Applied Research and Innovation Branch

CDOT RAPID DEBRIS REMOVAL RESEARCH PROJECT

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16. Abstract

Highway debris represents a traffic safety problem that requires a prompt response from state or local transportation agencies. The most common practice for debris removal currently is for agency personnel to leave their vehicles and remove the debris by hand in the case of large debris (tires, lumber, freight loss, rock fall) or to sweep traveled lanes, shoulders, or intersections in the case of crashes, mechanical failure, or embankment erosion. This exposes agency workers to safety risks, especially on high-speed and/or high-volume roadways. Currently, the Colorado Department of Transportation (CDOT) has no widely distributed formal guidelines for safely and effectively removing debris from the roadway.

Equipment modifications and innovations have been developed that can remove debris from highways without exposing agency workers to moving traffic. Innovative equipment has been introduced to the market which allows for high-speed debris removal, such as the Gator Getter®.

Through a combination of field observations, interviews with CDOT personnel, equipment manufacturers, and other state DOTs, the research concluded that the Gator Getter is very effective for collecting tire treads on smooth (asphalt) pavements where operating speeds can be maintained above 45 MPH. The effectiveness of the Gator Getter decreases when operating speeds drop below 45 MPH and on rougher pavements such as shoulders or tined concrete pavements. Both the safety and effectiveness decline when the Gator Getter is used on mixed debris, scattered or longitudinal debris, and low visibility conditions. The Gator Getter should not be used on segmented pavements, bridge decks, or railroad tracks, and should not be used to collect rocks, concrete fragments, or metal objects.

Implementation

The Gator Getter is recommended for use in clearing tire debris from smooth asphalt roadways in locations where speeds can be maintained above 45 MPH.

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EXECUTIVE SUMMARY

Highway debris represents a traffic safety problem that requires a prompt response from state or local transportation agencies. The most common practice for debris removal currently is for agency personnel to leave their vehicles and remove the debris by hand in the case of large debris (tires, lumber, freight loss, rock fall) or to sweep traveled lanes, shoulders, or intersections in the case of crashes, mechanical failure, or embankment erosion. This exposes agency workers to safety risks, especially on high-speed and/or high-volume roadways. For example, a Colorado DOT (CDOT) maintenance worker in Region 1 entered several lanes of traveled roadway to pick up debris and was struck by a passing vehicle doing in excess of 65 miles per hour, causing serious injuries. Currently, CDOT has no widely distributed formal guidelines for safely and effectively removing debris from the roadway.

Equipment modifications and innovations have been developed that can remove debris from highways without exposing agency workers to moving traffic. For example, some equipment modifications implemented by CDOT are effective at removing debris, but must travel at low speeds, potentially creating upstream crash hazards or driver distraction. Innovative equipment has been introduced to the market which allows for high-speed debris removal, such as the Gator Getter®.

Through a combination of field observations, interviews with CDOT personnel, equipment manufacturers, and other state DOTs, the research concluded that the Gator Getter is very effective for collecting tire treads on smooth (asphalt) pavements where operating speeds can be maintained above 45 MPH. The effectiveness of the Gator Getter decreases when operating speeds drop below 45 MPH and on rougher pavements such as shoulders or tined concrete pavements. Both the safety and effectiveness decline when the Gator Getter is used on mixed debris, scattered or longitudinal debris, and low visibility conditions. The Gator Getter should not be used on segmented pavements, bridge decks, or railroad tracks, and should not be used to collect rocks, concrete fragments, or metal objects. The performance on chip seals, rutted or alligatored asphalt, and snow/ice covered pavements was not evaluated. The safety and effectiveness of collecting animal carcasses was not evaluated.

Recommendations for operator training

- Watch the Gator Getter video and read all manufacturer literature
- Minimum two-hour “ride-along” with experienced operator
- One hour live-training in a controlled condition such as a low volume service road
- Explanation of acceptable materials and conditions
    - Tire treads
    - High friction solid debris (buckets, small plastic auto parts)
    - Smooth pavements
    - Moderate operating speeds between 45 and 65
- Explanation of high-risk materials and conditions
    - Mixed debris

    - Scattered debris
    - Uncertain debris
    - Low friction debris such as rocks, concrete sections, metal auto parts, etc.
    - Debris removal on shoulders
    - Low operating speeds (below 45 MPH)
    - Jointed concrete pavements and rutted or cracked asphalt pavement
- Explanation of prohibited materials and conditions
    - Bridge decks
    - Railroad tracks
    - Head-to-head traffic
    - Low operating speeds (below 45 MPH)
    - Sand, small gravel, and shredded debris

Recommendations for maintenance personnel

- Proper installation of lead blade at 2-3° angle from pavement is critical
- Polypropylene lead edge must be inspected frequently
- Inspect drum, vents, wheels, and wheel bearings frequently

Recommendations for central administration

- Move units to less urban districts (e.g. ,Pueblo, Glenwood Springs, Grand Junction) where operating speeds can be maintained and re-evaluate the Gator Getter
- Arrange for observation by Walter Hopkins to advise on equipment mounting, operation, and calibration

The highest risk operation for debris removal appears to be when a CDOT worker independently attempts to both move and collect debris under traffic without traffic control, advance warning, or traffic controls in place. The practice of “darting into a break in traffic” should be prohibited as a matter of policy.

CONTENTS

INTRODUCTION 1

LITERATURE REVIEW 6

RESEARCH PLAN.....7

RESULTS 8

CONCLUSIONS.....12

RECOMMENDATIONS.....13

REFERENCES 15

APPENDIX A - MISSOURI DOT AND OHIO DOT INTERVIEWS.....16

APPENDIX B - GATOR INDUSTRIES LLC (MFR) INTERVIEW 22

APPENDIX C - FIELD TEST RESULTS 26

APPENDIX D - TEAM INTERVIEWS.....33

INTRODUCTION

Reduction of traffic crashes and improved safety for both the traveling public and agency maintenance personnel continues to be a high priority for transportation agencies. Data support the need for continued innovation in traffic safety and highway maintenance. In 2009, an estimated 5,505,000 crashes occurred in the U.S., causing 30,800 fatalities and 1,517,000 injuries (*1*). An often overlooked factor contributing to crashes each year is highway debris. Highway debris represents a traffic and worker safety issue requiring a timely response from state or local transportation agencies. The most common practice for highway debris removal is for agency personnel to leave their vehicles and remove the debris by hand in the case of large debris (tires, lumber, freight loss, rock fall), either from the traveled lanes or from the shoulder if debris has been redirected, as with a snowplow or other attachment. For freight crashes, mechanical failure, or embankment erosion it may also be necessary to sweep traveled lanes, shoulders, or intersections in the case after the incident, often requiring lane closures. All of these practices expose agency workers to safety risks, especially on high-speed and/or high-volume roadways. For example, a Region 1 CDOT maintenance worker was seriously injured attempting to cross several lanes of traveled roadway to pick up debris when he was struck by a passing vehicle moving in excess of 65 miles per hour.

Some DOTs have experimented with equipment modifications and other innovations to remove debris from highways without exposing agency workers to traffic. Innovative equipment has been introduced to the market that allows for high-speed debris removal, such as the Gator Getter®, but there a need for rigorous research and testing of these innovations to determine their efficiency and potential operating limits. The objective of this research is to develop a set of recommendations and identify effective practices for rapid debris removal for the CDOT. Identification of best practices will be used to develop formal guidelines for safely and effectively removing debris from the roadway, which can minimize the frequency of debris crashes and reduce risk to agency maintenance workers. The research results can also be used by other DOTs, county engineers, municipal transportation agencies and general contractors to develop their own policies and guidelines for debris removal on highways.

Road debris is a broad category that includes a variety of substances, materials and objects that are foreign to the normal roadway environment (*3*). A 2000 study in Washington found that approximately 25% of road debris was attributed to tires, and over 8% was classified as plastic and metal automotive parts (*3*). Similarly, the Florida Center for Solid Hazardous Waste Management determined that tire debris was the most common highway debris item and that debris from a single tire can be distributed over a distance of 10 miles (*4*). These results are consistent with the findings of a National Highway Traffic Safety administration study which reported that more than 127,000 pounds of tire debris were collected in an eight-week period over a 658 mile stretch of interstate in Virginia (*5*).

Table 1: Colorado Crash Data

Year	Total Fixed and Other Object(s) Related Crashes	Crashes Caused by: Vehicle Debris/ Cargo	(% of total)	Crashes Caused by: Large Rocks or Boulders	(% of total)	Crashes Caused by: Debris and Rocks	(% of total)
2007	8,167	486	5.95%	265	3.24%	751	9.20%
2008	7,534	481	6.38%	291	3.86%	772	10.25%
2009	7,930	452	5.70%	262	3.30%	714	9.00%
2010	7,159	424	5.92%	287	4.01%	711	9.93%
2011	7,261	449	6.18%	250	3.44%	699	9.63%
						Average	9.60%

Although debris-related crashes constitute a small percentage of total crashes (*3*), there is still room for safety improvements with respect to highway debris-related accidents. A study by the AAA in 2004 established that vehicle-related road debris (VRRD) was estimated to cause over 25,000 crashes per year, claiming approximately 90 lives (*3*).

