It allows the driver to use hydraulic systems to control the plow angle and position. The plow can extend across two lane widths, which is a unique feature that other plow-type TTCD-pushing devices do not have. The contact surface with the channelizing devices consists of rollers that allow the devices to slide along the plow. It also folds for transport. Online videos are available on the manufacturer's website (*31*). The manufacturer reported costs near $100,000 per unit. There are a few contractors in Canada who use this device, but none in the United States (*32*).

Figure 13. Artec Innovation Sidewinder (*31*).

5.2. Barrel Mover 5000

The Barrel Mover 5000 is another pushing system that mounts to the front of a truck (Figure 14). The system can be mounted to a three-quarter ton pickup truck with just four bolts after removing the tow hooks. The system has rollers that allow the drums to slide across the lane and is relatively light weight compared to the Artec Innovation Sidewinder. It has no hydraulic control system (*33*). The manufacturer sells this product for $20,000, and several contractors in Kentucky and Indiana are using it with great success (*34*).

Figure 14. Barrel Mover 5000 (*33*).

5.3. SCR Industries Barrel Picker Pro

SCR Industries designed and fabricated an attachment for a skid-steer loader that can be used to pick up and relocate drums. It can be easily installed by customers on their own skid steer. In addition to moving drums across lanes, online videos show the device being used to load drums into the back of a dump truck where a worker stores them (*35*). Figure 15 shows the Barrel Picker Pro. This product is used by a few contractors in Michigan. The manufacturer reported a cost of approximately $4,300 for the device (*36*).

Figure 15. SCR Industries Barrel Picker Pro (*37*).

5.4. Synergy Innovations Safety Shift

The Safety Shift (Figure 16) moves channelizing drums and cones across a single lane. It attaches to the front of a standard truck and can shift the devices across the lane while traveling up to 15 mph. The surface that contacts with the channelizing devices is made from a propriety material. It folds for transport from one location to another and costs around $13,800 (including the snow plow mount). If the customer's truck already has a snow plow mount and does not need the Safety Shift mount, the price is $7,500 (*38*).

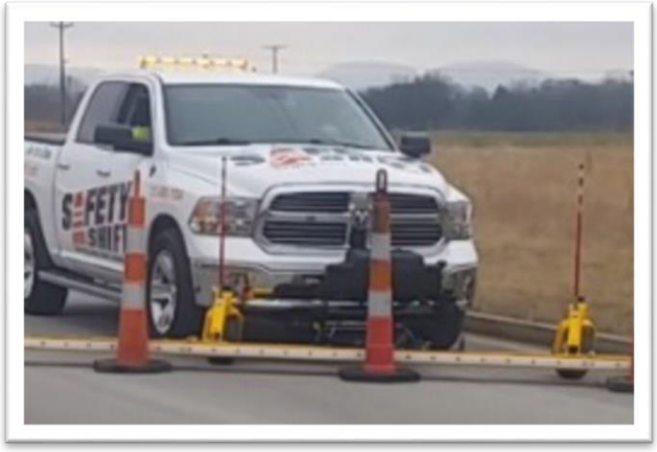

Figure 16. Synergy Innovation Safety Shift (*39*).

CHAPTER 6 TTCD SETUP AND REMOVAL SYSTEMS DEVELOPED BY TRANSPORTATION AGENCIES

The researchers found that several agencies involved in roadway construction and maintenance activities have designed and fabricated their own TTCD placement and retrieval equipment at a significantly lower cost than the purchase of commercial products.

6.1. Delaware Department of Transportation Cone Trailer

Delaware Department of Transportation (DelDOT) designed and fabricated two cone trailers (Figure 17). The trailer has a caged cone storage area, a covered path for one worker to access cones, and seats on both sides for a worker who is placing (or retrieving) cones. Including the driver, the operation requires three workers (*40*). The trailers were later modified to include some improvements (Figure 18). The cover was extended to the full length of the trailer, brighter paint colors were used, and an arrow panel was added to the back. The cost of fabricating the trailers was not tracked (*41*, *42*).

Figure 17. DelDOT original cone trailer (*40*).

Figure 18. DelDOT modified cone trailer (*41*, *42*).

