

Preliminary Investigation

Caltrans Division of Research, Innovation and System Information



Using Remote Control Mowers for Roadside Vegetation Control

Requested by

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Executive Summary

Background

The Caltrans Division of Maintenance continually seeks to improve its methods and equipment to increase efficiency and worker safety, thereby supporting Caltrans' mission and goals. The trimming of native grasses and general vegetation on roadside slopes has been identified as an area where improvements are possible. While Caltrans strives to design highway side slopes to be as flat as possible, embankments with slopes of 2:1 (26 degrees) or steeper are often found along highways. These require special approval by Caltrans District Maintenance.¹ Caltrans typically cultivates native grasses on roadside slopes to reduce maintenance, control noxious weeds, and naturally filter stormwater runoff. This presents a problem on slopes greater than 3:1 (18 degrees) where conventional riding mowers cannot be used, given the possibility of rollovers. On steeper slopes, Caltrans Maintenance crews usually default to manual operations, with workers using handheld gasoline line trimmers. However, this also presents its own set of safety issues, making the safest solution the total removal of workers from the slopes. In light of these worker safety issues, this report investigates the possible application of various commercially available remote controlled (RC) mower machines capable of maintaining steep slope vegetation while keeping workers safely off roadside slopes and potentially increasing cost efficiency.

Conventional ride-on mowing equipment is more efficient than RC systems under normal circumstances. Having the equipment operator directly on the equipment affords the operator the best possible view and optimizes mowing efficiency, in part due to mower size and speed. The utilization of RC mowers or tractors is only advantageous when operating in areas deemed too challenging for equipment operators to access directly. Trimming steep roadside slopes is the most common example and appropriate application for RC equipment. RC mowers are advisable on slopes from 45 to 60 degrees, depending on the type of equipment. No commercially available ride-on mower is capable of operating on slopes steeper than 40 degrees, given the possibility of rollovers. Thus, RC mowers are superior on two counts: first, they can operate on steeper slopes and, second, should a rollover occur, the operator is always at a safe distance from the machine, preventing serious injury. Moreover, Caltrans considers any slope greater than 40 degrees an elevated workspace, which requires additional worker safety measures that are more difficult to satisfy when conducting handheld operations compared to using RC machines.²

Summary of Findings

A multitude of RC mowing machines are commercially available worldwide that Caltrans could potentially utilize to improve vegetation control operations. These RC mowing machines have many similar features, as is expected due to their common basic function. Since operation on steep roadside slopes is the main advantage RC mowers have over conventional riding mowers, these machines are similarly optimized for operating on steep slopes. They are all self-contained, engine-powered, have a low center of gravity via a wide track-driven design, and have similar remote radio control functionality. This study only considers commercial quality, slope-duty specific machines suitable for transportation agency services. This class of RC mowing machines can be divided into two categories based on utility: the first category consists

¹ Caltrans Highway Design Manual, December 30, 2015, Topic 303 – Side Slopes, section 300-14.

² Caltrans Code of Safe Practices, Division of Construction, August 2010, page 17.

of single-purpose RC mowing equipment with integrated mowing decks, while the second category consists of multi-purpose RC tool-carrier tractors with hydraulic power connections to operate an array of attachments. All RC mower units identified in this report are powered by either gasoline or diesel engines. Many meet California Air Resources Board (CARB) requirements either as built or with an optional accessory kit. Typically, different engine options are available based on customer preferences. This PI only considers new equipment here, and the major engine manufacturers generally keep up with emission controls to remain competitive. Based on past experience, Caltrans will be able to obtain a CARB-compliant engine on most every model if requested.

In the following, note that the RC mowers' maximum operational slope angle was not given consistently between manufacturers. It was given as a generic value or, in some cases, different values based on direction of travel. It seems like a qualitative comparative study of maximum angle has not been conducted for these systems. The terminology may mean different things depending on the manufacturer's usage. Caution is essential if this information will be used as a purchasing criterion.

