

Efficient and Safe Removal & Debris Disposal of Dead Ash Trees Killed by Emerald Ash Borer



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As emerald ash borer infestations have spread throughout Ohio, standing dead ash trees are creating challenges for Ohio Department of Transportation "ODOT". ODOT has become overwhelmed keeping up with the volume of dead trees that potentially pose hazards and need to be removed. Davey Resource Group, Inc., worked with ODOT to develop an improved process for more efficient and safer ash tree removal and handling of generated debris.			
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November 2022

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Problem Statement

The Ohio Department of Transportation (ODOT) is challenged with managing fallen, infected, or standing dead ash trees along over 43,000 lane miles of roads throughout Ohio's diverse landscapes. Due to the invasive insect emerald ash borer (EAB), many ash trees throughout Ohio's right-of-way (ROW) have been negatively impacted. A high volume of ash trees are infected, in poor condition, or dead throughout ODOT's right-of-way (ROW). Ash trees infected with EAB will die over the course of a few years, becoming brittle. These brittle trees become a hazard to the traveling public and DOT staff tasked with removing them.

Davey Resource Group, Inc. "DRG", was selected by ODOT to conduct this research project. This project consisted of two phases. Phase I included investigating ODOT's current ash tree removal and disposal management practices and researching other tools and techniques that would result in greater efficiencies and increased safety. Phase II included field testing three pieces of equipment: Sennebogen 718E, Bandit 2090 whole tree chipper, and Rotobec 4042HD log grapple.

ODOT maintenance crews are responsible for hazard tree management on state, US route, and interstate ROWs. Across the state, managers and staff plan for ash tree removal and debris disposal to facilitate safe passage on roadways. However, ODOT maintenance crews are not able to focus solely on tree management, decreasing their efficiency of that task. Crew assignments change from day to day based on priorities and availability of both crews and equipment. ODOT maintenance crews perform a variety of tasks throughout the year including guardrail and pothole repair, chip sealing, snow and ice removal, and vegetation management which includes herbicide applications, mowing, tree trimming, and tree removal. Since the maintenance staff at each garage are responsible for performing a wide range of tasks, they cannot dedicate year-round consistent personnel, time, and focus for hazard tree management. During Phase I of this research project, DRG identified challenges in ODOT crews' tree trimming and tree removal operations. This included the lack of safety and efficiency while taking down and disposing of ash trees through the different processes and equipment being used.

The overall purpose of the research project was to identify and evaluate safe and efficient ash tree removal and disposal practices that can be implemented by ODOT to increase cost-effectiveness of roadside maintenance activities, improve worker safety, and foster safe highway use by the traveling public.

Research Background

Ash trees are a common species across the entire state of Ohio. The Ohio Department of Natural Resources (ODNR) estimates that prior to the introduction of EAB in Ohio, its forests contained 3.8 billion trees in the ash genus, *Fraxinus* (Herms *et al.*, 2004; MacFarlane & Meyer, 2005). Anecdotally, tree surveyors with The Davey Tree Expert Company estimated that ash trees comprised approximately 10% of trees found along highway ROWs prior to the discovery of EAB in Ohio in 2003 (Herms *et al.*, 2004), and estimate that ash, living or dead, now make up 5% of the ROW tree line.

Ash trees along ROWs are often at high risk of mortality, as mature EAB tend to gravitate toward exposed trees and are known to disperse readily along highway ROWs (Herms & McCullough, 2014).

Due to the likelihood of encountering a dead ash tree, ODOT roadside maintenance workers are at particular risk when managing these trees. The exceedingly brittle nature of the wood caused by the EAB's destruction of the tree's circulatory system makes the removal of dead or dying ash a dangerous task for untrained or under-prepared workers. First, it is key that workers can successfully identify ash trees and signs of an EAB infestation prior to any maintenance activity. Working around a dead ash tree can put workers at risk from falling limbs or trees. Second, brittle wood is unpredictable when cut, making normal tree removal safety standards insufficient for keeping workers safe. Removal can be further complicated by the surrounding entangled or plants capable of phytodermatitis, and concentrated stands of dead ash trees could pose even greater risk to workers. Lastly, although the federal quarantine on transporting ash trees has been removed (Federal Register, 2020), the issue of debris removal still presents a logistical concern.

In general, many roadside vegetation management plans provide decision tools and methods of control for trees determined to present potential hazards along roadways.

During Phase I of this project, DRG observed and noted the current practices and equipment of three ODOT garages in District 3 that were managing the removal and debris disposal of ash trees. The equipment and processes were compared against other industry standards, as well as other state DOTs, to identify solutions for immediate and future use that would increase safety and efficiency.

Once the researched equipment was approved and purchased by the ODOT Technical Advisory Committee through funds provided by the control board, Phase II began. Phase II consisted of training as well as field testing and gathering data from observing ODOT's crews use the current and new equipment for their tree removal operations. The equipment purchased included a Sennebogen 718E tree handler for tree removal, a Rotobec 4042HD log grapple mounted on a midsized excavator to move logs towards the chipper, and a Bandit 2090 whole tree chipper with Kesla loader. The Sennebogen 718E and the Bandit 2090 whole tree chipper were both able to be observed in the field. The Rotobec 4042HD log grapple was not available at the time of observation as it was being utilized in a different county.

Goals and Objectives

As part of Phase I, DRG researched and made recommendations on alternative processes to implement and innovative pieces of equipment to purchase to help ODOT crews more safely and efficiently remove ash tree hazards. To meet the goal of presenting an improved process for dead ash tree removal and handling of debris for ODOT, DRG completed the following objectives in Phase I:

- Presented national and international industry standard practices for dead ash tree removal and debris handling by public and private workforces
- Evaluated ODOT current practices and begin gap analysis
- Developed an equipment matrix to determine which equipment on the market in the United States would help improve ODOT crews work more safely and efficiently that should be purchased and tested in Phase II

Following ODOT Technical Advisory Committee's approval of recommended solutions, DRG completed the following objectives in Phase II:

- Developed a Site Assessment Form to assist the work planner in making tree work related observations to increase the safety and efficiency of crew planning and setup at each job site
- Developed a Decision Tree to determine the best equipment setup to use in different situations
- Provided a workshop to ODOT's work planners and tree crews to review the Site Assessment Form, Decision Tree, and operational and process efficiencies for ODOT to implement for tree work operations
- Field tested current equipment versus alternative equipment for safe ash removal and debris handling
- Evaluated process and equipment changes to complete a gap analysis and return on investment (ROI)

Project Tasks

Phase I of the project included the following three tasks:

- 1.) Research Kick-off Meeting and Status Meetings
- 2.) Present Standards for Ash Tree Removal and Debris Handling
- 3.) Gap Analysis and Matrix of Recommended Equipment and Processes

Phase II of the project included the following:

- 1.) Vendor Equipment Training and DRG Decision Tree and Efficiencies Workshop
- 2.) Field Testing of New Procedures and Equipment
- 3.) Report and Fact Sheet

Research Approach

Phase I: Determine Current Standards for Ash Tree Removal and Debris Handling

Industry Standards Background Research

DRG conducted a detailed review of current processes and standards for ash removal and debris handling across a variety of federal agencies, international organizations, trade associations, private industries, utility industries, and municipalities that have experience with EAB, providing standards, or guidelines for hazard tree handling. DRG utilized a combination of virtual interviews, in-person observations, reviews of published reports, manuals, management plans, and a primary literature review. Recommendations and practices for general tree removal along with ash tree removal was consolidated from this research. Research included the qualifications or conditions for tree removal, crew training, debris handling, electrical hazard/utility line clearance, site assessment, safety requirements, and equipment used.

Organizations from which information was gathered include: Tree Care Industry Association (TCIA), International Society of Arboriculture (ISA), United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS), Colorado Department of Agriculture (CDA), State of Illinois, Metropolitan Government of Nashville and Davidson County, companies working in the private and utility sectors, and other state DOTs including Connecticut, Michigan, Minnesota, New York, and Pennsylvania.

DOT Interviews

To allow for direct comparison to other DOTs and provide feasible recommendations to ODOT, DRG interviewed DOT representatives from Connecticut, Michigan, Minnesota, New York, and Pennsylvania where EAB is present to discuss their practices and equipment utilization for ash tree removal and debris disposal. Specifically, these interviews included a set of 17 questions (Appendix A) that covered topics ranging from the level of training of staff, crew efficiency, safety practices, site assessment and job planning procedures, monitoring, equipment used, and debris disposal processes. The responses from these interviews, combined with the background research of guidelines, standards and practices from other agencies nationwide, were integrated into recommendations provided to ODOT in Phase I of this project.

ODOT and Contractor Baseline Data Collection

To provide a baseline for comparison to current industry standards, guidelines, and practices for ash tree removal and debris handling, DRG conducted observations and interviews with ODOT tree removal crews, and observations of a contractor (VanCuren Services, Inc.) crew. DRG observed the Erie and Lorain County ODOT crews during a day of tree removal activities on December 15 and December 23, 2020, respectively. A contracted crew (VanCuren Services, Inc.) was also observed using a Sennebogen 718E during tree removal and debris handling on November 17 and 19, 2020 on US 30 in Wayne County. For the ODOT crews, each crew was interviewed using a questionnaire (Appendix B) in which they were asked to assess their level of experience with tree and ash tree removal, their work planning process, reliability of equipment, and team communication via multiple choice questions. In Erie County, the ODOT crew manager was interviewed utilizing a different questionnaire which asked him to assess their work planning and implementation process in more detail via additional multiple-choice questions. During the tree removal work, DRG observed each crew and completed a crew observation form which tracked each crew's efficiency, equipment condition and handling, and safety concerns. These crew survey responses and DRG observation forms were scored and compared to responses during Phase II of the project (see "ODOT Crew Survey Evaluation").



Photo 1: Lorain County crew observed in 2020 during baseline data collection.

Matrix of Recommended Equipment and Processes

Following the collection of baseline observations from ODOT ash tree removal in District 3, a matrix of recommended equipment and processes was developed. To create this matrix, issues that emerged from the questionnaires and issues observed during DRG's baseline data collection regarding crew training, crew efficiency, safety, job planning, and equipment operation were identified. Pathways to achieve these improvements were determined based upon the industry standards background research and the other state DOT interviews. To determine the ideal equipment for ODOT to integrate into these recommendations, a variety of equipment that is utilized or could potentially be utilized in ash tree removal and debris disposal were considered. This equipment included chippers, skid steers, excavators, grapple saws, and bucket trucks. The equipment was compared based on training difficulties, functionality, and efficiency in the field, and potential purchase challenges for ODOT. The chosen set of equipment based on this comparison was integrated into associated recommendations in the matrix. A total of 16 recommendations, the observed issues they addressed, and their potential benefits to ODOT were included in the matrix (Appendix C).