6.2. Arizona Department of Transportation Cone Truck

Arizona Department of Transportation (ADOT) designed and fabricated custom truck beds for use with standard truck-style chassis cabs. Figure 19 shows the ADOT cone truck setup, which includes an arrow panel. Operation requires two workers (a driver and a cone setter). The cones are accessed from a conveyor belt located in the middle of the truck bed, which can hold 60–80 cones. The cone setter works from a lowered seat that is integrated into the truck body, allowing him to reach down toward the pavement. The setup also includes PVC tubes to hold roll-up signs. The cost to manufacture was not tracked and is not known (*43*).

Figure 19. ADOT cone truck (*44*).

6.3. California Department of Transportation Cone Truck

California Department of Transportation has also used a truck body similar to the ADOT truck. Figure 20 shows the cone truck being used to deploy cones. This operation requires two workers. The cost of fabricating the truck bed is not known.

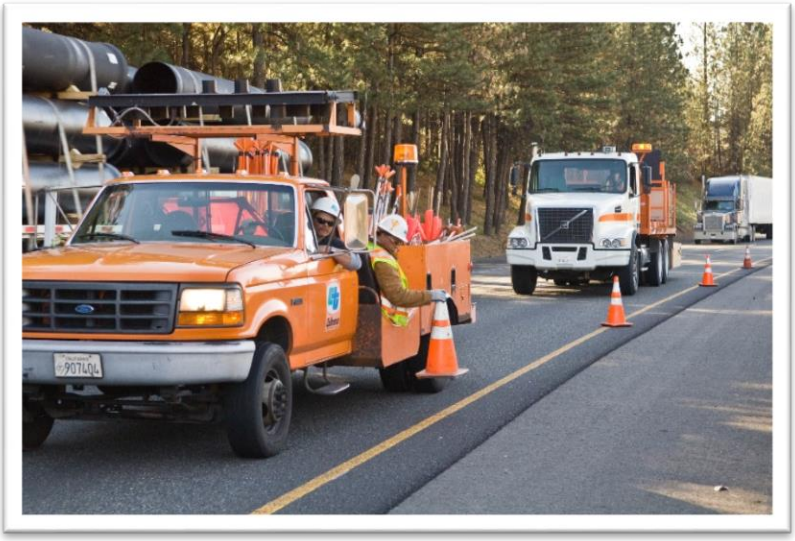

Figure 20. CalTrans cone truck (*45*).

6.4. Minnesota Department of Transportation Cone Basket

Minnesota Department of Transportation (MnDOT) developed a front-mounted basket for use in placing cones. The front-mounted style was intended to move the worker to the front of the truck and allow the mass of the truck to separate the worker from errant vehicles. Shown in Figure 21, the basket was fabricated by an outside source and cost approximately $4,000 (*47*).

Figure 21. MnDOT TTCD cart (*47*).

6.5. Missouri Department of Transportation Cone Baskets

Missouri Department of Transportation (MoDOT) investigated the use of automated equipment, but found that the use of 42-inch two-piece cones (they termed the devices trimline cones) could not be accommodated with existing off-the-shelf products. With no viable solutions commercially available, MoDOT employees came up with some in-house designs for baskets that could easily be attached to existing equipment. Figure 22 shows a front-mounted basket that can be hosted by any of MoDOT's plow trucks. The basket is designed with side gates, which allows cones to be set from either side. The bottom of the basket is near the pavement, so workers are not required to do significant bending to place and retrieve cones. The basket has room for two workers, which can be helpful when cones become stuck together (requiring two workers to separate them). The cones can be left in the basket when not in use, so the workers simply drop the loaded basket from the plow truck. MoDOT District 8 workers reported a feeling of increased safety because they were able to work in front of the heavy truck and felt more protected from traffic. In addition, they were always in view of the driver. Including the driver, this operation requires three workers. Records show that the fabrication effort was estimated to be $250 for supplies and 16 hours of labor (*48*).

Figure 22. MoDOT front-mounted basket (*48*).

MoDOT also developed a quick-loading trimline cone carrier with integrated work platform for use with their dump trucks (Figure 23). The carrier is a self-standing rack that slips into the dump truck and allows workers to place and retrieve cones from either side of the truck. While this figure shows three workers in the back of the truck, it is presumed that this operation could be performed with three workers (two in the back plus the driver). The fabrication effort was estimated to be approximately $1,000 for supplies and 95 hours of labor (*48*).