RC Systems

While the term "Remote Control" generally refers to the wireless control of a device at a distance using either radio frequency signals or infrared light, infrared light is poorly suited to RC mowing since it is limited to the line of sight, unlike radio frequency signals. As such, only radio frequency signal RC devices are considered in this report. Wireless remote controllers are an essential component of all RC mowing equipment. These controllers are based on common commercially available devices, which can be slightly customized by manufacturers depending on the particular machine's features. The typical mower/tractor radio remote controller is a bellypack, battery-powered device with an operating range of 300 to 2,500 feet, depending on the operating frequency (Figure 1). The most basic operator controls necessary to safely operate a mowing machine are a pair of joysticks to control differential steering and an emergency kill button. Additional common controls found on mower remote controllers may include speed controls, blade engagement, cutting height adjustment, engine speed, inclinometer, direction inverter, and LCD information displays (Figure 2). The remote controller devices for tool-carrier tractors have additional generic controls to support the operation of a wide array of powered attachments. Manufacturers intentionally engineer their remote controllers to be both intuitive to operate and to contain all the necessary controls to safely operate their machines. As such, special operator training and maintenance tasks beyond those for any mower are unnecessary. Since remote controller features vary only slightly between machines, these features are unlikely to be an influential factor when selecting a machine.



Figure 1. Typical Bellypack Wireless Controller



Figure 2. Wireless Controller with LCD display

Dedicated RC Mowing Machines

Single-use RC mowers may seem to have far less utility than a multiple function tool tractor, but the dedicated mower configuration offers several advantages. Depending on the particular task at hand, a single mower might prove to be the best tool for the job. Single-use RC mowers tend to have the following advantages over tool tractors:

- less expensive
- more maneuverable
- simpler to operate
- mow into tighter spaces
- lighter in weight
- easier to free when stuck
- less of a threat if rolled down an embankment given smaller size
- easier to transport
- integrated safety winch (Spider ILD only)

Spider ILD Series RC Mower

The Spider Company sells three versions of RC slope mowers. The most capable of these models is the ILD02 RC mower, which can cut brush up to 8-feet tall on slopes up to 41 degrees. The ILD02 has a 300-foot control range, a 24-horsepower (hp) gasoline engine, and a 48.5-inch cut width. Spider mowers have a 4-wheel drive and a 4-wheel omnidirectional wheel steering system. The ILD02 has two speeds and is the only machine with a patented hydraulic stabilizing winch, which is synchronized with the wheel drive. Utilizing the winch enables the ILD02 to safely mow slopes up to 55 degrees, which mitigates the risk of equipment tumbling down an overly steep slope.

Price: Unknown

ILD02 RC Mower

<http://www.spidermowers.com/spider-ild02.html>

SlopeCare, USA Distributor for ILD02 RC Mower

<http://www.slopecare.com/ild02-radio-controlled-spider-slope-mower/>



Figure 3. ILD02 RC Mower

The Illinois Tollway Authority (TA) has purchased eight Spider ILD02 RC mowers and is testing them in various locations. The Missouri Department of Transportation (DOT) (MoDOT) was the first DOT to experiment with the Spider ILD02, as illustrated in the below video.

<https://www.youtube.com/watch?v=P0aaaDVcXOk>



Figure 4. Illinois TA Operating ILD02 RC Mower



Figure 5. MoDOT Testing ILD02 RC Mower

Tiger Corp. SlopePro Prowler RC Mower

The Tiger SlopePro Prowler RC mower is designed to cut grass, light brush, and saplings up to $\frac{3}{4}$ -inch in diameter. The SlopePro Prowler can mow on side slopes as steep as 50 degrees and slopes vertically up to 35 degrees and has a 300-foot control range. It has a 23-hp gasoline engine, a double blade, 52-inch cut width, and 9-inch-wide rubber tracks. The SlopePro Prowler has a horizontal plane cutting deck and can be fitted with either fixed grass/mulching blades or swinging brush cutting blades.

Price: Unknown

SlopePro Prowler RC Mower

http://www.tiger-mowers.com/remote_control_mowers/prowler



Figure 6. SlopePro Prowler RC Mower

MoDOT has purchased a SlopePro Prowler RC mower for use in the St. Louis region, which is depicted in the below video.

<https://www.youtube.com/watch?v=8r77asJklyg>

Evergreen Co. & McConnel Ltd RoboZero RC Mower

The RoboZero RC mower is available from either Evergreen or McConnel. It is a 2-wheel drive RC platform designed to cut grass and light brush on slopes up to 35 degrees. It has a 33-hp gasoline engine and two cutting implements: a 59-inch-wide rotary mowing head and a 51-inch-wide flail head.

Price: Unknown

RoboZero RC Mower

http://www.mcconnel.com/remote-control-technology/_product/18/robozero/
<http://en.energreen.it/>



Figure 7. RoboZero RC Mower

Summit Mowers LLC TRX-44 Pro RC Mower

The TRX-44 Pro RC mower is Summit Mowers' premium offering commercial RC mowing machine. The 2016 model is designed to cut grass and light brush on slopes as steep as 50 degrees. It has a 24-hp gasoline engine, a triple blade, 42-inch cut width, and 9-inch-wide rubber tracks. The TRX-44 Pro has a horizontal plane cutting deck and can be fitted with either fixed grass/mulching blades or swinging brush cutting blades.