Gap Analysis and ROI - Phase I

To determine the final procedure and equipment recommendations, DRG compared the staff required, production rate, labor costs, cost per tree, and safety concerns of ODOT's current practices with those of the recommended procedure and equipment setup. Time estimates for return on investment (ROI) utilizing contractor rates and in-house costs were also calculated. The productivity and cost differences between current ODOT tree removal practices and those recommended by DRG were summarized and presented to ODOT to complete Phase I of the project (Appendix D). Equipment purchase costs are found in Appendix E.

Phase II: Test Alternative Equipment and Processes for Ash Tree Removal and Debris Handling

Trainings

Initially, DRG planned for three levels of training for ODOT crews: a vendor led training on ODOT's newly acquired equipment, a DRG-led efficiency workshop, and a three-day third-party safety training on electrical hazard awareness, pruning and felling, and rigging and cleanup. The intent was to compare the improvements to safety and efficiency through field observations of ODOT crews performing ash tree removals. The comparison was to be made between three crews: crews who received the extra trainings and continued to use the standard equipment, crews who received the extra trainings and used the new equipment, and crews who had previously received the standard ODOT trainings but not the additional trainings and were using the standard equipment (control). Due to the restrictions on all tree removals, except hazard trees during roosting season (April 1st - Sept 3rd for federally endangered Indiana bat (*Myotis sodalis*) and northern long-eared bat (*Myotis septentrionalis*)), ODOT performs most of its tree work during the winter months. Equipment arrival was planned for the fall and winter of 2021 prior to ODOT's more concentrated season of tree work. However, due to the COVID pandemic, there were supply chain issues that caused delays in the arrival of equipment. This led to the third-party safety training and DRG efficiency workshop to not be conducted until the summer of 2022. The only recommended new piece of equipment that arrived on time was the Sennebogen 718E. The delay in equipment arrivals led to these training events to be concurrent with summer testing observation events. Thus, the teachings from these additional trainings could not be implemented and practiced before the final assessments took place.

Safety Training

A three-day safety arborist safety training was provided by ACRT, Inc. The training focused on safe tree removals, machine operations, advanced skills, working around electrical hazards, and included both field and classroom components (Appendix F). The training took place during May, June, July, and August of 2022 for different groups of ODOT staff.

Vendor Training

Operators received vendor equipment training on the Sennebogen 718E during delivery of the piece of equipment on October 5, 2021. The Rotobec 4042HD grapple training occurred on the day it was delivered in March of 2022, and the Bandit 2090 training occurred when the piece of equipment was delivered on June 8, 2022.

Efficiency Workshop

DRG conducted an efficiency workshop on August 8, 2022. This workshop was broken into a classroom and field-based component. The classroom component was broken into two sections. The first section was geared towards ODOT's work planners as it introduced the Site Assessment Form (Appendix G) and Equipment Decision Tree (Appendix H) developed by DRG, and suggested improvements that managers would have control over such as production goals. The Site Assessment Form is used to help the work planner look for hazards associated with the job site and determine the priority of the work. The Decision Tree guides ODOT's work planners on how to arrive at the best equipment and methods to be used in different tree removal scenarios (*e.g.*, different site terrain, tree size, and accessibility).

The second section of the classroom training was geared towards the crews that perform the work and items they have control over, such as positioning of equipment, different cutting techniques, winching, and being prepared with the right equipment in working order. A rest stop with three hazard maple trees was used for the field portion of the training. At the rest stop, DRG staff referred to the Site Assessment Form and the Decision Tree and discussed with the attendees how they should be utilized. The ODOT bucket truck operator set up and removed the trees as DRG discussed with the personnel the different strategies that should be used for their safe removal. The Bandit 2090 chipper was utilized for disposing of the debris. As part of the discussion with the attendees, DRG staff discussed that the Sennebogen 718E would be the best equipment ODOT owns to remove the trees. This was due to the presence of the public at the site during the removal in combination with the height of the trees and the limited reach of the forestry bucket truck. The Sennebogen 718E would have been able to grip and hold the tree trunks with the grapple while the saw made the cut. Once cut, the grapple could have safely maneuvered the debris to the ground. The Sennebogen also would have provided the operator protection from any pieces of debris that may have fallen in the cutting and lowering process. However, only the bucket truck was available for the day's work. Since the bucket truck was not able to be positioned outside of the tree's fall zones due to the limited reach of the equipment, it was discussed that proper cuts along with ropes and rigging would reduce the chances of pieces of the trees coming down in unpredictable ways. Pull ropes could have been installed in the tree while the ground crew pulled, causing the cut debris to come down in the chosen, established drop zone, or a block and rope could have been used for lowering the pieces safely. However, ropes were not located on the bucket truck during the workshop, without the rope, pieces fell without much control, as can be seen in Photo 2. Taking the steps to gain control during tree cutting and maintenance increases the safety of the operator and nearby bystanders, as well as preventing damage to the truck itself.



Photo 2: Crews participating in DRG's efficiency workshop.

Field Tests

To determine whether the recommended equipment is worth the investment by ODOT to enhance their tools for managing ash trees and other hazardous trees in the ROW, field tests were conducted with new equipment. Two sets of field tests were planned: one in the fall of 2021 and another in the spring of 2022. The fall field test was meant to provide a baseline measurement for how the crews were functioning with their standard equipment (*i.e.*, forestry bucket truck and brush chipper) and a new piece of equipment, the Sennebogen 718E.

The plan was for the Sennebogen 718E, Rotobec 4042HD grapple, and Bandit 2090 to arrive during the fall and winter of 2021. This was to be followed by trainings, a winter of utilizing each piece of equipment, as well as implementing the new processes during ODOT's primary tree cutting season. The spring test was then planned to occur after the crews had time to settle into using the new equipment and follow the recommended procedures. The goal was to observe and measure improvements that were made. However, the second set of tests did not occur until the summer of 2022 due to supply chain difficulties that prevented timely delivery of new equipment (*i.e.*, Bandit 2090r and Rotobec 4042HD grapple for excavator).

Baseline field tests were conducted on November 4, 5, and 6, 2021, across three sites in Richland and Lorain counties. During these tests, each crew cleared ash, other dead or partially dead trees, and associated debris from a linear plot. Plots were selected each day so that the two crews working would be clearing similarly sized trees in plots with a similar density and biomass of trees. For each test, DRG measured personnel time on-site, equipment hours, equipment cost, tree count, tree species, tree size (height and diameter at breast height), and tree health (live or dead). Productivity based on tree removal and debris process rates and costs associated with labor and equipment were compared between crews that used ODOT's standard equipment combination and crews that utilized the Sennebogen 718E.



Photo 3: Sennebogen 718E being operated by ODOT in November 2021.

Note that although the Sennebogen 718E operators had received vendor equipment training prior to November 2021 tests, the third-party safety training and Davey efficiency workshop had not yet occurred. As a result, the “Control” and “Trained” bucket truck crews were operating with the same processes during these fall field tests, albeit with some potential differences due to having different personnel. Due to this, these two crews are represented independently in DRG analysis, but are referred to as “Bucket truck 1” and “Bucket truck 2” crews.



Photo 4: Forestry bucket truck used in the November 2021 observations.

Summer ODOT crew observations and field tests were conducted on July 6, 7 and August 11, 2022, across two sites in Wayne and Ashland counties. The plots were selected due to the high number of trees that had been left in a hazardous state or had fallen from a storm and the large volume of work at the sites.

On July 6 and 7, the Sennebogen 718E and the Bandit 2090 whole tree chipper were on-site. The Sennebogen 718E tree handler cut ash, dead or partially dead trees of all species, and associated debris from the ROW into pieces that were an appropriate size for the chipper. The Sennebogen 718 E then moved the pieces of trees and debris into piles along the bottom of the work site. The plan was for the dump truck to pull the Bandit 2090 chipper to each pile and have the Kesla loader attached to the chipper feed the wood into the chipper. However, on July 6th the chipper became jammed upon starting due to improper end of day work processes the prior day when a piece of wood was left in the chute. The piece of wood jammed the machine on startup on July 6. Due to the crew's unfamiliarity with chipper operations, they did not realize the cause of the problem, and forced engagement of the clutch. This caused damage to the clutch, resulting in the chipper being inoperable until the clutch was repaired. Thus, it was unusable until the August 11 evaluation. With both the Sennebogen 718E and Bandit 2090 chipper operational on August 11, DRG was able to collect the full suite of field test data in line with November 2021 evaluations (time on site, equipment hours, tree count, and tree size (estimated length and diameter). Productivity and costs from this August 11 test were compared to that of November 2021 crews. The Rotobec 4042HD grapple attached to a midsize excavator was not present during the Sennebogen 718E and Bandit 2090 tree clearing operations in July or August 2022 as the grapple was being utilized at another site clearing debris. For additional details regarding these tests and data analysis see Appendix I and J.



Photo 5: Bandit 2090 chipper attached to a truck with a dump bed in July 2022 operations.



Photo 6: Sennebogen 718E moving piles of debris in July 2022 operations.

Gap Analysis - Phase II

During Phase II, the observed productivity and labor costs from November 2021 and August 2022 field tests were utilized to update the Phase I gap analysis. This analysis had compared production rates and costs of ODOT's currently approved tree removal practices to those of DRG's recommended equipment combination. For Phase II, DRG calculated cost efficiency (cost/tree) based on the field data and compared that to the costs associated with contractor work. The updated cost comparisons also integrated equipment operating costs provided by ODOT. Additionally, annual ROI estimates were updated utilizing the observed field data.

DRG also compared the productivity increase (trees removed/day) experienced by ODOT crews operating a Sennebogen 718E and whole tree chipper to the increase in productivity between two experienced contractor crews (VanCuren Service, Inc. - Sennebogen and whole tree chipper crew vs Davey Tree, Inc. - bucket truck crews). Given the expected productivity benefits of DRG's recommended equipment setup, we expected that this increase in productivity over bucket truck crews should be similar for ODOT and experienced contractors.

For additional details regarding the methodology for these analyses, see Appendix J.

Contractor and ODOT Storm Event Response Cost Comparison

From June 15, 2022 through August 5, 2022, ODOT tree crews in Wayne County implemented a 35-day storm event cleanup response. During this period, ODOT utilized 2 of the 3 new pieces of equipment recommended by DRG (Sennebogen 718E and Rotobec 4042HD grapple attached to a midsized excavator). Since DRG did not have tree removal data, productivity, cost efficiency (cost per tree) or annual ROI (based upon cost per tree) could not be compared to other field tests observations or to that of a contractor. However, DRG was able to compare loaded labor costs of ODOT for this period with contractor labor costs based upon worker billing rates. Additionally, although DRG did not have direct equipment costs available for the contractor, DRG did have daily operating costs, which were also available for ODOT during the storm event response, as well as how many days each piece of equipment was used (Appendix L). DRG compared the relative differences in these labor costs, equipment costs and the total of these costs for the 35-day storm event.