Specifically in Colorado, a total of 7,261 crashes were caused by fixed and other objects in the roadway (e.g., not crashes related to other vehicles or single-vehicle accidents such as rollovers). Of these, 6.18% were caused by vehicle or freight debris, and 3.44 % were caused by large rocks and boulders (*6*). Combined, nearly 10% of all accidents related to Fixed and Other Object(s) in 2011were caused by road debris. Table 1 indicates that this trend is relatively consistent from 2007–2011, where the percentage of all accidents caused by Fixed and Other Object(s) is 9.60%. Utilizing a safe, effective and efficient means of removing highway debris has the potential to lessen the number of road debris-related accidents in Colorado and improve the safety of agency workers.

In addition to actual crash data and maintenance worker injury incidents, it is also important to consider so called “near miss events.” Although no records are kept on such events, it is reasonable to infer that the actual safety risk is higher than can be estimated from actual crash data. Highway debris can be a serious safety concern for both drivers and maintenance workers removing the debris. When drivers come upon road debris, unpredictable behaviors are likely, such as swerving to avoid the debris or moving to the shoulder at high speed. These behaviors can cause property damage (flat tire, broken windshield, etc.) to their vehicle without actually hitting the debris. Unpredictable and sudden driver behaviors at high speeds can also compromise vehicle control which increases the likelihood of a crash. There are multiple “near miss” situations in which the safety of the drivers and maintenance crews are compromised even if the driver does not directly hit the debris. For instance, the driver could veer off the road to avoid debris, could change lanes into oncoming or adjacent lane traffic, or could be rear-ended while slowing down to avoid/stop before debris. Each of these increases the risk of a crash or an injury accident to a maintenance worker (*3*). In the AAA funded study it was reported

that the motorist successfully avoided the debris in 21.5% of roadway debris crashes, only to crash after passing through the debris zone. In the remaining 78.5%, of the crashes the debris was struck by the driver (*3*). While not a direct measure of "near miss" incidents, one could infer that crashes and maintenance worker injury reports are underreported by as much as 20%.

Highway debris can also be costly for transportation agencies to clean up. Road authorities assume a responsibility for a "reasonable duty of care" to the traveling public, meaning that they are responsible for providing a reasonably safe passage. They are also bound by the principle of constructive notice, meaning that they must proactively inspect the roads for debris (*3*). If road authorities do not reasonably meet these two principles they may be liable for damages caused from neglect of reasonable care standards. The AAA survey found that over 70% of the jurisdictions removed road debris and, in general, that maintenance personnel manually remove the debris as soon as practical after notification (*3*). This can take some time and involve multiple workers, vehicles, and even temporary lane closures.

Highway debris represents a traffic safety problem that requires a prompt response from state or local transportation agencies. The most common practice for debris removal currently is for agency personnel to leave their vehicles and remove the debris by hand in the case of large debris (tires, lumber, freight loss, rock fall) or to sweep traveled lanes, shoulders, or intersections in the case of crashes, mechanical failure, or embankment erosion. This exposes agency workers to safety risks, especially on high-speed and/or high-volume roadways. For example, a CDOT maintenance worker in Region 1entered several lanes of traveled roadway to pick up debris and was struck by a passing vehicle doing in excess of 65 miles per hour, causing serious injuries. Currently, CDOT has no widely distributed formal guidelines for safely and effectively removing debris from the roadway.

In an attempt to address the aforementioned issues concerning safety and potential financial savings road debris, Colorado Department of Transportation (CDOT) commissioned a study to research highway debris removal system options. Equipment modifications and innovations have been developed that can remove debris from highways without exposing agency workers to moving traffic. For example, some equipment modifications implemented by CDOT are effective at removing debris, but must travel at low speeds, potentially creating upstream crash hazards or driver distraction. Innovative equipment has been introduced to the market which allows for high-speed debris removal, such as the Gator Getter®.

Multiple highway debris removal options were identified. For instance, the California Department of Transportation (CalTrans) uses a device called the Automated Roadway Debris Vacuum (ARDVAC), a large truck that has a mounted vacuum with an extendable arm (see Figure 1).

Figure 1: Automated Road Debris Vacuum

This system works well for picking up small debris and litter on the side of the road. This ARDVAC has an up-front capital cost of approximately $381,000 and is incapable of operating at high speeds or picking up larger pieces of debris (*7*).

Another system identified was the Automated Litter Bag/ Debris Collection Vehicle, which is also used by CalTrans (see Figure 2). This device uses a contractible basket to scoop up debris, and can handle larger debris such as tires, mufflers, litterbags, etc.

Figure 2: Automated Litter Bag/Debris Collection Vehicle

The Automated Litter Bag/ Debris Collection Vehicle has a similar up-front capital cost to the ARDVAC and cannot operate at high speeds. Both of the aforementioned devices have the potential to increase safety levels with highway debris removal; however, both are also expensive, operate at low speeds, and may require lane closures.

A third highway debris removal system identified is called the Gator Getter® (see Figure 3). This system is a metal cylinder that attaches to the front of practically all full sized or larger trucks, but some trucks require hitch modifications. Typically, the system is

specified by the diameter of the drum and the width of the pickup area. For instance, a 48”x72” system indicates that 48” diameter and 72” width of the pickup area. On the front, the bottom quarter is open to the road and has a scraping blade that protrudes horizontally a few degrees off of zero. When deployed, the scraping blade makes contact with the road and directs debris into the barrel, where the force of the traveling vehicle redirects the debris radially into the grated steel “catch tray in the top of the drum.”

Figure 3: Gator Getter High-Speed Debris Removal Equipment

Comparatively, the Gator Getter was a small investment to the other debris removal systems explored. The Standard 48”x72” Gator Getter costs $15,995 per unit. Some of the other associated costs are a frontal camera system, which adds $600 per unit. Operating the Gator Getter has no significant impact on typical operation costs since a vehicle has to be deployed to pick up debris using traditional methods. Having a Gator Getter mounted on a truck may impact the fuel efficiency of the vehicle it is mounted to and it is assumed that smaller vehicles will be impacted more than larger ones, however, these differences are assumed to be marginal at best.

Furthermore, the literature review reveals that there has been very little independent research on the safety, effectiveness, and traffic impact of debris removal practices, equipment modifications, or technical innovations, and there is little formal guidance on the best practices for debris removal. Most of the research that has been conducted pertains to catastrophic debris removal. Catastrophic debris is caused by large, traumatic events, such as hurricanes, tornados, floods, infrastructure collapses, and large wrecks

(*9*). These catastrophic events produce large quantities of debris and it is necessary that it is cleared in a timely fashion to open up emergency routes to bring in first responders.

This study aims to more closely examine the Gator Getter® as a high-speed debris removal option for increasing operation and maintenance worker safety and productivity levels. Of the three highway debris removal systems considered previously, this system appeared to best satisfy the CDOT's criteria of improving worker safety, having a low cost, and effectively picking up road debris.

LITERATURE REVIEW

A search of the Transportation Research Board database found one active study on debris management (NCHRP 20-59(37)), which is scheduled for completion in late 2013. The focus of this study is to develop best practices for rapid mass debris removal resulting from natural disasters such as hurricanes, tornadoes, and earthquakes in order to open emergency response infrastructure as soon as possible. The intent of this study is to better train state and local transportation agencies to work with federal authorities in contracted, large scale debris removal. Although the findings of the NCHRP 20-59(37) study, when completed, may be informative in general, the recommendations are unlikely to be applicable to the development of standard highway debris removal best practices.

Another NCHRP study (NCHRP-IDEA 159) is looking at the effectiveness of equipment such as hot-air blowers or vacuum trucks for debris removal, but the scope of this study is limited to clean up after localized maintenance operations such as crack sealing and sanding/aggregate placement operations. The equipment considered in NCHRP-IDEA 159 would not be applicable to most of the highway debris removal situations encountered by state transportation agencies.

Lee, Lasky, and Velinsky (2005) developed a robotic vacuum device for removal of debris from roadways. While the concept has theoretical efficacy and worked well in simulations, the product has not entered the commercial development stage.

The Schmidt Permanent Magnet is a highway debris removal system designed to remotely remove metal objects from the roadway (Alad Ltd, 2003). The magnet is permanently attached to a vehicle chassis and can be remotely operated. The Schmidt Permanent Magnet effectively removes ferrous metals, including small metal objects, but can only operate at low speeds of 10 mph and 20 mph.

A brief review of literature has revealed little research on best practices for highway debris removal that are general in nature and focus on worker safety, safety of the traveling public, and effectiveness of debris removal. The proposed research intends to fill that gap in the literature.

There has been very little independent research on the safety, effectiveness, and traffic impact of debris removal practices, equipment modifications, or technical innovations and little formal guidance exists on the best practices for debris removal.

The objective of this research is to develop a set of recommendations and identify effective practices for debris removal for the Colorado Department of Transportation and to outline a training program for implementation of these best practices. The training program would be delivered through the CDOT Training Academy as Phase II of the research. A separate proposal, including scope, budget, and schedule, will be developed for Phase II at the completion of this study as described in the Schedule section of this proposal.