Price: \$22,500

TRX-44 Pro RC Mower

<http://www.remotemowers.com/trx-44-pro>



Figure 8. TRX-44 Pro RC Mower

Lynex LX1000 RC Mower

The Lynex Company sells five versions of RC mowers. The LX1000 model is the only dedicated mowing machine that is designed to cut grass and light vegetation. The LX1000 technical specifications include a unique swiveling engine mount that ensures the engine remains vertical, which supports an impressive slope operational capability of up to 75 degrees. The remote controller has a 1,000-foot range. It has a 22-hp gasoline engine, a 58-inch cut width, and a rubber track drive system.

Price: Unknown

LX1000 RC Mower

<http://www.lynexuk.com/lx1000.asp>



Figure 9. LX1000 RC Mower

KommTek RoboFlail one RC Mower

The KommTek Company sells three RC mowers. The RoboFlail one model is the only dedicated commercial mowing machine they sell. It is designed to cut grass and light vegetation on slopes up to 55 degrees in any direction. The RoboFlail one has a swiveling fuel tank, which ensures the tank remains vertical while running on slopes. The remote controller has a 1,000-foot range. It has a 25-hp gasoline engine, a 48-inch cut width, and a rubber track drive system.

Price: Unknown

RoboFlail one RC Mower

<http://www.kommtek.de/products/automation/roboflail-one/?L=1>



Figure 9. RoboFlail one RC Mower

Alamo Industrial RidgeRunner RC Mower

The RidgeRunner RC mower is a 24-hp, air-cooled gasoline engine with electric motor-driven rubber tracks. It weighs 993 lb and has the ability to mow in either direction on slopes up to 50 degrees. This is the smallest dedicated mower included in this report. Due to its small size, it is questionable if it should be rated as commercial duty. The RidgeRunner specifications list a 44-inch cutting width with four swinging, mulching type blades able to cut grasses and light brush up to 1 inch in diameter.

Price: Unknown

RidgeRunner RC Mower

<http://www.alamo-industrial.com/RidgeRunner/Index.asp>



Figure 10. RidgeRunner RC Mower

MDB Technologies Mini Green Climber RC Mower

The Mini Green Climber RC mower has a 23.5-hp gasoline engine, weighs 1,100 lb, and runs on rubber tracks. It has a 40-inch-wide flail mower mowing deck and operates on a 60-degree side slope and 45-degree vertical slope.

Price: Unknown

Mini Green Climber RC Mower

<http://www.mdbsrl.com/en/green-maintenance/147-mini-green-climber>



Figure 11. Mini Green Climber RC Mower

RC Tool-Carrier Tractors

As the name implies, RC tool-carrier tractors are designed to operate an array of tools to accomplish a wide variety of tasks. What these tractors lack in agility when compared to dedicated mowers they make up for with added functionality. Over a dozen different tools are available for these tractors, but Caltrans' interest in RC equipment is generally limited to tasks with safety issues, which eliminates the need for most of these potential uses. Caltrans has demonstrated a clear interest in RC equipment for slope mowing and culvert clearing in confined spaces. All of the tool-carrier tractors presented in this report support a mowing function capable of cutting grasses and light vegetation, including saplings up to $\frac{3}{4}$ inch in diameter. Only a few models were identified with a standard design that supports a powered loader bucket accessory capable of lifting high enough to dump on a truck bed. The remote controllers all have similarly intuitive controls, safety features, and at least a 1,000-foot operating range, which is equal or superior to all dedicated RC mowers. Also, all of the following RC tool-carrier tractors either come with engine-powered hydraulic systems that meet CARB Tier 4 emissions standards or can be purchased with CARB-approved engines.

Evergreen Line of RC Tool-Carrier Tractors

The Evergreen Company, based in Italy, and the McConnel Company, based in England, sell the identical lines of rubber-tracked RC tool-carrier tractors and power attachments. The four models are listed here in order of horsepower. The 33-hp RoboEco (RoboMoz if sold by McConnel) operates on a 50-degree slope with seven available power attachments. The 40-hp RoboGreen (RoboCut if sold by McConnel, Traxx-RF if sold by Alamo in the U.S.A.) operates on slopes up to 55 degrees with optional spike tracks and over seventeen available power

attachments, including a bucket loader attachment. The 80-hp RoboMax operates on a 55-degree slope with at least six power attachments. The newest and largest machine in this line is the 140-hp RoboPower, which operates on a 45-degree slope with a standard three-point linkage, making it compatible with a large combination of power attachments.