ODOT Crew Survey Evaluation

During ODOT observations in December 2020, November 2021, and July and August 2022, DRG conducted interviews with ODOT crew members and managers. DRG staff also collected observations of activities to determine if improvements in crew efficiency, knowledge, safe operating procedures, and equipment issues have been made through Phase II of the project. Questions covered the following categories: communication; efficiency; equipment operation, maintenance, and reliability; site assessment and job planning; training and experience; and general safety practices. To quantify these responses and detect any improvement to these areas over the duration of this study, ODOT crew responses to the crew questionnaire and a DRG representative's responses on the crew observation sheet received scores ranging from 1 to 5, with a higher score representing a preferable response. Some questions asked were more open ended in nature and did not receive scores. Response scores were averaged across individuals interviewed and summed across each category, and the percent of the total possible score for each category was compared across dates.

Research Findings and Conclusions

Phase I: Determine Current Standards for Ash Tree Removal and Debris Handling

Safe and effective dead ash tree and debris removal approaches were found to vary slightly across institutions. In general, tree removal and debris handling practices for several state, local, and private institutions are based on guidelines set forth by federal and non-profit entities.

DRG reviewed industry standards including federal agency documents, international organizations, trade associations, private industries, utility industries, and residential/municipalities. DRG findings showed that these standards have a focus on safety and/ or efficiency that ODOT can learn from. Listed below are industry standards on safety and efficiency.

DRG research in Phase I determined that a lack of proper planning, experience, and high-volume tree removal equipment for the quantity of hazardous trees in the ROWs is causing inefficiencies. These inefficiencies increase the hazards associated with tree removal as well as labor costs or time needed to perform roadside ash tree maintenance tasks along the ODOT ROWs. Phase I research findings identified training needs and high-volume tree removal and disposal equipment that should be purchased and tested in Phase II followed by field evaluations to measure the impact of those changes to safety and efficiency.

DRG research also determined that private industries and other DOTs have developed ash tree removal management programs and processes that result in greater efficiencies and increased safety. It was proposed that if ODOT made significant changes in its ash tree removal and disposal program, there would be an increase in safety and efficiency. Some of those changes include having trained staff to safely perform tree work, and having staff utilize existing and new equipment more effectively and properly. These changes would improve safety, reduce costs, and increase efficiency for staff utilizing both the recommended new equipment and those utilizing the standard tree removal equipment in ODOT's arsenal.

For Phase II, the following areas were targeted to improve existing ODOT ash tree removal and disposal management operations:

- Safety: Reduce exposure to hazardous tree removal through equipment and processes.
- Efficiency: Increase productivity to reduce the backlog of hazardous ash trees and reduce the man hours for tree removal through equipment and processes.

Through Phase II testing, information was gathered and analyzed to make recommendations for implementation to improve ODOT's ash tree removal and disposal management program.

Industry Standards

Safety

Federal safety and site assessment guidelines are provided in the American National Standards Institute (ANSI-Z133) (2017). There are no standards specific to ash, only trees in general. Factors to consider in safe removal include tree lean, wind, and tree decay. Tree decay will be a factor to consider when dealing with infected ash. Site assessment includes seven steps to determine if a tree can be manually felled. Safety standards for aerial devices, cranes, chain saws, and other operations and equipment are also provided. Per ANSI-Z133, for worker safety, arborists who are not qualified by specific training and experience to work within 10 feet (3.05 m) of electrical conductors shall always maintain the minimum approach distances (MAD), which vary based on voltage. For example, 50 kV and less require a 10-foot minimum approach distance (MAD), while 785 to 800 kV require a 35-foot MAD. Gear and other conductive equipment, including aerial devices, shall also maintain the MAD.

Guidelines from the International Society of Arboriculture (ISA) were also explored. Regarding their safety standards, ISA is the secretariat for ANSI-Z133 safety requirements for Arboricultural Operations documents and thus also adopts those safety standards. According to their standards, any structurally unsound or dead trees that are left on the site, should be reduced in height so they do not strike the ROW if they fall.

The Tree Care Industry Association (TCIA) recommends against any kind of rigging if possible, and emphasizes evaluating site hazards, tree attributes, escape routes, and cutting plans prior to work.

Regarding safety, ANSI-Z133 standards are the foundation of most private tree service safety programs. Safety and training for crews are strongly emphasized. Most companies will either provide in-house training and resources for ongoing mentorship or provide resources for external training with certifications, or a combination of both.

Some industries identify all ash trees as hazardous, whether declining, dead, or still alive. All ash trees are removed as they threaten the integrity of the utility lines, or other surrounding property. Climbing of ash trees is generally not performed due to inherent hazards from EAB. ODOT crews should adhere to the safety aspects to ensure no property damage or injuries result from removal of ash trees along the ROW.

In Boulder County, CO, the county maintenance crews engage in active monitoring efforts to identify hazardous trees with EAB. Sites that are assessed are ranked based on a decision matrix to determine what action is to be taken. See additional details in the Efficiency section below.

Efficiency

Regarding standards established by federal agencies and documentation, USDA-APHIS recommends that dead or dying trees be cut down (USDS-APHIS 2020). USDA-APHIS published in the Federal Register a final rule that removes the federal domestic EAB quarantine regulations effective January 14, 2021. However, they strongly recommend all materials be kept on-site to be chipped, burned, or buried.

ISA calls for structurally unsound/dead trees without a target to be left for wildlife habitat. Leaving tree butts standing on the site will reduce the amount of larger wood that would need to be disposed of.

TCIA offers training and online courses to help crew members work efficiently, increase communication skills, and decrease the number of accidents that can occur on a job site.

Based on work conducted at DRG, The Davey Tree Expert Company, and observations of other companies DRG work within the private sector, hazard assessment for tree removal in the private industry is ultimately at the discretion of personnel on-site. Tree location, weather, and integrity of the tree are critical to determining the steps to be taken when removing a tree. The process for planning sites for removal begins with a sales arborist as the first point of contact, who then confers with district managers and foreman for additional assessment. Each of them may note safety concerns that will need to be addressed for the tree to be removed safely and efficiently.

Private companies with employees that perform tree clearance contracts go through a lengthy career development process which includes line clearance certification, tree identification, and other industry training. These trainings increase staff safety and efficiency. Tree evaluations occur when utility circuits are surveyed as part of a proactive maintenance program, homeowners notify the utility company or a safety compliance or electric reliability concern, or when repair work necessitates their evaluation. In contrast, surveys of all assets (hardscape and landscape) are completed biweekly by one to two staff members during drive throughs of the county. The lack of availability to perform extensive tree surveys results in ODOT being dependent on the public to report major deficiencies of trees. This may result in hazard trees not being removed when needed.

Several local governments are engaging in their own ash tree management programs as well. One municipal government that exhibits a fairly detailed management program for dealing with ash trees and EAB is Boulder County, Colorado (Boulder County EAB Management Plan 2015). To determine qualifications for removal, they use their own matrix table to prioritize removals throughout the County. EAB detection surveys are conducted from the ground by Boulder County staff that are trained to identify EAB, as well as via drones with the aid of the Colorado State Forest Service. Site debris is composted, and the County plans to secure a sorting yard to repurpose timber and chunk wood as wood chips or lumber.

Other State DOT Ash Removal and Debris Handling Practices and Equipment

DRG interviews of other state DOTs with EAB issues indicated that ash tree removal and debris handling practices were similar across state agencies.

Safety

Processes:

Several state agencies do not have formal ash safety guidelines, only for trees in general. However, individuals interviewed at the Connecticut, Michigan, and Minnesota DOTs did indicate that crews are made aware of the increased risks of working with ash, such as the ash being more prone to breakage when falling. As such, at the Connecticut DOT for example, crews will allow extra room for potential safety hazards when working near ash trees and give more space when felling ash trees and removing ash limbs.

State DOTs use a combination of in-house, contracted-out, or online training for safe and effective operation of tree removal machinery, equipment, and procedures. Of the DOTs interviewed, the Connecticut tree crews displayed the most extensive training programs.

All DOTs interviewed will either hire contractors or ask utility companies to perform work on trees near utility lines instead of scheduling DOT employees to manage trees near those lines. However, in New York State, all staff will still receive line clearance training. This is mainly as a safety precaution so staff can identify which lines are electric, know voltage, and can work near communication lines.

Equipment:

Crews will utilize machinery to take down any species of trees, when possible, to avoid climbing.

Efficiency

Processes:

In deciding when to remove trees, more of the state DOTs interviewed use a reactive approach instead of a proactive routine planned maintenance approach. A proactive approach includes planned cyclical maintenance work. With the reactive approach, DOTs interviewed respond to requests and complaints they receive or clear when requested for construction projects.

The amount of contracted versus in-housework varies across agencies and within districts, but in general, larger jobs are contracted out as well as jobs where the proper equipment is not available. Michigan DOT contracts out most of its tree work as they have compared the efficiency of their in-house crews to the contractor and have found the contractor to be more efficient.

Connecticut and Michigan DOTs have dedicated crews that perform most of the DOTs' tree work. They are stationed throughout the state to perform tree work year-round. Minnesota and Pennsylvania DOTs have just a couple of dedicated tree crews among their maintenance staff. In Connecticut, crew members are required to take ash-specific training and general training refreshers through a qualified skills trainer (ArborMaster, Inc.) twice per year. Each crew is comprised of staff with varying experience levels, which ensures mentorship for new employees.

For site assessment and work planning, the DOTs interviewed typically have either a landscape designer, resource specialist, resident engineer, or crew lead assess a work site, identify target trees, determine potential hazards, and decide what equipment is needed. Prior to a job, several of the DOTs generate a job planning and briefing form or work order form that discusses the work plan, equipment needed, and potential hazards.

The United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS) removed the EAB domestic quarantine regulations effective January 14, 2021. However, some states have active quarantines for moving ash material between infected and uninfected counties as well as from out of state. For DOTs that do not have state quarantine requirements for EAB infected trees, the crews will chip debris and leave chips and larger logs that can't be chipped on-site if site conditions allow. Some DOTs will dispose of chips and logs off site if a disposal site is nearby. In states with quarantine requirements such as Minnesota, when a district is within the state's quarantine requirements, the DOT will work with the state Department of Agriculture to find disposal sites.

Minnesota was unique with its debris disposal compared to the other states interviewed. In their Metro District, all tree removal debris, no matter what species, is trucked to District One Energy where they use the debris for energy production. This process increases hauling time; however, it is cheaper than renting a tub grinder or performing other debris disposal operations.

In the other Minnesota DOT (MnDOT) Districts, debris disposal depends on whether the district is included in the state quarantine. If the District is within the quarantined area, they work with the Minnesota Department of Agriculture to find disposal sites. If the District is not within the quarantined area, options include trucking debris to truck stations with burn piles, cutting and leaving on-site, and chipping and leaving onsite.

Minnesota was the only DOT with an existing DOT monitoring program. All public works employees are trained to identify EAB and have assigned crew members to make EAB reports. They utilize a management tactic table to determine when to formally monitor. Citizen science volunteers are also trained to identify EAB signs and conduct tree inventories which are conducted in infected areas.