Figure 23. MoDOT rear-mounted basket (*48*).

6.6. Ohio Department of Transportation Basket

Ohio Department of Transportation (ODOT) designed and fabricated a rear-mounted basket (shown in Figure 24) for use with their plow trucks during the off-season. This setup requires three workers, including the driver. One worker, positioned in the bed of the dump truck, assembles the 42-inch two-piece cones and lowers them to another worker (who is positioned down in the basket) for placement on the roadway surface. Initially, the worker assembling the cones had no fall protection and a serious worker injury incident occurred. ODOT later improved this basket by adding a strap across the top rear corners of the dump bed to provide fall protection (*49*).

Figure 24. ODOT rear-mounted basket.

ODOT also custom designed and fabricated their own maintenance of traffic truck (Figure 25). The original truck chassis was extended to allow a longer body to be installed. This increased the storage capacity available for TTCDs. The truck has a lower deck on each side that provides enough room for one drum with base and a worker to stand. This worker, positioned closer to the pavement, manually places and retrieves the drums, while two workers located in the main bed assemble or stack the drums. The truck has side rails to prevent worker falls. However, these

workers standing in the main bed must reach over the railing below their foot level to reach the handle of the drum on the lower deck. This setup requires three workers plus a driver to operate.

Figure 25. ODOT maintenance of traffic truck.

6.7. North Texas Tollway Authority TTCD Truck

The North Texas Tollway Authority (NTTA) designed, fabricated, and patented a traffic control truck using a much larger chassis cab (*50*). Figure 26 shows this truck. This setup requires three workers to operate. One worker drives the truck, while another stands on a lowered deck located just aft of the driver side door. A third worker, who is tethered to the cage, moves about in the cage to supply assembled drums or cones via a hydraulic deck that is raised and lowered. Figure 27 shows the hydraulic deck and online videos demonstrate its operation (*51*). This cage setup cost approximately $20,000 to manufacture. In addition, NTTA incurred the cost of the truck and other safety equipment to make this a dedicated TTCD vehicle (*52*).

Figure 26. NTTA TTCD truck.

Figure 27. NTTA Hydraulic deck for lowering and lifting devices (*51*).

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1. Summary of Systems

Table 1 summarizes all relevant placement and retrieval equipment available for purchase that has been identified by the researchers to date. The table provides a synopsis of automation level, type of TTCD that can be used, cost, vendor contact information, and some risk-reducing attributes of each system. All of the systems listed in the table remove workers from the pavement during TTCD set up and removal.

Table 1. Matrix of TCD setup and removal systems.

Automation Level	Manufacturer and System Name	TTCDs	Cost	Vendor Contact	Lift/Lower Mechanism	Fall Restraint	Minimum # of Workers
Full	Centreville AutoCone 500	cones up to 36”	$80,000 + truck chassis	John Doran 410-758-1333	Yes	N/A	1
Partial	J-Tech Dynamic Lift System	vertical panels	$70,000 + truck chassis	Preston Denlinger 610-458-4334	Yes	Rails/Basket	3
Partial	Epic Solutions Roadrunner	cones up to 36”	$35,000 + TTCD truck	Andrew Roberts 484-895-1281	Yes	Rails	3
None	Centreville Roadway Safety Trailer	cones up to 36”	$15,000	John Doran 410-758-1333	No	None	3
None	J-Tech Basket (large)	any	$25,000 + TTCD truck	Preston Denlinger 610-458-4334	No	Basket	3
None	J-Tech Basket (small)	cones up to 36”	$9,000 + pickup truck	Preston Denlinger 610-458-4334	No	Basket	3
None	Royal Truck Safety Pattern Truck	any	~$80,000 to $100,000	Andrew Roberts 484-895-1281	No	Rails	3
None	S.P.A. Safety Systems Cone Truck	cones up to 36”	$60,000	Steve Dudas 973-347-1101	No	Rails/Basket	3
Pushing	Artec Innovations Sidewinder	drums	$100,000	Serge Daignault 514-357-2525	No	N/A	1
Pushing	Barrel Mover 5000	drums	$20,000	Dave Wyrick 859-428-7411	No	N/A	1
Pushing	SCR Industries Barrel Picker Pro	drums	$4,300	Reed Felton 414-881-6630	No	N/A	1
Pushing	Synergy Innovation Safety Shift	drums	$13,800 or $7,500 + mount	Matt Stackpoole 313-600-1634	No	N/A	1