Price: \$75,000-\$80,000

RoboEco (RoboMoz if by McConnel) RC Tool-Carrier Tractor

<http://en.energreen.it/robo-remote-controlled-machines/roboeco-remote-controlled-equipment-carrier-for-slopes/>

http://www.mcconnel.com/remote-control-technology/_product/19/robomoz/

A contractor for North and South Carolina DOTs operates a Traxx RC tool-carrier tractor and claims a 25% increase in efficiency and 50% reduction in labor costs by utilizing the machine on slopes.

<http://www.equipmentworld.com/i-robot-dot-contractor-now-cutting-interstate-grass-with-robotic-lawnmowers-photos/>

RoboGreen (RoboCut if by McConnel, Traxx-RF if by Alamo) RC Tool-Carrier Tractor

<http://en.energreen.it/robo-remote-controlled-machines/robogreen-remote-controlled-equipment-carrier-for-slopes/>

http://www.mcconnel.com/remote-control-technology/_product/20/robocut/

<http://www.mcconnel.com/remote-control-technology/robocut-attachments/robo-bucket/>

<http://www.alamo-industrial.com/TRAXX/Index.asp>



Figure 12. RoboEco RC Tool-Carrier Tractor



Figure 13. RoboGreen RC Tool-Carrier Tractor



Figure 14. Caltrans Traxx-RF RC Tool-Carrier Tractor



Figure 15. RoboGreen RC Tool-Carrier Tractor Equipped with Bucket

RoboMax RC Tool-Carrier Tractor

<http://en.energreen.it/robo-remote-controlled-machines/robomax-remote-controlled-equipment-carrier-for-slopes/>

RoboPower RC Tool-Carrier Tractor

<http://en.energreen.it/robo-remote-controlled-machines/robopower-remote-controlled-equipment-carrier-for-slopes/>



Figure 16. RoboMax RC Tool-Carrier Tractor



Figure 17. RoboPower RC Tool-Carrier Tractor

MDB Technology Green Climber RC Tracked Tool-Carrier Tractors

MDB Technology offers two rubber-tracked and one six-wheeled (discussed in the next section) RC tool-carrier tractors in its Green Climber line. The Green Climber LV300 has a 23-hp diesel Tier 4 engine, weighs 1,500 lb, and comes with a standard 48-inch-wide flail mowing head. MDB says the Green Climber LV300 coupling head is designed to maximize interchangeability with accessories. The Green Climber LV600 has a water-cooled, turbocharged, 56-hp diesel engine with intercooler and can use nine different power attachments. The slope mower configuration can side-shift the flail head laterally 30 inches. The rubber or metal spike tracks can extend from 4.3 feet to 5.6 feet and operate on slopes up to 60 degrees in any direction.

Price: Unknown

Green Climber LV300 RC Tool-Carrier Tractor

<http://www.mdbsrl.com/en/green-maintenance/173-green-climber-new>

Green Climber LV600 RC Tool-Carrier Tractor

<http://www.mdbsrl.com/en/green-maintenance/148-jumbo-truck>



Figure 18. Green Climber LV300 RC Tool-Carrier Tractor



Figure 19. Green Climber LV600 RC Tool-Carrier Tractor

MDB Technology Green Climber Power-6 RC 6-Wheeled Tool-Carrier Tractor

The Green Climber Power-6 has a 39-hp diesel engine and six-wheel drive. The machine has numerous tools along with 30 inches of power tool side shifting. The Green Climber Power-6 wheel span can be varied from 60 to 75 inches to enable the Green Climber Power-6 to operate in all directions on slopes.

Price: Unknown

Green Climber Power-6 RC Tool-Carrier Tractor

<http://www.mdbsrl.com/en/green-maintenance/157-power-6>



Figure 21. Green Climber Power-6 RC Tool-Carrier Tractor

KommTek RoboFlail RC Tool-Carrier Tractors

KommTek offers two RoboFlail tracked tool-carrier tractors. They both have 38-hp diesel engines and can operate on slopes up to 45 degrees. The RoboFlail plus model is equipped with conventional swing lifting arms to support the vertical lifting motion of powered attachments. The RoboFlail vario model has a front-mounted lifting mechanism that supports 16 inches of lateral power accessory side shifting and a 990-lb maximum lifting capacity. The vario also has a unique swiveling engine-mount system, which accounts for the side slope tilt keeping the engine running in a vertical, upright position. The vario also has a standardized equipment assembly mounting system to support the connection of a multitude of power tools.