Equipment:

To perform tree removal, the DOTs generally use a combination of bucket trucks, chippers, log trucks, and specialized equipment. When specialized equipment is utilized (*e.g.*, grapple saw, tub grinder, *etc.*) either a contractor is used or the DOT's designated operator for the equipment travels with it to the site. Crews usually have one bucket truck operator, with 3-4 individuals on the ground operating chainsaws, feeding chippers, and clearing debris. Connecticut had been contracting crews that utilize Sennebogen 718E tree handlers in combination with whole tree chippers for three years at the time they were interviewed and are very pleased with the outcome. One crew with one Sennebogen used in conjunction with a whole tree chipper can clear 100-150 trees per day.

ODOT Current Practices and Equipment

During November and December of 2020, baseline observations of ODOT tree removal practices in Erie and Lorain counties were conducted. In June of 2021, morning mobilization of crews performing tree work in Ashland County was observed. DRG identified a variety of issues that were negatively influencing crew productivity, safety, and costs associated with dead tree removal procedures. Basic tree safety requirements appeared to be in line with industry standards, but the training of the crew, the general processes of carrying out the work, and equipment operation all required attention.

ODOT's "tree crews" as referred to in this report are county level maintenance staff that perform tree trimming and removal work amongst a variety of other tasks including chip sealing, pothole and guardrail repair, snow and ice removal, mowing, and herbicide applications. Due to the variety of tasks that must be completed by these workers, the workers do not focus on tree work daily, so they do not steadily gain experience with their skills. Furthermore, unless trees are a hazard, tree clearing operations are limited to October 1st through March 31st due to bat roosting restrictions the rest of the year. ODOT tree crews do not climb trees but remove trees with ground crews or forestry bucket trucks. These crews share one bucket truck between multiple counties. In only a couple of districts across the state, is there access to a tree mulcher or all terrain tree trimmer.

Safety

Processes:

Regarding crew training, DRG discovered that most members of the ODOT tree crews could not identify ash trees nor signs of EAB and relied on one person on the crew for that identification. Many crew members had little to no training beyond entry level chainsaw and chipper training, and many do not go on to receive advanced skills training. These trainings would help refresh their tree worker knowledge after not using these pieces of equipment for long periods, due to being scheduled to perform other types of work. Since these crews also conduct other work for ODOT, this sporadic use of equipment and techniques due to workload variety increases safety risks and decreases efficiency. It was also discovered that ODOT lacked a mentorship program in which the best and most competent tree workers can direct, guide, and train less experienced employees in safe and efficient tree work processes. This could lead to a significant knowledge gap over time for new employees and will decrease the collective standard competency levels. While on-site, the crews used some hand gestures or waiting and yelling for communication which reduces the frequency and depth of communication as well as provides opportunity for safety incidents to occur due to miscommunication.

Equipment:

Regarding equipment issues, all large machinery was in good condition and functioned well. However, the way the current equipment was being operated created safety concerns and could lead to damaged equipment or injuries. Also, certain scenarios made it clear that alternative equipment would have been safer and more efficient for those tasks. The positioning of the bucket truck created opportunities for safety issues, creating instances in which the saw was being used one handed, and cut limbs were being dropped directly on the boom. Also, crew members were observed feeding the chipper from the traffic side of the road and would wear chaps when feeding the chipper. Tree limbs entering a chipper can twist and can push and pull workers that are too close, as ODOT crews were. Employees feeding the chipper from the traffic side can get pushed into oncoming traffic and workers wearing chaps can get snagged by branches as they go in the machinery, pulling the workers into the chipper with them.

Efficiency

Processes:

Regarding processes and operations of the crew, crews were generally inefficient, and had low productivity. Specifically, crews were delayed when leaving the garage for job sites, with work not beginning until late morning. The crew needed to locate all the tools and equipment each morning to prepare for tree work before leaving the garage. DRG witnessed crews needing to wait at the garage for equipment due to miscommunication as well as crews arriving on-site having forgotten critical pieces that someone would need to drive out to the site to them. With crews packing up for the day between 2:00 pm and 2:30 pm, this left between four and five hours on-site to complete work. Before arriving on-site, crews were unaware of site conditions and equipment needs, and lacked instruction on truck and equipment setup to maximize productivity.

Crew sizes were larger than needed, with two to three individuals performing tasks that could be successfully done by less. This created significant crew downtime as well as potential safety issues for crew members in each other's way.

There was a lack of production goals or quota of linear feet to complete in one day, leaving crews with no daily objective to help guide their work rate and no standard or benchmark of comparison to strive toward.

Additionally, in some instances, the chosen work should not have been a priority; one crew had been directed to cut trees at a site to prevent shading of the road, but trees were only growing on one side of the road, and due to the direction of the road and rotation of the sun throughout the day, shading would not be possible. A proper site assessment with a more experienced work planner could have easily avoided this misstep. At another site, a bucket truck crew was assigned to work a site but after driving to the site in the bucket truck, never used the bucket truck that day due to the position of the trees and reach of the boom relative to the road. Since counties have a backlog of tree work and only get the bucket truck for 2-week rotations, this work was not planned well and should have been completed when the county did not have the bucket truck. Proper site assessment from a work planner could have made better use of the bucket truck on this day.

Furthermore, there is frustration and confusion around what to do with the material generated from the maintenance work. Employees say they cannot give it away or sell it and it will cost the state money for the crew to take it to the dump for disposal, so it often accumulates at garages.

Equipment:

Within the project's study area, District 3, there are two forestry bucket trucks that are shared amongst the eight counties. The bucket trucks are scheduled to spend two weeks in a county before rotating to the next county. This may be enough trucks if work is properly planned to utilize the bucket trucks when they are in the county. DRG witnessed the trucks on job sites where the crews did not use them but removed the trees with ground crews. DRG heard about rotations where the trucks went unused for the two weeks as there was other work that took priority during that time.

The bucket trucks are operated by the local county maintenance workers who have reached Highway Technician Level II (HT II) or above. Reaching HT II means employees have met the requirements to drive a vehicle of that size. It does not mean that they have advanced skills for operating the boom or advanced tree cutting skills or feel comfortable working aloft. While each county may have several HT II employees capable of driving the bucket truck, they may only have one or two people per county who feel comfortable going aloft when the bucket's boom is raised and work the day shift when tree cutting operations are scheduled.

Before commencing with tree cutting operations, developing a plan of action and assessing the lean and decay of trees within the work areas was not completed. This is unsafe as evidenced by numerous reports in the tree care industry across the region of tree crews working a tree when another tree fails, unfortunately often killing a member of the tree crew working nearby.

Brush that was cut was either being winched or hand dragged up steep slopes by crew members at times. A boom mounted grapple would have been more efficient.

Regarding equipment maintenance, hand files were being used by inexperienced personnel to sharpen saws in the field. Two men took 30 minutes to sharpen one saw, which is much longer than is needed by experienced tree crews. At another site, after setting up the bucket truck in the morning, the operator went aloft and made 2 or 3 cuts before realizing his saw was dull. He came back down and had someone sharpen his saw for him. Ideally, this maintenance should be done at the garage at the end of each day, or periodically throughout the workday, as needed with every saw operator being knowledgeable in how to properly sharpen their saw.

Gap Analysis and ROI - Phase I

From the ODOT crew observations, DOT interviews, and industry research, DRG found several areas for improvement. These areas were broken into processes/operations and equipment gaps. Most of the processes/operations gaps would have minimal, if any, costs. While some changes could be completed in a day, due to the nature of ODOT's labor union, some changes may be more difficult to implement. Due to the delays in arrival of equipment purchased for this study, the third-party safety training and DRG efficiency workshop that went into greater detail about recommended improvements were not held until late in the project. This meant that many of their components were not able to be implemented during the project. The recommended processes and equipment based on Phase I observations can be found in Appendix C.

ODOT baseline observations in December 2020, contractor observations in November 2020, and conversations with Connecticut DOT revealed that contractor tree crews that utilize a similar equipment setup recommended by DRG (Sennebogen used in conjunction with whole tree chipper and excavator with grapple) were five times more productive (trees removed per day) than ODOT's bucket truck crews. Furthermore, this increased productivity was accomplished with two less crew members, leading to a \$320 reduction in labor costs (assuming a \$20/hour rate for all crew members) and a \$23.47 decrease in cost per tree removed. Due to these reductions in labor costs and increased productivity, the savings would result in equipment purchases being paid off in 47.7 weeks. Note that this time to ROI estimate provided in Phase I of the project did not account for daily operating costs of the equipment and was updated in Phase II utilizing observed field data. For additional gap analysis results from Phase I research, see Appendix D, and for updated ROI estimates, please see "Gap Analysis and ROI - Phase II" below.

Phase II: Testing Alternative Equipment for Ash Tree Removal and Debris Handling

Due to supply chain shortages, two of the pieces of equipment purchased as part of this study were delayed and arrived at different times. The Sennebogen 718E arrived on schedule in October 2021. The Rotobec 4042HD grapple arrived in March 2022 and the Bandit 2090 arrived in June 2022. ODOT has put dedicated operators with these specialty pieces of equipment. These operators travel with the equipment between counties to work. The operators meet up with the local county garage staff on-site who set up the maintenance of traffic. This seemed to be working well as the dedicated staff are not held to an eight-hour workday. They schedule their day to arrive on-site at 8:00 am (when the local county garage staff should be arriving for MOT set up) no matter which county they are assigned to work in. They wrap up for the day when the local staff need to start MOT tear down before heading home.

For detailed methods and results for all field test data and comparisons, including data analysis and methodology, gap analysis, and equipment costs utilized in DRG analysis, please see Appendices J, K, and L.

Field Test Crew Productivity and Cost Comparisons

ODOT crews utilizing the Sennebogen 718E were found to have higher productivity (measured as biomass removed and/or processed per hour) than ODOT bucket truck crews. This held true for both the November 2021 and the August 2022 crews using the Sennebogen 718E. The productivity of the August 2022 crew was higher than that of the November 2021 crews using the Sennebogen 71E. The crews operating the Sennebogen 718E were also more cost efficient, measured as cost of labor per cubic foot of biomass removed and processed. ODOT crews were still using more on-site employees than were recommended or needed, contributing to more idle time that increased labor costs and reduced the potential cost differences between crews.