RESEARCH PLAN

Task 1: State of Practice and Literature Review
The research began by assembling an expert panel with CDOT personnel. An expert panel session facilitated by the CSU research team identified the types of debris removal operations currently utilized by CDOT. A literature review was conducted to identify debris conditions and debris removal equipment currently in use or development. Literature reviewed included academic journals, trade publications, transportation research technical reports, and state Department of Transportation web sites. The research team also looked at other state DOTs, (Ohio and Missouri) to identify safe and efficient protocols for removing or repositioning debris. The objective of Task 1 was to categorize the types of debris, debris removal activities, and current debris removal vendors and equipment providers.

Task 2: Field Observation
The research team directly observed the current debris removal operation and equipment as conducted by CDOT highway maintenance employees. The objective of the field observation was to aid in the development of performance tests and operator interviews to be completed in tasks 3 and 4.

Task 3: Interview Debris Removal Equipment Operators and Maintenance Workers
The research team developed a short (e.g., 15-30 minutes), standardized interview protocol to gather input from debris removal equipment operators regarding effectiveness, safety, and impact on traveling public of debris removal operations. The research team conducted ten interviews with CDOT personnel from different departments and districts, each of whom had operated, maintained, or observed debris removal equipment in the field. The opinions of debris removal equipment operators and maintenance workers helped inform the research team's recommendations for best practices and improve the chances for successful implementation of best practices.

Task 4: Performance Evaluation
The research described in the this proposal anticipated cooperation with CDOT Research Division and CDOT Engineering Regions 4 and 6 for specific performance evaluation of two Gator Getters® mounted on CDOT owned maintenance vehicles. One Gator

Getter® was mounted on a standard CDOT pickup truck and the second Gator Getter® was mounted on a larger vehicle typically used for snow plowing operations. This allowed the research team to evaluate comparative performance data such as percent of debris collected, visibility, ease of use, operating speeds, impact on traffic, and operator confidence to establish the ideal practice for future expanded use of such equipment.

The performance test was tentatively planned to be conducted on a section of I-25, but those plans did not materialize due to traffic management issues. Therefore, evaluations were conducted on an asphalt service road near the Frederick maintenance office and a concrete pavement section near Longmont, Colorado. Evaluations were conducted at various speeds and with various categories of debris. The research team developed a robust methodology to objectively evaluate existing debris removal practices at CDOT and compare those performance data to the performance of the high-speed debris removal equipment (i.e. Gator Getter®). The research team provided a synthesis of CDOT debris removal equipment, both modified and manufactured and provided comparative data on ease of use and installation, benefit/cost analysis, debris collection effectiveness, safety, and operator opinions.

Task 5: Development Outline Recommendations for Training Program
Upon completion of tasks 1-4, the research team developed recommendations for handling and operating debris removal equipment on CDOT roadways intended for CDOT maintenance staff. The best practices outline took the form of a technology transfer document (+/-2 pages). The technology transfer document was formatted such that it can be easily reproduced and laminated for field distribution in maintenance vehicles subject to harsh environments.

Task 6: Final Report
Task 6 was to prepare, review, and disseminate a final report of the research findings. The report, along with an executive summary, was submitted to the Colorado Department of Transportation Applied Research & Innovations Branch.

RESULTS

MoDOT, Ohio DOT, and Gator Industries Interview summaries

While gathering information on the Gator Getter® the CSU research team discovered that two state Departments of Transportation (DOT) are currently utilizing the Gator Getter rapid debris removal equipment. Both the Missouri Department of Transportation (MoDOT) and the Ohio Department of Transportation (ODOT) have integrated the Gator Getter® into their operations in select districts. As part of the CDOT research project investigating the effectiveness of the Gator Getter, phone interviews were conducted with each of these DOTs.

Mr. Jessie Skinner, the district maintenance engineer for MoDOT was interviewed by the CSU research team to determine MoDOT's experiences with the Gator Getter. Mr.

Skinner is very knowledgeable about the operation of MoDOT's Gator Getter as well as how MoDOT is utilizing this piece of equipment.

Mark Griffiths, the ODOT county manager of District 4 (Stark County) was also interviewed by the CSU research team about ODOT's experiences with the Gator Getter. ODOT also delivers s a short training session to operators of the Gator Getter.

The training session starts with the employees watching the Gator Getter demo video. Then the functionality of the Gator Getter is discussed along with associated safety issues. This training also emphasizes inspecting the equipment's physical condition before taking it out on the road. This inspection looks at the tires, lift chain, debris storage rack and the lead edge. The unit is inspected for loose debris, locking arms, and appropriate contact with the road surface. Effective speeds for using the Gator Getter are discussed, which for ODOT are between 55-65mph. The employees are then shown all of the moving/ functional parts to the system. After the "classroom" portion of training is completed the employees are able to see the Gator Getter in action in a field test, and then they operate the equipment themselves in a controlled field test.
On June 23, 2014 the research team conducted an interview with Gator Industries LLC. The main conclusions from the interview are that debris with a lower coefficient of friction can be hit at lower speeds, while debris with a higher coefficient should be hit at higher speeds. Driver expertise, experience and judgment of material and speeds impacts how safe the Gator Getter can be operated.

Complete interview responses from MoDOT and ODOT are provided in Appendix A. Complete interview responses from Gator Industries LLC, the designer and manufacturer of the Gator Getter are provided in Appendix B.

Field Test Results

Field tests of the Gator Getter were performed on June 5th, 2013, and August 12, 2013 in separate locations. Members of the CDOT advisory panel and the CSU research team met in Frederick for the June 5th field test and just north of Longmont for the August 12th field test. A third field test scheduled for September, 2013 was cancelled. The field test results findings are summarized in Table 2 and 3 below and are provided in Appendix C.

Table 2: Field Test Summary for Gator Getter Serial # 16

Test #	**Speed mph**	**Debris Composition**	**Outcome**
1	45	Large tire tread, 10 gal. bucket, bag of trash, short lumber lengths.	All debris picked up aside from bucket. Tire peal did not make it to the hopper
2	45	Lumber, bag of trash, 10 gallon bucket, tire treads	All pieces picked up
3	25	Lumber, tire treads, bag of trash, 10 gallon bucket	Only one piece made it into hopper.
4	75	Two chunks of concrete and a tire tread	Everything picked up. Lead blade dented, composite strip broke, camera cable broke

Table 3: Field Test Summary for Gator Getter Serial # 17

Test #	**Speed mph**	**Debris Composition**	**Outcome**
1	65	Chain, lumber, tire treads, bag of trash, 10 gallon bucket	All debris picked up. Some debris fell back out.
2	45	Lumber, bag of trash, 10 gallon bucket, tire treads	All pieces picked up (aside from light bag)
3	35	Lumber, tire treads, bag of trash, 10 gallon bucket,	All pieces picked up. Small tire tread fell out.
4	30	Lumber, tire treads, bag of trash, 10 gallon bucket	Debris held in the bottom of the drum
5	40	Tire tread and 3 concrete chunks	Tire picked up. Damage to tip lip, 1 piece of concrete not picked up.

CDOT Team Interviews

The research team conducted interviews with several CDOT employees who had observed, maintained, and/or operated the Gator Getter. The general findings from the interviews are that safe operating speeds range from 35-70, with the most common response that 60-65 mph is safe. Responses for effective operating speeds ranged from 25-50, with the most common response that effectiveness dropped off at speeds under 45 mph. The Gator Getter is best suited for tire tread debris but should not be used for rocks/gravel, metal objects, or mixed debris fields.
The perceptions of performance were moderate, with level of agreement to the statements "The Gator Getter improves the safety of workers during debris removal operations" averaging 3.0 (1=Strongly Disagree, 5= Strongly Agree). Level of agreement with the statement "The Gator Getter improves the efficiency of workers during debris removal operations" averaged ~2.5 (1=Strongly Disagree, 5= Strongly Agree).

A complete description of interview results appears in Appendix D.

CONCLUSIONS

The current debris removal practices of CDOT do pose safety risks to CDOT maintenance workers and, to a lesser degree, the traveling public, especially in high-speed, high-volume corridors such as I-70 and I-25, among others. This risk is heightened when CDOT personnel remove debris from constrained roadways (e.g., limited shoulders, median barriers, head-to-head traffic) and must exit their vehicles and collect debris. Benefits to specialized debris removal equipment such as the Gator Getter include the following:

- Minimize CDOT workers exposure to moving traffic
- Fewer agency workers needed to remove debris
- No lane closures needed
- Minimize "unexpected conditions" reactions from drivers, especially in high-speed or head-to-head conditions

However, there are potential negatives or safety hazards associated with debris removal equipment such as the Gator Getter, including:

- Debris coming through vent holes in back of drum and damaging trucks
- Debris being deflected into oncoming or adjacent traffic
- Lead edge of the blade getting hung up on uneven surfaces
- Visibility issues for drivers
- Uncertainty as to the composition of the debris field
- Debris scatter may require multiple passes (u-turns)

It is important to note that many of the potential hazards exist in the current practice of using a blade to deflect debris to the shoulder for pick-up.

In summary, the Gator Getter is best suited for use on interstates (no head-to-head traffic) at moderate speed on newer/ well –maintained asphalt pavements. The Gator Getter debris removal equipment may not be able to maintain effective operating speeds in urban corridors (e.g., I-25 and I-70 in Denver).