Price: Unknown

RoboFlail plus RC Tool-Carrier Tractor

<http://www.kommtek.de/products/automation/roboflail-plus/?L=1>

RoboFlail vario RC Tool-Carrier Tractor

<http://www.kommtek.de/products/automation/roboflail-vario/?L=1>



Figure 20. RoboFlail plus RC Tool-Carrier Tractor



Figure 21. RoboFlail vario RC Tool-Carrier Tractor



RoboFlail Video:

https://www.youtube.com/watch?v=4ZEfn99oM_E

Ferri iCut4 RC Tool-Carrier Tractor

The iCut4 RC tool-carrier tractor is powered with a 49-hp diesel engine and can operate on slopes up to 55 degrees in any direction. This rubber-tracked machine has four powered attachments; however, a bucket is not one of the options. The iCut4 has one of the most sophisticated remote controller units on the market.

Price: Unknown

iCut4 RC Tool-Carrier Tractor

<http://www.icut4.com/it/presentazione/overview-en>



Figure 22. iCut4 RC Tool-Carrier Tractor

Irus Deltrak 2.5 and Evotrak RC Tracked Tool-Carrier Tractors

Irus is a German company offering two models of tracked RC tool-carrier tractor. The Deltrak 2.5 rides on wide rubber tracks that extend laterally from 43 inches up to 50 inches wide. The Deltrak 2.5 is powered by a 38-hp diesel engine. The Evotrak model is a slightly smaller machine with a 30-hp diesel engine and a fixed 50-inch-wide track. Both models can operate on slopes up to 50 degrees, have hydraulic front attachment mounts, and several available powered attachments; however, a loader bucket attachment is not available.

Price: Unknown

Deltrak 2.5 and Evotrak RC Tool-Carrier Tractors

<http://www.irus.de/produkte/ferngesteuerte-geraetetraeger/>



Figure 23. Deltrak 2.5 RC Tool-Carrier Tractor



Figure 24. Evotrax RC Tool-Carrier Tractor

Gaps in Findings

Tether or Winch Utility

We could not find any discussion on the advantages or disadvantages of utilizing a tether or winch with RC mowing equipment on steep slopes. Tethers may help reduce rollovers and control the RC mower if it does roll over, potentially preventing damage from tumbling or landing in traffic and helping the operator return to operations. Only the Spider mower has an integrated winch system, but no discussions regarding the benefits of this feature based on field trials could be found.

Extreme Angle Shutdown or Warning Feature

Several of the RC mowers listed refer to an extreme angle shutdown feature for their machines. It is unclear if this function is tied to an inclinometer or just to engine oil pressure loss. Any description of the process to safely retrieve an RC mower that has been shut down on a severely steep slope without risking workers is undetermined.

Extreme angle warning may also be of interest. However, such a feature may not be in demand. Angled banks are not uniformly flat surfaces and flipping would logically be more a result of localized rutting. Protecting the engine with a low oil pressure shutdown is common among systems. This can be related to tilt. Any machine could be easily fitted with one of various methods to indicate tilt angle. Caltrans may want to determine their needs and approach manufacturers for a customized package. Use of an uphill winch would be quite effective, as noted above.

Fire Mitigation Measures

One drawback of RC mowing equipment is the wildfire risk. All of the RC mowers considered in this report use steel blades that increase the risk of wildfires since they may produce sparks

when striking rocks. Handheld gasoline trimmers, on the other hand, use plastic blades, eliminating the risk of sparks. Cal Fire discourages the use of steel blade mowers to trim dry vegetation due to the risk of a rock-strike-induced spark starting a wildfire. As an added concern, the operator is at a distance from the machine, so a fire may go unnoticed or be too difficult to reach while still small enough to be easily extinguished. Additionally, small engines of any type should be fitted with spark arrestors to avoid engine exhaust ignition and all hot mufflers should be protected (doing this, however, should not be problematic). No references to RC mower wildfire mitigation measures were found.

Slope Margin of Safety

Steep roadside slopes covered with vegetation are subject to erosion and may be rutted and have uneven grading. It is unclear if the manufacturers' specified maximum slope limit for each machine was determined on an ideal flat and smooth slope or on real-world terrain. Caltrans may have to institute a nominal operational margin of safety and derate the maximum slope angle below a manufacturer's specified maximum angle on rough terrain.

Remote Controlled Mower Deployment Study

A comprehensive literature search failed to identify any quantitative or empirical studies that examined RC mower deployment strategies, testing, or best practices. Sales literature and contractor assertions were the only information found related to the in-service effectiveness of RC mowing equipment operations.