Gap Analysis and ROI - Phase II

There was a 118% increase in productivity (trees removed/day) for the August 2022 ODOT crews utilizing the Sennebogen 718E and Bandit 2090 whole tree chipper when compared to the November 2021 ODOT bucket truck crews. This increase in productivity for ODOT crews is similar to the difference in productivity between contractor crews that are dedicated to operating the Sennebogen 718E and contractor crews that are dedicated bucket truck crews. The productivity of an experienced contractor (VanCuren Services, Inc.) utilizing a Sennebogen 718E and whole tree chipper was found to be 114% higher than that of another experienced contractor (Davey Tree, Inc.) utilizing bucket trucks. Annual ROI was based on productivity of observed ODOT crews using a Sennebogen 718E in August 2022 was 8.65%, which would result in equipment purchases being paid off in 11.5 years, assuming only 26 weeks of tree removal work per year. This ROI demonstrated a substantial improvement for ODOT crews when compared to the annual ROI calculated based on November 2021 crew costs and productivity (annual ROI = 0.25%). While ODOT did switch to a dedicated crew to operate the three pieces of specialized machinery, which likely resulted in the improvement, there was some turnover on the crew so some additional familiarity with the equipment is needed to improve efficiency amongst the crew. Reducing crew size of the staff that accompanies the Sennebogen 718E, following efficiency recommendations, implementing all recommended equipment (e.g., the excavator with grapple was not being used during the November 2021 or August 2022 Sennebogen work) and continuing to become familiar with the new equipment will all contribute to ODOT being able to continue to improve ROI.

Contractor and ODOT Storm Event Response Cost Comparison

The total cost of loaded labor and daily operating costs of equipment for ODOT during the storm event cleanup in Wayne County from June 15, 2022 to August 5, 2022 was nearly double the total cost of labor and equipment operating costs for a contractor crew to conduct the work (VanCuren Services, Inc.). This was mainly a result of substantially higher labor costs for the ODOT crews (Appendix L). The labor and equipment represented in this data include staff and equipment that provided MOT. These results further demonstrate that the size of the local staff that meets up with ODOT crews operating a Sennebogen 718E are inflating costs by operating inefficiently and staying longer than is needed to set up MOT. This contributes to more hours and increased costs for ODOT.

The storm event that happened in the summer of 2022 resulted in high winds and even a tornado that felled trees, caused a mess on the roads, and left hazardous trees on the roadside. It took 35 days to clean up from that event with the specialized equipment purchased as part of the study. It would have been more difficult and far more dangerous to access and remove all the trees with the combination of a bucket truck and ground crews. The Sennebogen 718E, Rotobec 4042HD grapple, and Bandit 2090 chipper proved extremely beneficial in this situation. If ODOT did not have the specialized new equipment to perform the work themselves, they would have been at the mercy of the contractor's schedule to perform the work while there would be many competing demands on the contractor's time following a storm event such as this.

Safety Analysis

Zero safety incidents were recorded during any field tests or during any ODOT work with the Sennebogen 718E, Rotobec 4042HD, and Bandit 2090 from October 5, 2021 through the end of data collection on August 31, 2022. However, during this same period, a total of 35 crew injuries were reported for all ODOT tree/brush job tasks across the state of Ohio. Seventeen of these injuries were a result of crew members being struck by falling/flying objects, and 7 injuries were caused by crew members lifting/lowering objects or pushing/pulling or twisting. Although we do not have the data available to compare the total number of hours worked for the Sennebogen 718E, Rotobec 4042HD, and Bandit 2090 to the total hours worked for all other crews across the state, this discrepancy in safety incidents is still a testament to the fact that the recommended equipment setup for tree removal has allowed ODOT crews to avoid these kinds of injuries. Over time, DRG expects ODOT will realize a much larger benefit in safety incidents from utilizing the new equipment. The operator of the Sennebogen 718E works within a climate-controlled cab protected by bullet proof glass and falling object protective structures (FOPS) and is therefore protected from any injuries from falling debris. The Rotobec 4042HD grapple mounted on midsized excavator will safely move logs and debris closer to the chipper. The remote-controlled Bandit 2090 chipper with Kesla loader arm can pick up those logs and piles of debris to feed itself. Both pieces of equipment reduce the chances of ground crews being exposed to falling debris and reduces the risk for injuries caused by lifting/lowering objects or pushing/pulling or twisting, as well as more serious injuries that can result during hazardous ash removals including loss of limbs and death.



Photo 7: Sennebogen 718E and remote-controlled Bandit 2090 working in tandem moving piles of debris

ODOT Crew Survey Evaluation

Differences in scores for ODOT crew responses to survey questions and DRG's crew observations (Appendix M and N) indicated that ODOT crews did not demonstrate substantial improvement in training, efficiency, and safety between baseline observations in December 2020 and the final field test in August 2022 (Appendix O). This did not differ whether DRG were considering the responses of all ODOT crew members or just equipment operators. ODOT crew survey responses did demonstrate approximately 10% to 15% improvements to communication, general efficiency, job planning procedure, and training, but DRG observation scores had either a smaller improvement to these areas or a slight decline. These results indicate that ODOT crews need additional time to improve upon tree crew operations, get used to operating the new equipment, and more thoroughly implement DRG's recommended procedures.

Recommendations for Implementation

Key Recommendations Overview:

The following recommendations are based on DRG's observation of ODOT crews during fall of 2020, 2021, and summer of 2022. These recommendations cover ODOT's processes/operations, training, and equipment used during tree removal and debris handling, and are aimed to improve ODOT's efficiency and safety performing tree work. Appendix P outlines steps needed to implement the recommendations, expected benefits from implementation, potential users, improved work planning and organization with the use of tools used by the work planner to assess whether a site needs to be worked, the priority of the work, the hazards associated with the site and the trees, whether a contractor or ODOT crews should perform the work, and what equipment should be used if performed by in-house crews.

- Enhance tree worker training by providing documented periodic training refreshers, advanced equipment training, and establishing a mentorship directive.
- Create specialized crews in all districts that are dedicated to tree work year-round to keep up with workloads and eliminate large backlog of tree work.
- If ODOT decides to follow ISA guidance to leave structurally unsound or dead trees with the bole left standing as habitat after clearing operations are completed, the remaining bole height should be less than the distance of the base of the tree to the ditch or the distance of the base of the tree to the clear zone, whichever is smallest. This is to prevent blockage in the ditch, roadside where mowing takes place, and roadway.
- To mobilize, all tree crews should have a goal for leaving the garage at a certain time in the morning. To help meet this goal and prevent necessary items being left behind, crews should have a checklist of what is needed for each day. Equipment for tree work should be kept in a specific area of the garage or near tree machinery, which would save time loading and unloading gear and thus reduce costs associated with mobilization.
- On-site work should operate like an assembly line with each employee assigned a task, and the tree cutting and chipping machines should be operated in unison while safely distanced.
- Hire contractors for larger or more dangerous jobs, such as sites with utility lines present. This will reduce ODOT crews' workload while reducing the risk associated with working around electrical lines.
- ODOT should continue to contract out tree work along roadways with utility powerlines present on the same side of the road. However, since it is still possible to damage utility hardware and pose safety risks to the ODOT crews and the traveling public, it is highly recommended that all ODOT staff receive refreshers on ANSI-Z133. This is to ensure the safety of workers and passerby when working adjacent to areas with powerlines due to the unpredictability of tree felling, particularly brittle ash trees.
- Recirculate the email from June 17, 2016 from ODOT Cost Accounting and Inventory Manager Brian Church based on a meeting with Chief Legal amongst each county maintenance garage within ODOT to remind county and district level employees that the maintenance operations debris disposal process has been simplified while they await formalized changes in the Ohio Revised Code.

- Prioritize integrating the equipment purchased for this study (Sennebogen 718E tree handler, Rotobec 4042HD log grapple mounted on midsize excavator, and Bandit 2090 whole tree chipper with Kesla loader) into ash and other species of hazard tree removal work to be completed by ODOT crews.
- Sennebogen operators and mechanics should complete additional training at the Sennebogen facility in North Carolina as it will improve proficiency with operating the machine and its maintenance and troubleshooting.
- To further help with debris disposal, DRG recommends that crews construct a removable chip bed with high sides and lid to insert into dump beds to handle larger volumes of chips than the chip beds can currently handle. This will reduce offsite time and downtime from crews awaiting the return of the dump bed.
- The rental of a horizontal grinder for approximately 1-2 weeks out of the year for districts that perform a lot of tree work but do not have a whole tree chipper may be warranted.
- DRG highly recommends the use of headsets for communication while on-site. Headsets will improve the ease and frequency of communications amongst the crew members and is especially important for those in enclosed equipment or aloft to be able to communicate with others on-site. It will help improve safety, reduce the risk of accidents, improve efficiency, and will help improve training and mentorship opportunities.

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Appendix A DOT Interviews

Questions	CTDOT	MDOT	MnDOT	NYS DOT	PennDOT
1. Is all tree maintenance conducted in-house?	Large sections contracted out. Some climbing if access through a backyard (10%)	Contract a lot out.	No	No but majority is. Have crews in 10 of 11 regions (NYC does their own work)	90% done by contractor
<i>a. If not, what percentage is out-sourced?</i>	30-40%	78 road commissions 90% contracted (80% County Road commissions/10% Subcontractor) 10% in house MDOT. Tree/trimming removal, mowing, snow removal (different for each Region). Some work activities have private contractors (low bid) and in-house crews. Tree Trimming/Removal and herbicide spraying: variable within regions of state or counties.	Less than 10 trees per year.	Varies year to year and by region. 5-50% contracted	Smaller stuff done in-house. Depends on what equipment a district has. Have some guys with prior tree experience. Ground to sky. Have 40' bucket trucks. Chainsaws, chippers. Use chainsaws for brushing mostly
<i>b. How many DOT crews are there working on trees around the state?</i>	11 dedicated crews year-round in house 55' & 75' buckets for singular or sm clumps of trees, secondary roads.	7 regions	Each District is set up differently. MnDOT's Metro District is the only one with dedicated tree crews (2). Do technical removals for bigger closer to the road removals. In addition to the 2 tree crews, each truck station trains selected personnel on chainsaw operation. Other Districts depend on the personnel in the truck stations to perform tree removal. A truck station is a local maintenance garage	15 total tree crews. 1-2 tree crews per region. In 2 areas the crew is part of the bigger maintenance crew. 5-6 people per crew	Every county has brushing capabilities. Not working year-round. 67 counties do emergency work and small trees
<i>c. Is maintenance clearing restricted to certain months of the year due to endangered species (i.e., Indiana bats)?</i>	Work with office of environmental protection for eastern diamondback rattlesnake, trout, etc. to determine timing and avoid impacts.	Will do a bat survey if they need to do work during roosting season	Yes, in MN it is the Northern Long Eared Bat	During summer exclusively do tree work. In winter solely do snow/ice removal. Long Eared Bat/Indiana Bat. Regular maintenance doesn't happen during roosting. Hazard trees come down when needed. But 90% of trees taken down are hazard trees	Winter months only. Some people with tree crew experience but won't be on same crew. Better production from contractor
<i>d. What are the standards for out-sourcing a given tree (height, diameter, hazards, accessibility)?</i>	Not answered	Work is contracted out due to workload. In house crews are doing different tasks than in past so forestry work has reduced	There are a couple of triggers. These include difficulty in removal including distance from overhead utility lines, road surface, and private property structures, terrain, and tree structure and condition. MnDOT does not allow employees to climb using rope and saddle.	Too much work to do in-house, also contract when near utility lines or when a crane is needed. Regional decision based on available funds.	Want them to be trained, discourage tree work from untrained staff due to safety and production
2. What training do your in-house tree crews receive?	Not answered	One area has a forestry crew, other counties the crew is part of maintenance garages	Not answered	Not answered	Chainsaw training depends on county and who's available. State foresters and private contractors will do training
<i>a. Are there any ash-specific training programs?</i>	Use ArborMaster®. Give extra distance, don't tie into top. Shut down whole road. Use Sennebogen. https://www.sennebogen.com/en/products/material-handler/sennebogen-718-718-E-728-E , https://www.arbormaster.com/ in spring and fall over last 3 years for precision tree felling, climbing technique, removal techniques. Follow modules and customize training for different levels of experience. Would use Game of Logging for basic training, http://www.gameoflogging.com/	They notice the way they are prone to fail by breaking apart mostly	No	No	Put 2-page pamphlet to show what dead ash look like. Cutting down any dead tree
<i>b. Can they all identify ash trees?</i>	80% of the time. When mistakes happen, the tree is usually a Norway Maple. EAB found in 2013	Most people can, at least someone on crew. Lost most ash trees already. EAB came in 2002 to MI	No	Specialty crew can	1-2-page Ash Bulletin to identify (internal). Self-made...
<i>c-1. Do crews have access to refresher training on equipment such as basic power tools and heavy equipment?</i>	See ArborMaster® above	Yes, in house and contracted out for training. There is a work training element to take training and demonstrate proficiency	Yes	There are certifications for using specific pieces of equipment, chainsaw, log loader, aerial lift, log loader, climbing and rigging, chipper, stump grinder, winch training. Need to show them competency on the equipment	Not answered
<i>c-2. How often is the refresher training?</i>			Every other year training on log loader. Does operator travel with log loader (i.e., a dedicated operator)? Used primarily in Metro, operator goes with it. With Covid, adding online training module option instead of just in person training	Every spring chainsaw and chipper training, used to have more advanced training that they will start again at some point. Also do yearly line clearance training- full training -receive same training a utility crew would, hazard In general, in some areas there is a policy to call the utility to take care of it not to automatically work trees near lines themselves even though they have the training. But it's helpful to have the training to be aware of which lines are electric, know voltage, and can work the communication lines	Not answered
<i>d. Do crews have access to skill development courses?</i>	ArborMaster®	Not answered	Not answered	Not answered	Depends on county