RECOMMENDATIONS

Recommendations are to minimize the exposure of CDOT employees to traffic through the strategic deployment of specialize debris-removal equipment such as the Gator Getter in conditions where such conditions improve both efficiency and safety. In conditions where debris removal equipment is not effective, CDOT maintenance crews should deploy the following safety procedures whenever possible:

- advance warning signs
- traffic control devices such as dynamic message signs
- use of equipment mounted with impact attenuators
- multiple crew members to assist with spotting, debris movement, debris collection, flaggers, traffic control, etc.
- maintaining traveling speeds and reducing lane changes on the travelled roadway

The highest risk operation for debris removal appears to be when a CDOT worker independently attempts to both move and collect debris under traffic without traffic control, advance warning, or traffic controls in place. The practice of "darting into a break in traffic" should be prohibited as a matter of policy.

The Gator Getter is recommended for use in clearing tire debris from smooth asphalt roadways in locations where speeds can be maintained above 45 MPH. It should not be used to collect rocks, gravel, metal objects, objects oriented longitudinally to the drum, or mixed debris fields. The Gator Getter should be used with caution on shoulders. The Gator Getter can likely be used at low speeds to move (as opposed to collect) debris similar to how snow plows are currently used, but collection efficiency drops off at speeds under 45 MPH. The Gator Getter should not be deployed over railroad tracks or bridge decks. The effectiveness of the Gator Getter on segmented Portland Cement Concrete paving, alligatored or rutted asphalt paving, or chip seals was not comprehensively tested, but results suggest expectations of diminished performance in these conditions. The Gator Getter will also likely experience performance declines in partially snow covered pavements.

The performance of the Gator Getter in the Denver metro area was compromised by the inability to maintain operating speeds above 45 MPH due to traffic congestion. In addition, metropolitan traffic makes it difficult to straddle lanes to pick up a debris field that may be distributed across multiple lanes. The Gator Getter may be

better suited to high-speed debris removal in mid-sized urban settings such as Pueblo or Glenwood Springs or Grand Junction or in lower-volume beltways during non-peak travel (e.g., I-225).

Recommendations for training operators should include the following:

- Watch the Gator Getter video and read all manufacturer literature
- Minimum two-hour "ride-along" with experienced operator
- One hour live-training in a controlled condition such as a low volume service road
- Explanation of acceptable materials and conditions
    - Tire treads
    - High friction solid debris (buckets, small plastic auto parts)
    - Smooth pavements
    - Moderate operating speeds between 45 and 65
- Explanation of high-risk materials and conditions
    - Mixed debris
    - Scattered debris
    - Uncertain debris
    - Low friction debris such as rocks, concrete sections, metal auto parts, etc.
    - Debris removal on shoulders
    - Low operating speeds (below 45 MPH)
    - Jointed concrete pavements and rutted or cracked asphalt pavement
- Explanation of prohibited materials and conditions
    - Bridge decks
    - Railroad tracks
    - Head-to-head traffic
    - Low operating speeds (below 45 MPH)
    - Sand, small gravel, and shredded debris

Recommendations for maintenance personnel

- Proper installation of lead blade at 2-3° angle from pavement is critical
- Polypropylene lead edge must be inspected frequently
- Inspect drum, vents, wheels, and wheel bearings frequently

Recommendations for central administration

- Move units to less urban districts (e.g., Pueblo, Glenwood Springs, Grand Junction) where operating speeds can be maintained and re-evaluate the Gator Getter
- Arrange for observation by Walter Hopkins to advise on equipment mounting, operation, and calibration

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APPENDIX A

MISSOURI DOT AND OHIO DOT INTERVIEWS

1) **How long have you been using the Gator Getter?**
   MODOT- Since 2010 or 2011. Several years of experience.
   ODOT - Eight or nine months. I would have like to use it sooner but the paper work took a while
2) **How many Gator Getters do you currently have in operation within your DOT?**
   MODOT- Unsure statewide but there are three in the Kansas City Metro area.
   ODOT - One. This was the first one. We did a beta test on it. We have 88 counties and they've already canvassed the northern counties for who wants one/ who has interstate miles because they are going to potentially work on a contract for the bulk sale and get them state wide. I had the first one, so I had the "Guiney-pig" for the state, but it passed with flying colors. Everybody's floating the concept and we are definitely going to get more.
3) **How many times do you use the Gator Getter on average per week?**
   MODOT- In the Jackson county area (or Kansas City "proper"), which is highly urbanized, it is used every week. It is also occasionally used on patrol at high speed on multi-lane, divided interstate.
   (a) So you actually patrol with it as opposed to people calling in debris?
   MODOT- Yes. There is enough of the type of material that we can pick up with it that we take a proactive approach the problem."
   ODOT - During the winter it is not as much because we get more tire peels in the summer. In the winter time maybe once a week but now that we are into regular driving weather it's consistently probably 3-4 times a week if not more, but that's just for the reactionary ones where there is a call that there is a problem. We have also used it to clean up the berms of six-lane highway going up towards Akron.
   (b) So you patrol with it during the spring?
   ODOT - Yes. My goal is that we will get enough staggered on the interstate that you can deploy from different places with it so if you get a call during the day you have one with you right there.
4) **What are the traffic control and safety procedures when using the Gator Getter? (For example, do you have a lead vehicle, a dynamic message board, flashing lights on the truck, etc.?)**
   MODOT- Typically, the vehicle we use is one of our heavy duty dump trucks, either a single axle or tandem axle International dump truck, equipped with our typical vehicle lighting for our DOT dump truck fleet so we probably have at least four LED amber beacons or strobe type lights on it so it's fairly large type profile vehicle with the lighting. Typically, what we have is the Gator Getter® in the front of that and a light duty trailer on the back, just a little trailer because they use it as

a mobile operation. As far as traffic control it is usually there by its self. It will pick up whatever objects or debris they are picking up then they will go over to the shoulder, somewhere where it's safe, maybe an exit ramp or wide spot in the shoulder where they can unload the Gator Getter then to put it in the trailer. Like I say, as they are patrolling they may pick up quite a few pieces of debris.

ODOT - [For normal operations] All that is used is the lighting on the trucks. Depending on where it is going to be, we can send out a trail vehicle with an attenuator. "We went with an eight foot [wide Gator Getter®] instead of the six foot. We are doing this so that operators do not have to switch lanes or swerve to pick up debris in-between lanes. We told the drivers to try not to be shifting lanes, just take the debris straight on.

5) **At what range of speed do you normally operate the Gator Getter?**

MODOT- I would say 40-55mph is probably a pretty realistic operating speed for it. One of the modifications we did have to make was in the front flap type material to reduce the back spray when picking up animals at higher speeds because it was kind of a pretty messy, nasty operation when it would spray onto the windshield.

ODOT - We tested it on a controlled area. We found that better results are achieved above 50mph. 55-65 mph seems to be the optimum to get the debris up there because if you get larger or heavier stuff like super single tire or some 4x4 or other pieces of metal you need that extra speed. When you do it at 50 it seems like you might get some stuff coming back down [from the debris holding tray]. When you hit it at 65 the debris just disappears right off the road. What we did learn when we bought it, using a little bit of listening to what Gator said and some common sense is: When you first get it, the paint is brand new and it creates movement resistance. He said you could put some Pam or something on their to get it slick until you get enough stuff going across it that it basically makes the paint slick in there and the tires will just slide right across it instead of grabbing on to it. We did that for the first day and once we ran enough debris through it, it becomes smooth and relieves some of the friction so the debris can go easier into the trough up top.

6) **What types of vehicles do you have the Gator Getter installed on?**

MODOT- I think we have talked about putting them on one-tons and they have some field stuff they were exploring with that as an option but typically were putting it on a large dump truck.

ODOT - A full sized single axle and tandem International 7400.

7) **What type of hitch do you use with the Gator Getter? Is it hydraulic?**

MODOT- I'd have to go back and review it but if I remember correctly it is hooking up to the front of the dump truck much like a snow plow would. I think they are using the existing mounting brackets for the snowplow. I believe it has hydraulic controls for up/down.

ODOT - All of our trucks in ODOT, over 1300 snow and ice trucks, all of them have a Gledhill snowplow on them. They have a very unique receiver. It's an A-Framed receiver. We shipped one out to Gator Getter and they fabricated it so it's the exact same setup. We can just pull right up, you pull the pin and it slides right into the receiver you mount the chain and your gone. It's a two-point connection: one at the bottom for the receiver at the truck and the chain to pick it up.

8) What types of materials do you generally pickup with the Gator Getter?

MODOT- A variety of everything from pieces of tire treads to dead deer and everything in between. If it's something that is substantial enough that you can use this while moving to pick it up, we've had fairly good success on picking it up.

ODOT - The majority of it is tire peels, but we have picked up 2X4's, 4X4's, and metal such as an aluminum fender.

9) What are the size/ weight limitations of an object you will pick up?

MODOT- It's kind of driver's experience. Obviously you can't fit a couch or a refrigerator in there but we assign the same drivers to that equipment so there is a pretty good familiarity. As far as the capacity, I think it can get overloaded with material, that's one of the reasons why, after we pick up an item we then go to a safe spot on the road or a facility to go ahead and unload it and then continue resuming with the patrolling activities.

ODOT - The largest piece (a super single tire peel) we have ever picked up was close to 75-80lbs. The Gator Getter can go out and easily pick up 250-300 lbs and still have capacity up in the top that it's not falling back down and that it's not putting and strain on the cage itself.

10) How do you identify materials that are suitable to be picked up in the Gator Getter before retrieving them?