Ohio DOT is finishing a research project with the Davey Resource Group looking into slope mowing. ODOT purchased two remote control mowers for review. The project is ending at the time of this PI, and the final report will be completed soon thereafter. Information on the research project can be found at:

http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Pages/Project_Details.aspx

Recommendation for Mower Rental for Evaluation

This PI does not provide a recommendation for a mower rental for Caltrans evaluation. It is difficult to provide such a recommendation without a clearer understanding of what Caltrans specifically wants or needs. At this stage, it is not clear which category of machine Caltrans would want, i.e. a dedicated slope mower or a tool-carrier system. Caltrans seems to favor the flexibility of the tool-carrier system, but the former has significant advantages for the specific task of slope mowing. Without being able to make this top-level choice, it is impossible to refine a recommendation down to an individual system. Developing such a recommendation seems best-suited for an evaluation project, wherein Caltrans' wants and needs can be clarified, and an appropriate system can be recommended with more certainty.

Next Steps

Caltrans Remote Controlled Mowing Objectives

This study catalogs the wide array of commercial-duty RC mowing equipment configurations and functional possibilities. The next step may be for Caltrans to decide which functions and utility achieve their specific operational objectives. Caltrans may want to consider some of the following issues when developing a remote mower deployment plan:

1. The expected maximum grade the mower can climb and/or traverse

2. The importance of a top of slope safety leash to prevent equipment damage and improve safety
3. Type of vegetation to be trimmed (native grasses/weeds, bushes, or small trees)
4. The range of functions required of RC equipment (mowing-only or multiple uses)
5. The preference for small size and maneuverability versus multi-functionality
6. The required vertical mowing head travel (mow height)
7. The importance of vegetation friendly rubber tracks
8. Safety functions unique to Caltrans necessary for RC operation on highway roadsides

Detailed Findings

Related Research and Resources

A comprehensive literature search utilizing both Google and Google Scholar did not reveal any useful references, studies, or analyses related to the deployment or implementation of RC mowers on slopes. The search did, however, find several references which indicated the higher-level control capabilities of the Spider RC Mower, as well as several patents concerning the fundamental features and designs of RC mower technologies.

Consultation with State DOTs

A survey was conducted of other transportation agency's current practices or experiences in operating RC mowing equipment as related to innovative methods for mowing roadside vegetation on slopes. This survey was sent by the Caltrans Division of Research, Innovation and System Information (DRISI) to the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee (RAC) for distribution. Of the 50 states and other transportation agencies contacted, the following responses were received to the questionnaire.

1. In general, does your agency have any innovative methods to improve safety for workers mowing roadside vegetation? If so, please briefly describe the current methods and equipment your agency utilizes.
2. Has your agency investigated or utilized remote controlled commercial-duty mowers to improve worker safety in trimming vegetation growing either on flats or steep roadside slopes that are difficult to access with conventional mowing equipment? If so, please briefly describe the methods and equipment your agency utilizes or has utilized.
3. If your agency has considered or utilized remote controlled mowing equipment, would equipment that can support multiple attachment accessories be preferred over a single mowing head function? Please explain why. Also, if you prefer multiple attachments, please share any attachment ideas of interest.

4. If you feel your agency has more information to offer on this subject, please provide contact information to allow a follow-up discussion.
5. Please provide any other information or feedback that you believe may be of value for this research.

The following agencies and persons responded to the survey:

Florida DOT

Responder: J. Darryll Dockstader, Manager, Research Center
Florida Department of Transportation, Darryll.Dockstader@dot.state.fl.us

1. The Department uses traditional large, medium, and small mowers and hand equipment with maintenance of traffic.
2. The Department has looked more generally at the use of sensor technologies for maintenance vehicles, which could include those used for mowing, pavement inspection, etc.
3. N/A
4. N/A
5. N/A

Kansas DOT

Responder: Clay Adams, Bureau Chief of Maintenance,
Kansas Department of Transportation, Clay.Adams@ks.gov

1. We use slope mowers, boom mowers, and a truck mounted boom mower and a boom mower with a saw blade attachment for trimming back trees. We have added additional lights, allow them to mow toward traffic and use head and tail lights in addition to strobes.
2. We are aware of the remote control mowers but we do not have any at this time.
3. We would be willing to look at any type of attachment that would allow us to use this during the non-mowing season. Cleaning out culverts would be one thought.
4. No response
5. No response

Minnesota DOT

Responder: Steve M. Lund, P.E., Director, Office of Maintenance
Minnesota Department of Transportation, steven.lund@state.mn.us

1. In recent times, we have used two pieces of equipment, the Highline Mower and the 3 Point Boom Mower. We have funded both through the MnDOT maintenance research

program and both involve attachments to a tractor. Both are essentially a one-person operation and have had positive reviews.