Questions	CTDOT	MDOT	MnDOT	NYSDOT	PennDOT
3. Do you have a proactive or reactive approach to addressing ash trees?	Mostly reactive work. 4 districts with 48 maintenance garages each with a general supervisor to patrol roads for any work needed. 1 Landscape designer per district investigating complaints, utility permits, sightline issues, plan work orders, coordinate contractors. Once there, can take down ash. Want to obtain 30' clearance no matter what the species. Database tracks work orders	Initially was more proactive with hazards. Contract crews are more proactive, in-house crews are more reactive	Both, tree removal is done in Maintenance Operations and Construction. In construction projects, ash trees are targeted for removal within the project limits even if the construction does not require tree removal for work. Maintenance Operations remove ash trees reactively as there are requests from cities. They will remove additional ash trees in the vicinity to complete their day in that area	Reactive	Reactive, working with owners would have required more resources they didn't have. D10 had it worse, Butler County
<i>a. Do you have an inventory of the ash along the ROW that could be a hazard?</i>	No. CTDOT has gypsy moth and oak issues	There was an inventory that may have been region by region - windshield survey	No but do know where the privately treated ash is	5 years ago, did survey to figure out amount of ash they would be dealing with but haven't updated it.	They did in 2016 but not updated since. A lot have fallen or were removed since then. Looked at number of trees x ADT/1000 to determine priority. Stayed on road once they were on it to get any species of dead trees until road was done. Didn't paint individual trees
<i>b. If using pre-treatment or preemptive removal, how does your team identify areas in need of attention?</i>	Not done	May have done pre-emptive removal while cutting other trees in an area	Construction project limits or requests from MN Dept of Ag (EAB regulatory agency) or municipalities.	To help figure out what impact would be, but it didn't develop into a management plan to remove trees	Not answered
4. Does your tree crew approach ash tree removal differently from other tree species?	Allow for more space due to the nature of the wood.	Not answered	No	Not sure to the extent. Assess each tree before they remove them. Let everyone know they are working on ash. Don't climb ash. Plan ash in the work plan. Not formally written but planned out during site assessment	Not answered
<i>a. How do your safety protocols change?</i>	If rigging is needed, will use Sennebogen instead	Know they'll break apart	N/A	Not answered	No, more likely to contract out
<i>b. How do your removal procedures change?</i>	Allotment of more space when felling and removing limbs, brittle wood. Split and splinter upon ground impact. Rigging/Climbing considerations.	Not answered	N/A	Not answered	No. Based off public calls. In-house hesitant to take on dead ash due to inexperienced staff and equipment
5. What types of equipment are utilized by your crews for ROW tree removal?	Albach Diamont 2000 chipper rubber tires can drive to job, side feed, has its own grapple. ODOT could try to demo it Use contractors, cranes, tracked and wheeled feller bunchers or whole tree chippers; Brontosaurus used (by contractor) for invasive mgmt. for autumn olive or other invasives; Use contractors, cranes, tracked and wheeled feller bunchers or whole tree chippers; Could use Sennebogen and 1 chipper and the chipper will keep up 718E Sennebogen - 4 under contract, 1 for each district and a 718 crawler on tracks - reach = 44' can pick up 2500 lbs., can do a 65' tree. 728E recently bought has a 68' reach, beefier, 3' wider, easily used on highways, more selective on secondaries	Bucket trucks 40'-60', chipper, Fecon 10' travels around state used for brush up to 10" on front end loader. They've rented a Brontosaurus and it has worked well - a dedicated operator runs it	Chainsaw, bucket truck, chippers, log trucks, skid steers, forestry head mowers up to 6" trees and brush Tub grinder - have rented for truck stations. It made sense financially. Haven't used in years since they are taking material to energy plant now. DNR scaled wood and did a timber sale. Worked with Dept of Ag to get wood moved from yard. They are not looking to make money from sale, just put it to use and get it out of yard and not to landfill or burn. Shears (smaller version of feller-bunchers) area used by dedicated operators in Duluth, in boreal forest. May have decided to get it due to the number of trees in Duluth area	Climbing, bucket, chipper, log truck, no crane. Looked into Teupen but didn't buy it (like a Spider).	Not answered
6. What size chippers do you generally use?	Tree crews use 12"-15" capacity to go with bucket. Winch on chipper. Often chip into truck unless wooded then will leave on site. Multiple lanes, chipped on to side of road. Chip into semi sometimes. Used to have more rear mounted buckets, have more mid mounts now. Cost wise, mid mounts are cheaper. DOT work is often in back or front of truck whereas utility is over middle so that's why mid-mount isn't ideal	14" Vermeer	Chip and leave where they can	12" and 18" Have rented tub grinders for large pile of logs at yard so they chipped and disposed of them. Now, try to not let them pile up like that	Not answered
7. If specialized equipment (grapple saw, tub grinder, etc.) is utilized, is there a dedicated team that travels with the equipment around the state to operate it?	N/A	Rented a tub grinder once, closed road to use it	NA. Do you have contractors that ever use this type of equipment? Advantages/disadvantages? Don't contract much work	Special crew travels between districts	Not answered
<i>a. Is the cost of purchase and operation more cost effective than contracting out with a specialized crew?</i>	More efficient to contract out specialized work than buying and maintaining equipment. Internal repair operations are already stretched thin so don't want to take on additional work. Sennebogen has repair parts in VA, but Diamont is out of Germany	NA	Not answered	Not answered	Not answered

Questions	CTDOT	MDOT	MnDOT	NYSDOT	PennDOT
8. How do you approach tree damage or debris in the communication line ROW?	Communication companies wait until tree falls. Contractor will have that training and they can work around lines (EHAP). Bucket will cut away from wires and Sennebogen will take the rest of it down;	No MAD training	We communicate with the owner of the utility line to remove the tree to below the line (topping) then we follow up with final removal and clean up if it is MnDOT's request to top the tree. What about if tree is near Communication line? Try to push staff to go to EHAP training. They make the communication company deal with it probably because they push to have all lines on one utility pole, they have leverage due to the electric company. Will follow up with John on any solo communication line processes	Not answered	Not answered
<i>a. Do your crews have Minimum Approach Distance Incidental Training for working with trees on/near communication lines?</i>	No	No, use contractors	Crews maintain minimum distance of 10 feet from lines Do crews have incidental training? No	Not answered	Not answered
9. How long does it take your crews working on trees to mobilize in the morning? Is anyone at the garage assisting to prepare the equipment for the day's work?	Tree crew leader helps mobilize crew. Tree crew is w/in maintenance crew. 5 staff in crew. 8 am start 8:45 driving out of yard	It varies, dedicated crews are ready to go within 30 minutes, but regular maintenance crews can take up to 3 hours	30 minutes. The crew mobilizes on their own without assistance	30 minutes for pre-trip inspection on bucket. May leave bucket and log truck on site and go back and forth to garage in pickup each day	Is anyone at the garage assisting to prepare the equipment for the day's work? In winter, reconfiguring on a daily basis so 1hr + and then need to set up unless separate crew goes to set up. In summer, dedicated crew in one county - took 15-20 minutes in the morning for CDL check and job briefing. Prep equipment/tools the afternoon of the day prior for the next working day. Stage from central location so 30 minutes from there, 45-60 minutes overall. Winter hours 4-12 and 12-8, two shifts.
10. How many workers are on a typical tree crew?	11 total crews across 4 Districts: 2 districts have 2 crews, 1 has 4 crews, other has 3, 4 -5 crew. Crew leader, highly skilled tree climber, skilled tree climber, 2 helpers. Top 2 positions do most diff tasks	4 and forestry crew is 6	4-8+ Location determines size of crew, traffic control, hauling, etc.	5-6. 75' bucket, they have both rear and mid-mount booms. The two areas that were asked recently asked for different mounts for different reasons. They like to have a dump truck with a self-fabricated chip bed to chip into. When chip truck is unloading, they use bucket to load chips so bucket stays working. Majority of time, bucket stays with flow of traffic rather than opposing it	6+
<i>a. How are duties on site organized?</i>	9am maint mtg, crew leader gives work orders, equipment needed, garages put signs out usually but may say what signs are needed. When they get on the site where to park, signage, set up. Use communication headsets and they really appreciate them. Crew leader can use them to explain what to do and pointers for training and safety, much better communication	1 bucket operator - usually contractor. In house crew = 2 dragging brush to feed chipper, 2 using chainsaws on ground	As directed by the Truck Station Supervisor or Tree Crew Lead	1 bucket operator, 1 assistant to operate getting ropes and saws, 1 bucking up logs (if no log truck), 1 getting on log truck (Apprentice brand with grapple on Mack chasse), others on chipper duty. Crews take time off during summer so may not be 5-6	2 flaggers, 1 bucket, 1 foreman, rest on ground
11. How many members (or percent) of your crews performing tree work were hired with prior professional tree crew experience?	Need to have some prior tree experience. General maintenance crew experience varies	A few people from Asplundh or local tree companies	Employees with previous tree removal is a lucky coincidence for MnDOT, maybe 10 statewide.	Come in with forestry or horticulture background or some other related prior experience, previous tree crew experience	<5%, one county 2 (Foreman) out of 60 with some experience.
<i>a. How much value do you feel these workers bring to your operations?</i>	Essential due to danger of work	Help with efficiency and mentoring	Valuable, cannot place value.	Not answered	For the most part they do.
12. Do you have a site assessment tool to help create the work plan that includes obstacles, terrain, hazards, tree height, species, approach, etc.?	Landscape designer makes these notes on work order and coordinates private property access, targets, structures	Resource specialist (may have a forestry degree) will mark trees that need clearing and note hazards. Then crew leader will check it out before sending the crew out	May vary. A sub area supervisor oversees 5 truck stations puts together WO's and includes what they think they'll need for the job. It mimics construction companies' safety booklets. It's filled out for every job. Essentially a job planning and briefing form. It forces them to look at the big picture before they go out to the site.	Assistant resident engineer (maintenance yard engineer with the county)	Job briefing (job safety analysis booklet -for specific jobs), foreman's manual, Job safety booklets - general safety tips (i.e., Safety Tailgates)
<i>a. Does it discuss increased exposure to risk when removing ash trees?</i>	This question was not on questionnaire	This question was not on questionnaire	We have an internal job task requirements book with safety, needed equipment, and PPE included.	This question was not on questionnaire	This question was not on questionnaire
13. Do the crews have a job planning and briefing form that discusses the day's work plan and potential hazards?	Crew uses the notes on WO to locate and determine site set up	Yes	We have an internal job task requirements book with safety, needed equipment, and PPE included.	Bring all equipment to each site, supervisor will assess the site when they get out there and point out hazards. No formal form	Foreman leads and crew provides input
<i>a. Does it discuss increased exposure to risk when removing ash trees?</i>	Yes, will address when arriving on the site, not a formal job briefing	Yes, or any dead tree	No	Not answered	Not answered