MODOT- Drivers assess the items as they approach. A bucket of paint or a bucket of liquid or something that might be a hazardous material is the only thing off the top of my head that would be within the size and weight constraint of the product but would probably not be picked up.

ODOT - Just like anything else out in the middle of the interstate, sometimes it's called in, sometimes its state patrol or local police or fire department. If it's tire debris, we know right off the bat we are going to send it out on that. If we get this report of debris in the road sometimes we will see if somebody is in the area or get a manager to go out there and "eyeball it" first to see what the debris is and what the location is. If you're going down the interstate on a six-lane and going around a bend, the driver needs to know where that is. If he is traveling at posted speeds and the debris is in the middle lane the driver needs to know where that sits so he can be ready for it. We also leave it up to the drivers to make the call. We tell them, as they are approaching items; if it doesn't look like it should be picked up because it is the wrong type of material, then don't pick it up. We can go back to the old way of picking up materials if necessary.

11) What materials or types of debris do you avoid using the Gator Getter to pick up?

MODOT- The biggest risk identified is making sure you unload it in a safe area. It is not really the operation of the equipment but the logistics of unloading the Gator Getter that make it unsafe.

ODOT - Heavy metal, like a cast iron. We're not going to pick up a pallet because the pallet itself even if it's not heavy, is going to be a larger piece. You want to be sure it's all going to break up before it goes up the back of that radius. The big thing is not picking up anything heavy or not picking up gravel and rocks with it because of the aerodynamics- there are ports open on the back of the Gator Getter so the air will circulate through the drum so it doesn't bounce up and down with the wind but if you try to hit gravel it will go through the vents and could hit your window or radiators.

12) Have you identified any potential risks or hazards associated with the Gator Getter?

ODOT - Small debris coming through the air holes.

13) Have you identified any materials that have damaged a Gator Getter to this point?

MODOT- Not to my knowledge but to be definitive I would have to go back and talk to some of my operators.

ODOT - None. After a full day of training (which included 50-55 passes) we barely started to bevel the cutting edge. If something does break we anticipate it to be the piece of metal that the cutting blade attaches to. So far we haven't done any damage to it.

14) Have operators of the vehicles using the Gator Getter ever mentioned any safety issues or potential injuries experienced from picking up larger items?

MODOT- No, I haven't had any kind of concerns like that brought to my attention

ODOT - No. That's the whole point is to alleviate having that happen. To date that hasn't been an issue at all. We don't want it as a false comfort for our employees; we still want them to be cautious. It's a tool, it's not always going to pick up all the debris. There are certain circumstances for it. It reduces the amount of "high-hazard" time experienced by employees who would normally have to be out in traffic. It could help reduce injuries and fatalities.

15) Have you ever had issues with the Gator Getter hanging up on bridge joints or manholes?

MODOT- I think there is some potential for that. That's part of the reason for that plastic cutting edge that we put on the bottom to help scoop things because that plastic cutting edge kind of helps abrade and conforms to the surface better than say a carbon steel blade would. There is still some operator need to pick up and lower just like you would with a snowplow but if I remember correct because of the mounting there is some flux built into the system.

ODOT - Not so far. The ODOT operators were cautioned on this during training. In one instance, one employee was unable to pick up all of the road debris because part of it was after a bridge joint. The operator was unable to pick up.

16) Have you identified additional benefits or uses for the Gator Getter?

MODOT- Safety benefits, such as reducing exposure for employees. Reduces "lane drops" by keeping operations mobile instead of static.

ODOT - No, not so far but it does save on personnel costs.

17) Has the Gator Getter proven to be a safe and reliable method for high-speed debris removal for your DOT?

MODOT- Yes

ODOT - Absolutely

18) On a scale of 1 to 10 (10 being most satisfied) rate your satisfaction with the Gator Getters performance to this point?

MODOT- A solid eight

ODOT - A strong nine

19) Why did you give it this rating?

MODOT- We have made some minor tweaks here and there to it to better fit MoDOT's needs. There are always improvements that can be made on any piece of equipment but it has been a very solid performer for us.

ODOT - I probably wouldn't give anything a ten but it has far exceeded my expectations. It can pick up materials that you would normally have to get a crew out there or wait for the semis/ traffic to kick it closer to the edge of the road so you can get it, but now you don't have to do that. It doesn't get it all and doesn't work for all situations but we are extremely satisfied with it.

Additional Modifications made to Gator Getter:

MoDOT-

1. Upgraded chain that hoists the Gator Getter off the ground.
2. A 36" mud-flap was put over the rear vent
3. The cutting blade was substituted out with a high-density polyethylene blade. (this has purportedly increased the efficiency of the Gator Getter by lowering the angle of contact)
4. The Gator Getter mounts were lowered from the bumper with plow lift arms.
5. Scrap metal was welded to the back of the drum for additional structural support.

Modifications are described in Figure 1

ODOT-

1. Modified their Gator Getter to work with their Gledhill snow plow hitch
2. Added a hitch mounted jack so that the height of the Gator Getter could easily be adjusted for trucks of various heights.

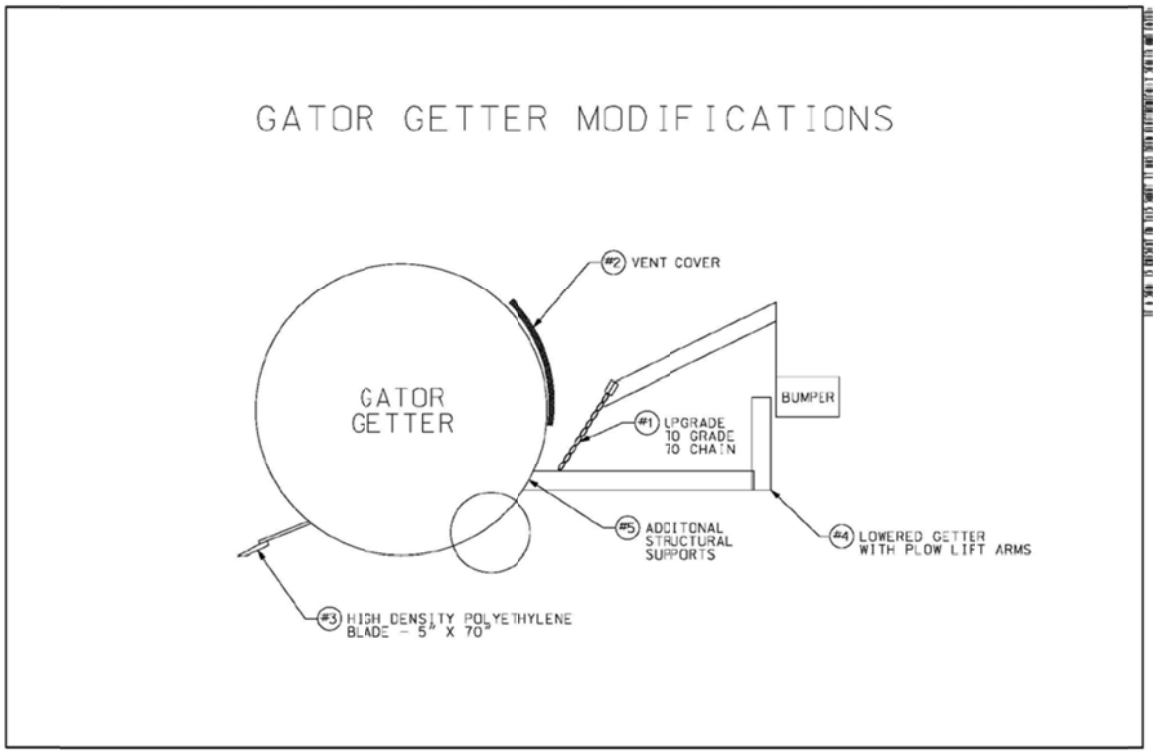

Figure 1: MoDOT Gator Getter Modifications

APPENDIX B

GATOR INDUSTRIES LLC (MFR) INTERVIEW

On June 12th, 2013 the CSU research team conducted a telephone interview with Walter Hopkins (Gator) and Gail from Gator Industries LLC. The summary of that interview follows:

Questions:

1. **What are the most effective speeds to operate the Gator Getter?**
   a. Does this speed vary for different items?
   Yes, it varies for different items based on the friction coefficient (fc) and the friction characteristics of the debris. For instance, a small rock will have a lower friction coefficient compared with dead animal (friction coefficient glue-like) or tires (the most common debris) that will need more speed from the Gator Getter.

2. **What are safe operating speeds for the Gator Getter? (Range of speeds)**
   a. So, what is this range of acceptable speeds for picking these things up?
   Other examples of low fc debris typical found in nation roads are auto parts (brakes, mufflers, brake shoes from transport trucks, bolts, nuts, etc.)
   The operator should drive slowly and evaluate the conditions. The operator should decide the speed based on the type of debris (low vs high friction debris). For instance, picking up a rock at 40mph compared with 60 or 70 mph can impact the radial spin out/ ratio, which can be so aggressive that you can throw it all the way through the receiving tray.