7.2. Conclusions

Fully automated cone placement and retrieval equipment has several benefits. It enables the TTCD to be deployed by one worker who also drives the equipment. By removing workers from the pavement and from the back of the vehicle during this critical time, it eliminates the opportunities for workers to be directly struck by passing motorists. If an errant vehicle strikes the piece of equipment, injury severity for the worker is greatly reduced. It also reduces the likelihood of back injuries because the worker does not handle the cones directly while operating the equipment. Finally, a worker is not located in the bed of the vehicle, so not at risk for falling from the vehicle.

However, fully automated cone placement and retrieval equipment also has several disadvantages. Specifically, due to the mechanical complexity of fully automated devices now on the market, they are subject to frequent cone jams and breakdowns. The benefits obtained by removing workers from the pavement are reduced or lost if the worker(s) have to exit the vehicle to clear jams or resolve mechanical issues with the equipment. These systems are also typically designed to accommodate only one type of TTCD.

Partially automated equipment can eliminate the lifting and lowering tasks for workers, but this equipment still requires that at least one worker stands on a moving platform, namely the truck body. These workers are at risk for falls if they are not tethered or caged. These systems may also experience periodic mechanical breakdowns. In addition, they may be designed to use only one type of channelizing device.

TTCD pushing systems remove workers from the pavement and provide a significant benefit in long-term stationary work zones where lanes may open or close frequently (for example, when multiday work is limited to certain times of day or night). Thus, these types of devices would not be applicable to those types of maintenance activities are short-duration or short-term operations at a single location.

Equipment with no automation (such as baskets, carts, trailers, and custom truck bodies with raised platforms and lower decks) can keep workers off of the pavement and allow them to ride instead of walk. If an errant vehicle were to strike a worker, injury severity could be reduced. But

these devices also increase the vertical and lateral distance that workers must reach to place and retrieve cones, increasing the risk of sprain/strain injury. Workers are also at risk for falls if they are not tethered or caged. In other TTI research, the researchers have found that, without any type of lifting assistance, cone trucks and baskets have a significant potential for worker injuries during TTCD setup and removal. In addition, when compared to placing and retrieving cones on foot, they typically do not reduce the number of workers required to perform these tasks (*49*).

The researchers were not asked to assess the types of injuries CDOT maintenance forces are currently experiencing as part of this project, nor to estimate how a change from current practices would affect injury rates. Consequently, Table 2 simply summarizes the relative risks and cost of each type of TTCD setup and removal system when compared to the risk experienced by a worker setting and retrieving TTCD on foot.

Table 2. Relative risk and cost for each type of TTCD setup and removal system.

Type of TTCD Setup and Removal System	Bodily Injury and/or Fatality Risks			Relative Cost
	Lifting/Lowering Injuries	Falls from Platform(s)	Struck by Errant Vehicle	
Fully automated	Eliminated	Eliminated	Reduced	$$$
Partially automated	Reduced	Increased	Reduced	$$ to $$$
No automation	Increased	Increased	Reduced	$ to $$$
Pushing systems[a]	Eliminated	Eliminated	Eliminated	$ to $$$

[a] requires previous staging of TTCD by other means

7.3. Recommendations

As a result of these findings, the researchers recommend the following:

(1) CDOT will need to determine which TTCD setup and removal systems best fit into their risk-balancing practices reviewing the types of injuries that CDOT maintenance forces have experienced and comparing them to the types of injuries that each TTCD setup and removal system can reduce or eliminate.

(2) If CDOT is interested in a fully-automated system, consideration should be given to performing a peer exchange with the Minnesota DOT, which has recently procured and is

now using such a device. CDOT should contact their Federal Highway Administration (FHWA) Division to explore the funding potential for such a peer exchange.

Ultimately, if the implementation of automated or semi-automated TTCD setup and removal systems results in reducing or eliminating an injury to one worker, tens of thousands of dollars could be saved. If the one worker fatality is eliminated, millions of dollars could be saved.

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