Questions	CTDOT	MDOT	MnDOT	NYS DOT	PennDOT
14. How do you handle debris of dead ash?	Large logs and limbs are removed ASAP	Don't use log truck, only mow first 15' not to fence so they are leaving logs behind where they would brush hog. Use brush hog every 4 years, trees are okay in ROW	In Metro District, all tree removal debris (all species) is trucked to District One Energy where they use it for energy production. Hauling time increases due to this but overall, it is cheaper than tub grinder or other operations. In the other Districts, it depends on whether or not the district is included in the state quarantine. If the District is within quarantine, we work with the MN Dept of Ag to find disposal sites. If the District is not within quarantine, options include trucking debris to truck stations with burn piles, cutting and leaving on site, chipping and leaving on site	Leave debris on site if possible or leave chips on site if possible. Empty and blow out and off equipment, hose off equipment before moving on to other areas	Contractor is responsible for finding place to dump, property owner gets first dibs on logs so PennDOT will remove (mostly logs) if owner doesn't want.
<i>a. How do quarantines affect your ability to efficiently dispose of ash debris?</i>	Statewide quarantine doesn't affect disposal	Initially in certain counties, then couldn't take to Upper Peninsula. Could chip under 3" and leave on-site. They leave where they can	Yes	Not answered	Not answered
<i>b. Do you have access to companies to process the waste?</i>	1 school does take chips, but they are booked up to 2". Dump logs at approved facility or hire contractor w/tub grinder at approved dump site or back of garage. Pay to dispose of wood as opposed to thousands to tub grinder. Wood disposal = less handling by ODOT	A plant in Detroit but they don't use it	In some areas of the state, yes.	Not answered	No. Blow chips as long as they don't end up in ditch
15. Does your tree crew set up MOT for themselves or does another crew do that for them?	Not answered	Another crew sets it up	Setting up their own	Different crew sets up	Sometimes
16. Do you treat stumps with herbicide?	Mostly foliar after stumps resprout by contract rather than stump treat. Use truck with hose and spray gun for 20'-25' reach	Yes, and for brush cutting waiting until relief then treating. Don't treat ash stumps	Some	Applicators are on crew but haven't applied in a while.	Contractors are required to, in-house may or may not
17. How efficient are your crews? How many trees/volumes are removed per day?	100-150 for Sennebogen for clearing - provided a production report. In house crew = 1 large or 12-15 medium depending on variables. Contractor is paid by the day and what equipment is out there, different pieces are diff costs; 100-150 trees per day on 2-lane routes. Contractor crew has 3 guys 1 for Sennebogen, Crew Size for Sennebogen/Chipper/Blower: 1 for chipper, 1 pickup for blowing off road and cutting stump down a little farther	Contractors are more efficient. Would need to pull crews off bridge work crew and other crews. Did a comparison of in-house vs contractor. In-house did 1 mile for \$10,000, contractor did 10 miles \$225,000 more expensive but got it done faster. If there are single trees and in-house crew is in area in-house crew will do it. If a larger group, contract out. 24" tree will contract out.	This metric is not tracked statewide. We track labor/equipment hours instead of quantity.	Quantity may not be as efficient as contracted tree crews, but they are safer. In-house crews don't use one hand, wait for wood to hit ground before they go get it where contractors may do these things. Production depends on site and tree conditions	For contractors 1/10 mile per day
Misc. Notes	Maintenance supervisor flags area to be cut. District landscape designer evaluates and approves work		Still working through a lot of ash removals particularly in northern MN towards the black ash. Still has a lot of area to make it through. I-94 towards Wisconsin is probably where they have the deadest ash, and they have issues with accessing due to the terrain. - Working with the state parks where they can. Will leave as crews will need to rappel to trees	Quarantine restricted movement of wood between counties before whole state was affected.	
	Use contractors, cranes, tracked and wheeled feller bunchers or whole tree chippers				Bark white due to birds picking made ID easy
	Large logs and limbs removed ASAP				Rely on tree contractors to remove trees near communication lines. Prioritize work by targets, ADT
	Communication device is Pelzer light com heavy and bulky, will move over to Seena Toughtalk mount inside helmet with Bluetooth				Contractors use 55' bucket, self-feeding chippers by contract specs and 5 guys, 2 guys flagging, 1 in bucket, 2 feeding chipper. Stump grinder if needed for yard trees, log truck for hauling logs sometimes. Some contracts based on miles where they can use what equipment they want, will need to make correct cuts afterwards if not done initially. Contractor used Sennebogen to remove for efficiency.
	Could use two Sennebogen and 1 chipper and the chipper will keep up				~10 Ash trees at DOT facilities- Use Tree Age for high value trees.
	Could get a splitter to attach to chipper allows you to put larger wood into chipper				MnDOT is divided into 8 regional Districts and 1 Central Office. Central Office personnel are the statewide experts that set standards, policy, procedures, etc. The main customer of the Central Office staff is MnDOT Districts. MnDOT's Districts direct the activities of that District. Each District operates slightly differently from the other Districts. They "hold the purse strings" for projects and make decisions for which activities are performed in-house and which are hired out. For tree work, MnDOT's Roadside Vegetation Management Unit provides recommendations and advice to the Districts.
	Fallback rubber-tired crane - could do huge trees, high cost per day				
	Starting to get away from feller buncher due to impact driving off road crossing streams, etc.				

Questions	CTDOT	MDOT	MnDOT	NYSDOT	PennDOT
	<p>Tried hybrid buckets but they didn't work well</p> <p>Contract with spider lifts for difficult access areas (i.e., backyard access)</p> <p>In house crew made bed for dump to hold chips out of old signs, allowed them to enclose top and build up sides, it's more effective than just using dump and can be easily lifted out of bed.</p>				

Appendix B. ODOT Tree Crew Questionnaire

Employee Name: _____

Employee Positions: _____

County: _____

Date: _____

1. Have you worked on a tree crew outside of ODOT work
 - a. Yes
 - b. No

2. How many months/years of experience do you have trimming or removing trees?
 - a. 1-6 months
 - b. 7-12 months
 - c. 12-24 months
 - d. 25-36 months
 - e. 36+ months

3. How confident are you in your ability to identify an ash tree?
 - a. Not at all
 - b. Somewhat confident
 - c. Confident
 - d. Could teach others

4. How confident are you in your ability to identify an ash tree infected with Emerald Ash Borer?
 - a. Not at all
 - b. Somewhat confident
 - c. Confident
 - d. Could teach others

5. How frequently do you work on or near ash trees, living or dead, on the job during the tree clearing season?
 - a. Multiple times per day
 - b. Daily
 - c. Weekly
 - d. Monthly

6. Who decides how an ash tree is to be removed?
 - a. County manager
 - b. Transportation Manager
 - c. Transportation Administrator
 - d. Crew Foreman
 - e. Heavy equipment operator
 - f. Other

7. Is that process strictly followed or open to change by another person?
 - a. Yes
 - b. No

8. How is a work plan modified for variances in tree condition (size, shape, and level of decay)? By whom and what process?

9. Are you aware of any general practices within ODOT or the tree care industry as a whole that center around the removal of dead ash trees (things you should do or not do)?

10. What additional conditions do you or your crew consider when working on an ash removal compared to most other species of trees?