3. **What are the weight limitations of debris?**
   It will depend on the ability to store the impacted energy (structural characteristics of the Gator Getter)
   - Super single tire tread can weigh as much as a 100lbs
   - Have picked up deer that weighted 250 lbs. Most common animal problem in North American roads is deer.
   - Gator Getter is able to take on a static mass at 50-70 mph. The radial spinout of the Gator Getter absorbs some of the energy of impact while a snow blade, for example would have to take the impact all at once.

4. **What are size limitations of the Gator Getter?** (CDOT is running a 48”x72”)
   72” is its width of the drum and 48” is the diameter of the drum. These numbers indicate the diameter and the width of the pickup area.
   Ohio DOT has the larger width size Gator Getter (48”x96”). Have approximately 20% more capacity. Also, it has the opportunity to get more debris with less skill and equipment maneuvering by the operators.

5. **What is the purpose of the vents on the back of the Gator Getter?**
   a. Have these posed any safety hazards during your testing?
   The air vents (on the back of the Gator Getter) are intended to:
   - Pass the air to the radiator
   - Air filtering (aeration); to give it some breathing room let the device air out, and
   -Help to operators to see through the vents to the receiving tray for those models without a camera.
   b) Have these (air vents) posed any safety hazards during your testing? Or have you ever had anything come through the vents?
   No, no safety hazards have been identified. When the debris has headed far enough around the radius it has already been redirected upwards.

6. **What other materials should be avoided with the Gator Getter?**
   - Pieces of debris laying longitudinally on the highway such as steel. If the object is flexible longitudinally then the Gator Getter may be able to handle it. If it is a 2x4 or a piece of steel such as an exhaust pipe is lying longitudinally be cautious and take slow down so the object will have time to turn and make the radial curve to the receiving tray.
   - It is OK when there are pieces with flexibility because they make the radius curve.

   b) **Have you had anything pierce the back of the drum?**
   - No
   - They have experimental model with aluminum (to reduce the weight by 33% - Size: 36”x72”). This model is more susceptible to stone/rock damages because of the material used (aluminum). The model was developed for smaller municipal vehicles with ½ ton capacity and be able to utilize with lower speed power.

7. **Have you tested the Gator Getter on uneven surfaces or bridge joints?**
   a. If so what were the results?
   - Bridge joints are the most cautious thing that we need to be aware of. Also, railroad crossings or anything else that has any deviation of the road surface.
   - The Gator Getter has no recourse for hitting a mis-aligned bridge joint. The Gator Getter has more susceptibility than a snow plow because of the (sharp) angle of the approach blade. A steeper approach angle will have a tendency to trip over rather than lower one.
   - They have not performed any purposeful destructive testing on the Gator Getter, such as hitting a bridge joint.
   - Overall, it is a bad idea to use it over bridge joints.

8. **Are there any other potential safety issues you have identified with the Gator Getter?**
   - Biggest safety issues they know: Inexperienced drivers hitting the debris without being properly aligned. Also, picking up debris too wide for the capacity of the drum.
   - Rear of the tip lip needs to be contacting the road surface.

- Major interruption of the incoming debris rotation will cause it to spin out.

9. **What is the ideal angle (or range of angles) for the tip lip (this is the given name from the manufacturer for the poly edge attached to the front of the drum)?**
   - The tip lip approach angle needs to be low (2-3 degrees off of zero)
   - **The approach angle shouldn't be running as high as it is currently set on the CDOT hitches (12 to 15 degrees).**
   - The rear of the tip lip needs to made contact with the back of the drum. Otherwise, you will have a major interruption of the upcoming debris, resulting in the debris spinning out.

   a. How often does the polypropylene tip lip edge need to be replaced?
   - Doesn't need to be replaced until you have bad width/zone more than 4" to 6" or when you come in close proximity to the bolt line. Worst case scenario if the bolt surfaces do come in contact with the road they will just get ground off. They are unlikely to do substantial damage to the road.

10. **What type of maintenance is required with the Gator Getter?**
    a. Is there additional maintenance you would recommend?

    "Making sure the tires are in good shape." "They are crucial aspect for the Gator Getter stability or landing stability."

    Purposes of the wheels:
    - Frontal stability – quick reaction.
    - Landing

11. **Have there been any assembly issues with the Gator Getter (hitches)?**
    - As a manufacturer, it has been difficult to standardize the Gator Getter because the different types of hitches out there. Thus, the Gator Getter needs to be customized because of these different hitch styles across the DOTs. Also, there is a lack of hydraulic lift standards.
    - Would like to adopt an standard but all DOTS seem to have their own hitch.
    - The lack of standardization affects the cost of the Gator Getter because they need to be customized.

12. **Are there any other DOTs, aside from ODOT and MoDOT that are using the Gator Getter?**
    - Those two depts. (ODOT & MoDOT) are the only other two DOTs that are utilizing the Gator Getter.
    - There are other 3rd party contractors working with DOTs on privatization of roads/surfaces (particularly, road maintenance services). For instance, DeAngelo Brothers (DBi Services) running in north Virginia.

13. **Is there anything else you want us to know about the Gator Getter?**
    Selling points:

- Provides workplace safety
- Affordability: Upfront costs justified by lower personnel costs and avoiding litigation surrounding injury or death of road workers. This product can also excite the public seeing tax dollars well spent

14. Would you be confident with the Gator Getter running down the inside shoulder at a fair speed (up against a Jersey barrier) if it had a trailer with a message board moving traffic over?

In an urban corridor (with Jersey barriers) swiping the inside shoulder should be done with caution. Because of this, an inside shoulder debris removal process should be a function of driver expertise, joint quality, day light conditions, road conditions, etc. Then, if all these conditions are set, you can pick up the debris in a lower speed.

Conclusions:

- Debris with a lower coefficient of friction can be hit at lower speeds, while debris with a higher coefficient should be hit at higher speeds.
- Driver expertise, experience and judgment of material and speeds impacts how safe the Gator Getter can be operated.

APPENDIX C

FIELD TEST RESULTS

CDOT has two Gator Getters

1. Serial # 16
    a. Truck mounted on: International 7600 2.5 ton w/ flatbed
        i. Gator Getter wheel clearance (location based on drivers perspective)
            1. Right: 8”
            2. Left: 9”
        ii. Blade clearance
            1. Right: 3”
            2. Left 4.5”
    b. Hitch Type: Boss
        i. $2500 + $250 modifications
        ii. Self contained hydraulics
    c. Model 48x72
    d. 50005601
    e. Approximate angle of “tip lip”: 15°
2. Serial # 17
    a. Truck Mounted on: tandem MACK truck with attenuator
        i. Gator Getter wheel clearance(location based on drivers perspective)
            1. Right: 10.5”
            2. Left: 9”
    b. Hitch type: Huston
        i. $2000
        ii. uses the truck’s hydraulics
        iii. Maintenance
            1. Tires/ bearings
            2. Resetting front plate
    c. Model 48x72
    d. 50005594
    e. Approximate angle of “tip lip”: 12°

General notes:

- Welding on Gator Getter needs to be checked
- Air vents in back of Gator Getter should be covered
- Amber lights only (similar to snow plows)
- The CDOT currently uses a V-plow to remove debris at high speeds
- It was speculated that nothing bigger than a coyote should be picked up using the Gator Getter

- Blade of GG 1 (Serial # 16) was at a high angle

Gator Getter field Tests:

Serial # 16

1. Test 1
    a. Speed: 45mph
    b. Test Summary: The International 7600 truck was used during the first test. A large tire tread, bucket, bag of trash, and assorted pieces of nominal lumber (a short length of 2x4 and 4x4) were laid in the road. The Gator Getter successfully picked up the majority of the debris, however, the bucket was not picked up and the tire peel did not flip up into the drum (but was safely contained inside the drum of the Gator Getter).
2. Test 2
    a. Speed: 45 mph
    b. Test Summary: The International 7600 truck was used during this test. The drum of the Gator Getter was lubricated for this test. The Gator Getter successfully picked up all debris.
3. Test 3
    a. Speed: 25 mph
    b. Test Summary: only one tire tread made it partially into the drum. The rest of the debris stayed in the bottom of the drum.
4. Test 4
    a. Speed: 65 mph
    b. Test Summary: The International truck tried to pick up two small (12" X 12" X 6" approx) concrete fragments and a tire tread. One of the concrete fragments fractured on impact and travelled several yards in the direction of impact, bouncing into the opposing lane of traffic. The other fragment was collected in the drum. The tire tread was only half way on the drum. The concrete chunk broke off the high-density composite strip on the tip lip and also sheared off several of the bolts used to attach the lip tip to the edge of the metal drum. While picking up this debris, the Gator Getter twisted backwards and the cable broke that was attached to a camera mounted on the Gator Getter. The camera line needs more slack to prevent this from happening in the future.