2. No
3. No response
4. No response
5. No response

Montana DOT

Responder: Jeff Gleason, Equipment Bureau Chief,
Montana Department of Transportation, jegleason@mt.gov

1. We use the traditional mowing tractors for our operations.
2. We are not at this time.
3. We have not considered remote mowers.
4. Not at this time
5. Not at this time.

Nevada DOT

Responder: Anita Bush P.E., Chief Maintenance and Asset Management Engineer,
Nevada Department of Transportation, abush@dot.state.nv.us

1. No
2. No
3. N/A
4. N/A
5. N/A

New Hampshire DOT

Responder: Elizabeth S. Kleemann, P.E., Assistant Research Engineer
New Hampshire DOT Bureau of Materials and Research, EKleemann@dot.state.nh.us

1. New Hampshire DOT does not use this technology.
2. No response
3. No response
4. No response
5. No response

New Jersey DOT

James Schmidt, Fleet Management Systems Administrator
New Jersey Department of Transportation, Jim.Schmidt@dot.nj.gov

1. The NJDOT does not have any large slope that we mow. For the smaller slopes that we do maintain we utilize Ventrac mowers. When mowing near the shoulder of the road way a crash attenuator truck is deployed for safety
2. We have had demos from Dvorak Spider, Alamo Traxx and Tiger Prowler. While we determined that we had no real need for this type of mower it was our findings that we preferred the Prowler if we were to purchase one.
3. N/A
4. N/A
5. N/A

New Mexico DOT

Responder: Ray C. Chavez P.E., Research Implementation Engineer,
New Mexico Department of Transportation, Research Bureau, Ray.Chaves2@state.nm.us

1. NMDOT D3 Standard Operating Procedure is to have shoulder work ahead sign and mowing ahead sign with operators in standard and non-standard mowers.
2. No
3. N/A, see answer to Q2
4. N/A, see answers to Q2 and Q3
5. Interested to see the compiled information on this subject

North Carolina DOT

Responder: Derek Smith, Roadside Vegetation Asset Management Engineer
North Carolina Department of Transportation, dcsmith@ncdot.gov

1. NCDOT is currently sponsoring a 'senior project' with NC State University's Biological & Agricultural Engineering Department to research types of remote controlled mowers. These seniors will conduct a thorough literature search and develop a proto-type median cable guard-rail mower. This project is expected to be completed by May 2017. Also, please see our response to questions 5 below...
2. NCDOT has not used remote-controlled mowing equipment.
3. NCDOT has not used remote-controlled mowing equipment.
4. If you need additional information, please contact Derek Smith (dcsmith@ncdot.gov)
[919-707-2939](tel:919-707-2939).

5. NCDOT is working with NC State University to evaluate low-growing warm-season turf varieties for use under median rail-systems. Cooperatively, we have selected 9 varieties of Zoysia grass (5 un-named genotypes and 4 commercially available species) for rights of way evaluation. Zoysia is a warm-season, perennial, turf-type grass that spreads by stolons and rhizomes. Its dense turf is characterized by stiff leaf blades. Zoysia exhibits exceptional wear tolerance, good drought tolerance and moderate shade tolerance. Zoysia has a low-water and nutrition requirement. Once fully established, it resists weeds well due to its dense growth pattern and thus supports the need for fewer mowing cycles. This thick vegetative cover will prevent weed growth and because of its growth habit will reduce the need for mowing.

Ohio DOT

Responder: Scott Lucas MBA, CPM, Administrative Officer III, Office of Maintenance Operations, Ohio Department of Transportation, Scott.Lucas@dot.ohio.gov

1. Yes. We use chariot style slope mowers. One of the main ones we use is made by Kut Kwick. We also have a research project with the Davey Resource Group looking into slope mowing. ODOT has purchased two remote control mowers for review. The project is due to complete this November and you are welcome to the data. Attached below is a link to the research page on the project and to Kut Kwick's website.
 - http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Pages/Project_Details.aspx
 - <http://kutkwick.com/superslopedmaster.htm>
2. Yes, we have purchased two remote controlled slope mowers and are reviewing their performance as part of our vegetation management research project. The mowers purchased are the Alamo Traxx RF. They seem to work pretty well and unfortunately, we have rolled both of them, but each of them were easily repaired and only suffered minor damage.
 - <https://www.youtube.com/watch?v=Ukv12bvUcdY>
3. Yes, we were interested in multiple heads for our machine. The reason we would like to use multiple heads is it provides a greater amount of use for the machine and keeps workers further away from the cutting head of the machine or out of a harsh environment. Some of the heads we are considering are front buckets for removing debris from box culverts and a stump cutter attachment.
4. Yes, please call me after the first of the year. Our project is scheduled to end on 11/18/2016. My number is 614-644-6603. My email is Scott.Lucas@dot.ohio.gov