Serial # 17

1. Test 1
    a. Speed: 65mph
    b. Test Summary: The Mack Tandem truck was used. All debris was successfully picked up but some of the debris fell back out of the drum. The debris may have fallen back out because the drum was too full to hold everything. The debris included in this test were as follows:

i. 10 gallon bucket
ii. 2- 2x4 pieces of lumber ranging from 3'-4' in length
iii. chain
iv. 1- 4x4 piece of lumber that was approximately 2' long
v. Large semi tire tread or "gator" that weighed approximately 50 lbs.
vi. Smaller tire treads
vii. Bag of trash

2. Test 2
    a. Speed: 45 mph
    b. Test Summary: The Mack tandem truck was used for this test. The Gator Getter on this truck was also lubricated. The Gator Getter successfully picked up all pieces of debris other than a small, light bag of trash. The large tire tread was omitted from this test.
3. Test 3
    a. Speed: 35 mph
    b. Test Summary: The Mack tandem truck was used for this test. The Gator Getter successfully picked up all pieces of debris during this test but one of the small pieces of tire tread fell back out.
4. Test 4
    a. Speed: 30 mph
    b. Largest tire tread did not kick up into the drum. Debris was held in the bottom of the drum.
5. Test 5
    a. Speed: 40 mph
    b. Test Summary: The Mack truck was used during this test. A tire tread was placed before 3 small concrete fragments (8" X 8" X 6" approx). The Gator Getter did not pick two of the concrete fragments, pushing them ahead of the drum. One concrete fragment was in the drum. The tire made it into the drum. No substantial damage was done to the Gator Getter aside from a small dent in the drum.

Operator Comments and Concerns

- It was hard getting used to hitting debris at a higher speed, However the Gator Getter felt sturdy when doing so.
- The speeds of the test runs seemed slower than the actual speed that it should be run at.
- Concerns:
    - Debris being thrown as a result of not hitting it head on
    - The structural integrity of the Gator Getter when run @ 70mph
    - Debris coming through the vent in the back
    - Hitting an expansion joint with the Gator Getter in the down position.
    - Hitting steel (sheet metal, angle iron, etc.)

Zachariah Junk observed the Gator Getter in operation on a trip to remove debris on the shoulder. The trip was planned for ¼ mile to pick up 5-8 tire treads varying in size from three feet to a full size single tread. The Gator Getter picked up the full size tread but did not effectively collect the smaller pieces.

Zach believes the problem may arise from the accumulation of sand and gravel on the shoulder. The sand and gravel collects in the drum and gets wedged under the tip lip, which then does not make even contact with the road surface on deployment. As a result, some of the treads were deflected sideways into the travelled lanes. The shoulder run was extended to ½ mile, and at the end of the run there was approximately ten pounds of sand and gravel accumulated in the drum along with four tire treads. The gravel was less than two inches (2"-) and several pieces were deflected into the lanes ahead and adjacent. At the end of the run, the adjustment screws were loose and some attachment bolts for the tip lip were excessively worn. The poly tip lip blade was also excessively worn. The wear on the tip lip blade could be an ongoing maintenance issue at the current wear rate. As a result of these observations, it appears that non-visible debris such as sand and gravel and perhaps other fragmented debris could be an issue. This debris can cause safety issues resulting from deflections of debris into lanes ahead and adjacent.

Zach suggests there may be performance difference between asphalt and concrete roadways. Also, new asphalt versus worn and rutted asphalt should be tested, as well as newer, well maintained concrete road surfaces (such as I-15 and I-70 mainlines) compared to older concrete pavements, such as Hwy 287. The best results for the Gator Getter to date are on mainline Interstate and newer asphalt pavements.

Based on the issues with gravel displacement, we may want to think about how big a stretch of chip seal we want to test. We want to take care not to damage the road surface.

These issues were added to the August field tests.

On August 12, 2013, the CSU research team went down to Longmont, CO to conduct a second round of field observations on the Gator Getter with the CDOT. CDOT has not adopted the Gator Getter as a regular part or its operations and it has only been utilized few times since the first round of field testing took place on June 5, 2013. Members of the CDOT were unimpressed with the Gator Getters previous performance and remained doubtful that this tool would provide much value in their day-to-day operations.

Since the first round of field-testing, repairs have been made to the previously damaged Gator Getter. In addition several adjustments were made to the Gator Getter. First, The slope of the cutting blade was lowered to approximately 6° (or a 1:10 slope) from a 12° angle during the first field test. The drum, which previously sat 1.5 inches higher on the driver's side of the truck, was leveled out. Lastly, the

drum was lowered so that it was only two inches off of the ground when the Gator Getter was in the lowered position.

In the following tests only one truck was used. It was a MACK tandem truck that had the Gator Getter serial number #17 mounted on it. The test summaries are as follows:

Test Summaries:

Test #1

- Speed: 55mph
- Road: I-25 Frontage (near exit 235)
    - Traffic: Light
    - Surface: Asphalt
    - Condition: Moderate to good
- Debris:
    - 1 - 2 gallon bucket
    - 2 - 2”X4”X18” pieces of lumber
    - 3 - Tire treads (Gators)
        - 2 of which were scraps
        - 1 was a full round
    - 1 - 5 gallon bucket
- Results-
    - 1 tire tread was not picked up
    - The tire round and bucket were picked up but came out as the truck was slowing down and raising the Gator Getter.
    - The remainder of the pieces made it into the hopper.

Test # 2

- Speed: 65mph
- Road: I-25 Frontage (near exit 235)
    - Traffic: Light
    - Surface: Asphalt
    - Condition: Moderate to good
- Debris
    - 1 - 2 gallon bucket
    - 2 - 2”X4”X18” pieces of lumber
    - 3 - Tire treads (Gators)
        - 2 of which were scraps
        - 1 was a full round
    - 1 - 5 gallon bucket
    - 1 – 12”x12”x10” Igloo Cooler
- Results
    - All debris was picked up aside from one tire scrap
    - The cutting blade flapped violently

Test # 3

- Speed: 55 mph
- Road: Highway 287 (approx. 1 mi north of Mineral Rd.)
    - Traffic: Moderate
    - Surface: Cement
    - Condition: Good to fair
        - Approx. 15 years old
- Debris
    - 1 - 2 gallon bucket
    - 2 - 2”X4”X18” pieces of lumber
    - 3 - tire treads (Gators)
        - 2 of which were scraps
        - 1 was a full round
    - 1 - 5 gallon bucket
    - 1 – 12”x12”x10” Igloo Cooler
- Results
    - Tire round was not picked up
    - 3.5 ft. tire tread was not picked up
    - 2x4 splintered and smaller chunk was left behind
    - Remainder of debris was picked up

Test # 4

- Speed: 65mph
- Road: Highway 287 (approx. 1 mi north of Mineral Rd.)
    - Traffic: Moderate
    - Surface: Concrete
    - Condition: Moderate to good
- Debris
    - 1 - 2 gallon bucket
    - 2 - 2”X4”X18” pieces of lumber
    - 3 - Tire treads (Gators)
        - 2 of which were scraps
        - 1 was a full round
    - 1 - 5 gallon bucket
    - 1 – 12”x12”x10” Igloo Cooler
- Results
    - The tire round was not hit straight on, which caused it to roll approx. 100 yards across oncoming lanes
    - The remainder of the debris was picked up

Conclusions:

- The Gator Getter appeared to work better on asphalt than concrete pavements.
- Not hitting debris straight on can cause debris to be kicked to the side, causing a hazard for motorist traveling in both directions.

- Less experienced drivers may not be as familiar with the dimensions of the device, causing them to not hit debris head on.

Additional Observations:

- The Gator Getter appeared to be rotated slightly forward due to how it was mounted on the truck.

All tests will use a mixed and staggered debris field. The location of the treads will be alternated. There will be no attempt to pick up debris in longitudinal direction.

The following additional field tests were planned but subsequently canceled due to traffic management concerns, in addition to a diversion of CDOT resources due to the floods in and near the Big Thompson canyon:

- One year old chip seal near Frederick
- Rutted (aged) asphalt on HWY 119
- Winter test on the service road near Frederick
- Aged concrete pavement I-25 at HWY 52*

APPENDIX D

TEAM INTERVIEWS

Phillip described the background of the Gator Getter research project. The research should be focused on how to make the Gator Getter work better and developing a set of best practices (dos and don'ts). He also stressed the need to use the equipment more frequently so the benefits and limitations are better understood.

A brainstorming session was held on potential future modifications to improve the Gator Getter and adapt it to actual conditions such as low speeds on I-25 through the metro corridor

The phone interviews will be conducted during the last two weeks of September. Participants will be sent the questions via e-mail one week prior to the interviews. The participants will be given a choice of three days/time blocks to participate, with requests in descending preference (e.g., first choice, second, choice, third choice). This should allow the research team to have two recorders present for each interview, minimize conflicting time requests, and maintain as much flexibility for participants as possible. Interviewees will be informed that participation is voluntary, responses are confidential, comments will be reported in the aggregate only, and the interview can be terminated at anytime.
Participants will be instructed to keep their responses specific and concise. The following questions will be asked of each participant:

1) Have you operated the Gator Getter?
    a. If yes- How many times have you used it?
    b. What type of vehicle was the Gator Getter
2) Have you observed the Gator Getter in operation?
3) What types of debris are best suited for removal with the Gator Getter
4) What types of debris should not be collected using the Gator Getter
5) Do you have any suggested adjustments to the Gator Getter or truck/mounts to improve efficiency, safety, and durability of the system?
6) Are there any road surfaces for which the Gator Getter should not be deployed (e.g., shoulders, aged PCC, alligatored Asphalt, elevated sections, etc.)?
7) What are the safe and effective operating speeds for the Gator Getter?
8) What type of training program or operator preparation should be implemented prior to being sent on debris removal calls with the Gator Getter?
9) Do you foresee any ongoing maintenance issues with the Gator Getter or the hitches?

10) Do you have any other issues or safety concerns regarding the utilization of the Gator Getter for rapid debris removal on Colorado Highways?

11) The Gator Getter improves the safety of workers during debris removal operations

1……2……3……4……5

Strongly Disagree	Somewhat Disagree	Neither Agree/Disagree	Somewhat Agree	Strongly Agree

12) The Gator Getter improves the efficiency of workers during debris removal operations

What is your level of agreement with the following statements:

1……2……3……4……5

Strongly Disagree	Somewhat Disagree	Neither Agree/Disagree	Somewhat Agree	Strongly Agree

Interview Response Summary

Question										
Have you operated the Gator Getter?	NO	YES	NO	YES	NO	This person never used the equipment nor has seen it in action	NO	NO	NO	YES
a) If yes, How many times have you used it?		2		8						3
b) What type of vehicle was the Gator Getter mounted on when you used it?	NA	One of our debris-crew trucks. It's a 2 1/2 ton with an attenuator on the		Tandem MACK truck						Tried on different vehicles-both with Huston hitch, Different heights and suspension Bigger

		back.							tandem than original
Have you observed the Gator Getter in operation?	YES, on Video	YES	YES	YES		YES	YES	YES	YES
What types of debris are best suited for removal with the Gator Getter?	Tire treads & five gallon buckets	Tire tread and small debris	Small and softer items, such as small tire treads and bag of trash.	Tire treads, plastic parts/debris.	Not sure	Mostly anything but caution should be used when picking up round objects that can roll out and caution must be used when trying to pick up solid heavy	Tire shrapnel and treads, smaller debris that can be scooped up in multiple axes; debris in longitude	Any type of debris in limited quantities	Consistently good for tire treads/gators

						objects such as large rocks and big chunks of concrete			
What type of debris should not be collected using the Gator Getter	Heavy items such as: Rock, concrete, metal, etc. because the weight can damage the GG. Also, full tire tread rounds because they can	Concrete chunks anything that can tumble down the road, long wood.	Junks of concrete and small items such as sand and gravel. Also, hard objects (trunk of metals) and large items.	Heavy parts such as concrete parts.		Unknown	Debris wider than the drum; debris at deflection angles. Tire caps (full rounds)	Stone, concrete, gravel, rocks or really light objects that could bounce out	Hard concrete, metal, solid caps/round retreads. Small rocks/gravel, large rocks, wood/lumber (splinters and comes through the vents); big debris field with mixed

	bounce off the GG and roll into traffic.							debris
Do you have any suggested adjustments to the Gator Getter or truck/mounts to improve efficiency, safety, and durability of the system?	Didn't think being mounted on the Huston hitch was the best because it dries up and is prone to seizing this causes devices mounted on the front not to drop smoothly. A More of a flexible	reinforce front plow edge with metal	The boss hitch and a self-contained hydraulic system seems to more adjustable. The other (tandem Mack truck) was difficult to adjust.	Change plastic lead lip blade		The unit should be mounted in manner that is fully adjustable and able to get the optimal angle and pitch so it can work effectively	Plastic tip lip catches edges or variations in pavement, Attach wear guard or "curb feeler" so the lip can ride up over uneven surfaces. On the back of the drum. The vents can pass debris to the grille- add a deflector that comes down when the drum is deployed	Camera in the drum is useless but using it as a back-aimed camera to see if debris picked up might be useful. Some durability on the edge. Some type of	Don't use the Huston hitch- it hangs up and then deploys with too much force- feels like a plane landing. Don't know what other adjustments to recommend without input from the designer

	blade.						fish scale or blades on the sides to prevent bounce out	(Gator)
Are there any road surfaces for which the Gator Getter should not be deployed (e.g., shoulders, aged PCC, alligator Asphalt, elevated sections, etc.)?	Rutted roads, bridge joints, railroad tracks, etc.	Bridge joints, rumble strips on shoulder, uneven or rougher roads	The operators need to be familiar with the area. Because they may be issues with expansion joints and irregular asphalt surfaces. Other areas,	Bridge joints and rail tracks.		I believe it depends on the debris being picked up. On tined concrete, smaller debris is harder to pick up. Even with this challenge it should be	Worked good on all surfaces. Concrete paving (PCC) will work better if modifications are made to the tip lip. Should not be used if there is snow/ice on the surface	Any bridge joint. Avoid roads with lots of gravel. Some shoulders- use judgment- it is not a sweeper.	Concrete is a bad idea. Did not work well on I-25. Rutted and alligatored asphalt paving is questionable

		inside barrier walls that separate the traffic (shoulders next to the wall or dividing walls) since there is not enough space (width).	recognized that the Gator Getter is to keep people out of harm's way like being in the middle of the road unprotected to remove a piece of debris. Goof judgment and common sense should dictate, b asked on experienc e, what can and

		should be removed with the Gator Getter and what should be removed with other methods and procedures. Even if the Gator Getter can't pick something up, it was my observations that it could be controlled with the device and safely moved to the side of the road

					and our of traffic all the while keeping the operator safe from harm			
What are the safe and effective operating speeds for the Gator Getter?								
Safe (maximum) operating speed:	70 mph	65	35-55 mph	55 mph	65	60-65	60-70	70
Effective (minimum) operating speed:	45 mph	35-45	35 mph	45 mph	25	50	35	40

What type of training program or operator preparation should be implemented prior to being sent on debris removal calls with the Gator Getter?	Make the person familiar with the adjustments to best suit this to each road surface. Safety do' and don'ts. Training on the principle behind it: make sure speeds are correct	The training should consist of "what, where and when not to use the Gator Getter"	Operators should be familiar with the equipment and the operation such the type of material that should not be collected. They should do practice runs. Also, the training should discuss of speed requirements, identification of materials, and type of objects. This should	Giving information of the type of the debris can be collected. Also, testing few runs for couple days, so they get used to it. Getting the feeling of how fast and align the need to be going.		Video, hands-on and training runs in the actual equipment picking up actual debris. Minimum of 4 hours	Similar to snow plow operator training. Familiarity/basics- how it attaches, how low it should be when deployed, how high it goes when retracted, inspections, etc. The basic operation review should be followed by 2-4 hours hands-on test under different conditions with different types of debris	Practice on service road without debris; Deploy and Retract Gator Getter from stopped position, then while moving but no debris, then make practice runs on service road with debris. Make a video	Similar to snow plow operator training (Do's and Don'ts) + 2 hour ride along with experienced operators, then 2 hour operating Gator Getter under observation of an experienced operator

			be more awareness training. Finally, it is important sharing informatio n with other people about issues during operation.					with Go=Pro (drivers view) and a road-side video to have operator s watch	
Do you foresee any ongoing maintenan ce issues with the Gator Getter or the hitches?	Possibly the tires on the gator getter going from 0 mph to operating speed. Tire wear, bearings, and cutting edge.	Yes, I think it is too light of a system to use in Denver and the suburbs or Denver. Due to volume and speed of	Just normal maintenan ce (lubrication) and daily inspections of the equipment to check for cracks or breaking parts.	Leading lip blade		It must be kept clean, all wheels inspected and repaired when necessary, all fasteners inspected and tightened as	Lip tip blade; wear and tear on front axle, shackles, and suspension. Premature wear on grille. Chipped windshields. Short term but not much different than snow plows. May need different types	Seems to catch (hang up) more with Huston hitch. Boss hitch may be better, but not sure how much the Boss	Tip lip wears too fast- will be changing it often, Tires and bearings will age quickly if used with a Huston hitch

		traffic this will not be an effective way of removing debris.			necessary and the neoprene front lip blade replaced when worn down	of lube grease on the Gator Getter. Main issues will be the tip lip blade and warping the lock pin on the cage	hitch is being used under normal traffic.	
Do you have any other issues or safety concerns regarding the utilization of the Gator Getter for rapid debris removal	Hitting the debris wrong could shoot it out into traffic. Unseen debris (like small rocks could be shot out)	I think it should not be used in high populated areas with a high A.D.T. This will work very well in	It's not a good idea for metro or high traffic areas. It's more suitable for rural areas or less congested roadways. It doesn't work in	It can't get hold of multiple items. Also, there are issues with bouncing debris.	Not anymore so than with snow plow blades on trucks. On the contrary, this is a perfect solution to keep our	Have not seen it on an uneven lane situation (depressed shoulders). Debris scattered across lanes could be problem. Old segments with uneven surfaces. If	Bounce outs and liability to traveling public. Should not be used if pedestrians or bicycles are nearby.	Potential for debris bounce out and not knowing what debris is in the field. Debris passing through the vents in the back

on Colorado Highways?		the rural areas of Colorado State Highways.	dividing walls. Make sure the operator identify the type of debris or objects that he will be picking up. Not knowing the object may cause some issues such as junk of concrete that may shoot out into traffic.	employees from getting struck trying to remove debris on foot	the tip lip blade rolls under the drum, does the Gator Getter roll under and stop the truck? Could potentially injure the driver.	of the drum
What is your level of agreement with the following statements:						

1=Strongly Disagree, 5= Strongly Agree									
The Gator Getter improves the safety of workers during debris removal operations	3	1 (in cities) 5 (for rural areas)	4	5	3	4.5	3	4	3
The Gator Getter improves the efficiency of workers during debris removal operations	2	2 (in cities) 5 (for rural areas)	4	3	3	4.5	3	3	2