5. Make sure you know what type of material you are wanting to mow. If it is mainly grass, that is one thing, but if it is a mixture of grass and brush, that is another.

Saskatchewan Ministry of Highways and Infrastructure

Responder: Iftekhar Kalyar, P.E., Senior Project Manager

Government of Saskatchewan, Preservation Standards, Ministry of Highways and Infrastructure,
Iftekhar.Kalyar@gov.sk.ca

1. Ministry uses standard mowing equipment (rotary or Sickle) tractor drawn type. Hand trimming equipment is used for neat trimming around signs and guardrails. Traffic accommodation signs are not required since it is slow moving operation in highway ditch. Contractors are recommended to install a rotary flashing light.
2. No
3. N/A
4. N/A
5. N/A

South Carolina DOT

Responder: David Cook, South Carolina DOT, State Maintenance Engineer,
South Carolina Department of Transportation, CookDB@scdot.org

1. SC Department of Transportation depends on work zone setup to protect workers. SC DOT uses chemical, mechanical (tractors and mowers), and hand tools (weed eaters) to perform vegetation management activities. Work zone signing, follow trucks, and attenuators are used where appropriate to provide protection for workers.
2. It has been investigated, but not implemented. Boom mowers are utilized to cut areas on steep slopes, or these areas are maintained by hand. The vast majority of these areas are outside of the mowing limit and are not routinely mowed.
3. N/A
4. No response
5. No response

Texas DOT

Responder: Wade Odell, P.E., Research Project Manager,
Research & Technology Implementation Division,
Texas Department of Transportation, Wade.Odell@txdot.gov

1. No, all mowing operations for Texas Department of Transportation (Tx DOT) are contracted and used with manned tractors and shredders as the primary method.

Currently, further interest in Remote Control Mowers would be dependent on the contractors.

2. Yes, some research has been done in the past, however no further interest was shown due to the fact the mowers were small and expensive.
3. A piece of equipment that can handle multiple attachments is usually better due to the ability to work on multiple different types of projects with one piece of equipment. Less major equipment means less cost and mechanical maintenance. For example: 1 skid-steer can operate many different attachments. Some attachments ideas might include a large bat-wing mower/shredder, brush shredder/chipper, herbicide sprayer.
4. Currently, TxDOT shows no interest in Remote Control Mowers.
5. Include a GPS navigational type system to keep the equipment in the correct area and to make sure there is 100 percent coverage.

Washington DC DOT

Responder: Stephanie Dock, AICP, Research Program Specialist,
DC Department of Transportation, stephnie.dock@dc.gov

1. I do not think DC has roadside vegetation to mow and if we do, the department of public works probably does it. The only comparable item I could point to is our urban forestry division that does a lot of tree work. However, that won't involve RC mowers. Let me know if you would like me to check with them about innovative safety methods. We are an urban environment though, so it is always a bit different here.
2. No response
3. No response
4. No response
5. No response

West Virginia Division of Highways

Jeffry Pifer, P.E., Operations Section Leader
West Virginia Division of Highways, Maintenance Division, Jeff.M.Pifer@wv.gov

1. No
2. I saw a demonstration of the Alamo Industrial TRAXX - RF with brush cutting attachment. It worked really well but was expensive.
3. I would think multiple attachments would increase the versatility of the machine. The TRAXX RF has the option of a front loader bucket which would make it useful for cleaning out box culverts of sediment and for use in other confined spaces you wouldn't want to put a laborer or machine and operator.

4. N/A

5. N/A

Contacts

AHMCT and Caltrans DRISI contacted the following individuals to gather information for this investigation:

Florida DOT

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Florida Department of Transportation

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Kansas DOT

Clay Adams, Bureau Chief of Maintenance

Kansas Department of Transportation

Office: (785) 296-3233 Clay.Adams@ks.gov

Minnesota DOT

Steven Lund, P.E., State Maintenance Engineer, Director, Office of Maintenance

Minnesota Department of Transportation

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Montana DOT

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New Jersey DOT

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