11. Are you aware of any practices ODOT crews do differently than tree companies when removing ash trees and debris?

12. What types of equipment are you trained to use for tree trimming & removal?
 - a. Chipper
 - b. Chainsaw
 - c. Bucket truck
 - d. Jarraff
 - e. Brontosaurus
 - f. Loader
 - g. Other

13. What ODOT sponsored or lead training have you received for performing tree clearing work?

14. How well do you feel NEW team members are trained and equipped prior to engaging in field work?
 - a. Not at all
 - b. Very little
 - c. Adequately
 - d. Proficiently

15. How comfortable do you feel using the equipment being used today?
 - a. Not at all
 - b. Somewhat uncomfortable
 - c. Comfortable
 - d. Very Comfortable
16. How well do you feel you understand the daily work plan?
 - a. Not at all
 - b. Somewhat
 - c. Well
 - d. Very well
17. How free do you feel to speak up if you don't understand something or feel a task is unsafe?
 - a. Not at all
 - b. Somewhat uncomfortable
 - c. Comfortable
 - d. Very Comfortable
18. How reliable is your fleet of large engine transport equipment (i.e., trucks and trailers used for tree clearing)?
 - a. Unreliable
 - b. Somewhat reliable
 - c. Reliable
 - d. Very reliable
19. How reliable is your small engine equipment (i.e., chainsaws, blowers, etc.)?
 - a. Unreliable
 - b. Somewhat reliable
 - c. Reliable
 - d. Very reliable
20. How reliable is your additional miscellaneous equipment (i.e., ropes, pulleys, slings, etc.)?
 - a. Unreliable
 - b. Somewhat reliable
 - c. Reliable
 - d. Very reliable
21. How often do you think miscommunications are part of the challenges involved in daily operations?
 - a. Not at all
 - b. Somewhat responsible
 - c. Often
 - d. Most of the time
22. How effective do you feel communications are with Fellow Field Employees in areas concerning training, equipment malfunctions, and safety issues?
 - a. Ineffective
 - b. Somewhat ineffective
 - c. Effective
 - d. Very effective

23. How effective do you feel communications are with Management in areas concerning training, equipment malfunctions, and safety issues?
- Ineffective
 - Somewhat ineffective
 - Effective
 - Very effective
24. How easy or difficult do you find morning routines of gathering gear and preparing for your day?
- Very difficult
 - Somewhat difficult
 - Relatively easy
 - Very easy
25. How long does it take to prepare for a workday MOBILIZE?
- 0-30 minutes
 - 31-60 minutes
 - 61-90 minutes
 - 91-120 minutes
26. How long does it take to Demobilize?
- 0-30 minutes
 - 31-60 minutes
 - 61-90 minutes
 - 91-120 minutes
27. Are there any individual pieces of equipment that have a long-standing history in hindering efficiency of daily tasks or duties without replacement or repair? Chainsaws that don't perform correctly, chippers that often plug up or have faulty accessories?
28. Are there any additional things (equipment, training protocols, etc.) that you feel would be of great aid in the areas of safety or efficiency to your daily operations

Appendix C. Phase I Matrix of Recommended Equipment and Processes

Area of Improvement	Topic	Recommendation #	Recommended Improvement	Problem Addressed	Action Items for Improvement	Justification	Potential Benefits		Estimated Cost		Time to ROI
							Safety	Efficiency	Purchase Cost	Additional Daily Labor @\$20/hr	
TRAINING	Identification of ash and EAB infection	1	Identification books & posters Twig & leaf collection In field crew training	Many ODOT workers cannot identify ash trees nor signs of EAB	Train employees in tree species commonly found in OH, in particular, ash trees	Tree identification is important in helping to learn the nuances, forces, and reactions when working with different species Working on or near ash can be deadly. Crew members should identify ash on site prior to beginning work to alter work plan if needed	Greater identification of potential hazards inherent in working near trees with EAB Plan appropriately to avoid ash-related safety incidents	Not dependent on others for ash identification	Identification books cost \$15 Posters cost \$25 Building a twig & leaf collection \$0 In field crew training \$0	\$0 if done passively when arriving at job site & reviewing work plan	6 months
	Improving worker safety	2	Training refresher & skill advancement training with chainsaws, chippers, bucket trucks, winches	Little to no tree crew training beyond entry level chainsaw & chipper training to refresh or advance skills Sporadic use of equipment & techniques due to workload variety increases safety risks & decreases efficiencies	Provide annual refresher training prior to tree work season	Crews observed performing practices that were unsafe (one handed trim saws, chipping from the traffic side, not assessing lean and decay before work) Risky behaviors become habits and will lead to safety incidents and equipment damage	Reduced risk of accidents & damage to equipment Reinforces a baseline of safe practices when dealing with hazardous ash trees Increases comfort level with different situations Reduce risks associated with winch use through training	Familiarity with equipment will increase efficiency and production rate Increase production rate on current buckets & chippers with recurrent training			
	Leadership Development		Ash removal training	Update tree removal procedures to mitigate increased hazards of brittle, dead ash trees	Assess the <u>target tree and work area</u> to determine safest approach to removing ash → Use DRG decision tree tool	Ash trees infected with EAB unsafe to work around	Tree crews trained on ash less likely to make simple errors; minimize risk to workers	Learn efficient practices while maintaining safety	ArborMaster: \$28,000 for 20 employees for annual week-long training	\$0	6 months - 1 year
	Mentorship program		Mentorship program foundation	Lack of mentorship program to continue training after initial chainsaw and chipper training	Tree foreman should mentor less experienced crew members Include demonstration and critiquing of skills, building a step-by-step system that adds consistency	Provide training to lead who can become tree foreman Supervise and assist in proper maintenance, preparation, and operation of tools and equipment	Provide oversight, site assessment, planning, and mentorship	Effective mentoring raises the collective standard competency level			
PROCESSES & OPERATIONS	Improving general efficiency and safety	3	Create year-round trained & dedicated tree crew	Keeping up with workload	Hire people with specialized skill set/ assign employees with appropriate skill sets to this team	Crew will be more efficient than crews that sporadically performing tree work Equipment always be at the ready	People with advanced skill sets, knowledge, and experience are more prepared to prevent and handle safety incidents	Eliminates need to get back up to speed at beginning of season Increased familiarity with equipment, maintenance, procedures 2x more productive than seasonal crew with same equipment Reduce crew count by 2 saving \$320/day	\$0	\$0	6 months
		4	Schedule change	Keeping up with workload	Work 10 hour days	More efficient use of daylight Increased production time compared to mobilization time	N/A	Increases daily production 20% Decrease days spent on job, reducing mobilization to each job site	\$0	\$0	Immediate
		5	Contractor	Keeping up with workload Utility lines near trees that need to be worked Accessing and working hazardous trees safely with current equipment	Contract out: • Large sections in need of clearing • Large/dangerous trees & communication lines • Trees difficult to access with ODOT equipment Have contracts in place in each area for when the need arises	Less expensive, safer, and more efficient for qualified contractor with appropriate training and equipment than to have ODOT maintain line clearance training Working safely near ash trees requires training and planning If crews are not well trained, or don't have appropriate equipment, it is better to hire a qualified contractor	Keeps workers away from electrical hazards Allows ODOT tree crew to focus on less dangerous work	Qualified contractor has higher production rate ODOT crew available for smaller and less dangerous sections	\$0	\$0	Immediate
	Job Planning and organization	6	Site assessment tool	Crew unaware of site conditions, equipment needs, and how to best set up before arriving on site	Use site assessment tool prior to work order creation to better anticipate obstacles, equipment needs, worker skill sets	Helps determine proper tools and staff to bring to job site, making tree work more efficient and safer Proper equipment planning more critical for specialized equipment	Correct equipment and set up for each site reduces risk for injuries	Helps crew bring proper equipment to site and set up efficiently	\$5/site		Immediate
			Tree crew job briefing	Inefficient coordination/time utilization Mobilization to job site	Regular job briefing at garage prior to mobilization and work → Incorporate whiteboard/ emailed work plan to communicate daily/weekly job plan including equipment needed → Establish roles and identify equipment to mobilize	Prepares crew for what to expect when arriving on site; improves efficiency, helps identify safety issues	Provides crew information about site conditions ahead of arrival helping them set up and work more safely by identifying potential risks	Mental preparation for the day's work Provides clear roles for each worker during morning mobilization	Covered by Phase II of research project workshop training	\$5/crew member/day	
			Efficiency guidance	Improving efficiency for debris removal.	Set up operation like an assembly line → Set up bucket truck/trimmer in front of chip truck Trimmer should continue cutting while chips are dumped off site Reassess remaining workload after lunch to determine end of day wrap up/site clean up	Increases production rate Minimizes maintenance of traffic setup and disturbance to travelers	Minimizes confusion of travelers thereby reducing risk of accidents in work zone	Minimizes crew downtime - Saves a minimum of \$320/crew per day Minimizes time loss from second traffic control setup to return for wood	\$0		
	Daily Job Prep/ Mobilization/ Demobilization	7	Change in Storage	Delayed time in leaving the yard	Keep tree related tools in bucket truck or similar equipment used for tree work or specific area of garage	Allows for more efficient mobilization, decreases time locating and loading gear	N/A	Saves time loading and unloading gear Saves \$10-20/day/person	\$0	\$0	Immediate
		8	Set goal	Delayed time in leaving the yard	Set goals for leaving the garage by a certain time	Provides an expectation and goal to meet	N/A	Holds an equal standard of accountability to crews mobilizing in the morning Saves \$10-20/day/person	\$0	\$0	Immediate
	Tree crew creation and scheduling	9	Change in crew organization	Team is inefficient and has low productivity	Allow crew foreman to flex qualified people into roles as needed throughout operations → Prioritize scheduling workers with the correct skills and experience over other work without safety component	Will improve team efficiency & productivity	More competent crew will work more safely	More competent crew will work more efficiently Tree foremen with competent crews can devote more attention to mentoring and filling production gaps in work tasks	\$0	\$0	6 months
		10	Work planning	Team is inefficient and has low productivity	Schedule secondary tree crews to work on non-emergency jobs within reasonable proximity to provide tools or backup as needed (if possible)	Will improve team efficiency & productivity	N/A	In situations far from the garage, secondary crew may play support role with equipment or manpower	\$0	\$0	6 - 12 months

	11	Hiring change	Team is inefficient and has low productivity	Prioritize 3yrs + professional tree work experience and training with a reputable employer(s) and leadership potential/demeanor in new hires	Will improve team efficiency & productivity	More competent crew will work more safely	Integrates new insights, strategies, and techniques into tree crews making for more knowledgeable field personnel	\$0	\$0	6 months	
Safely and efficiently using equipment in the ROW	12	Removal Equipment: Sennebogen 718 on wheels Debris Handling: Dymax 360 hydraulic rotation grapple for midsize excavator Bandit 1855 whole tree chipper on wheels with Kelsa loader and remote control	Accessing and working hazardous trees safely with current equipment Keeping up with backlog Improving efficiency for debris removal	Felling equipment should work ahead of debris disposal equipment by 1.5 tree height → Use equipment that allows workers to work with a safe buffer zone/ provides an enclosed cab Shut down the road while dead ash work is conducted Perform work with a grapple saw on a boom to reach 80% of work → Purchase equipment with a grapple saw → Move debris into chipper with a grapple attached to an excavator → Chip debris with a whole tree chipper	Working near ash trees is dangerous. Equipment combination provides the safest and most efficient option for crew Increased reach facilitates working from road Grapple on excavator keeps removal equipment moving down the road while reducing manpower to load chipper. Grapple on midsize excavator should also be used with bucket truck/chipper combination to reduce crew levels Whole tree chipper on wheels can keep up with production rate of grapple saw. Loader on chipper can feed larger volume of wood into chipper than people while keeping body parts far from chipper	Minimize worker exposure to ash by maintaining distance and limiting personnel on roadside Keeps personnel in enclosed cabs Grapple saw minimizes safety hazards by holding pieces being cut rather than dropping them and allowing pieces to shatter and scatter in different directions Grapples move heavy logs decreasing risk of strains, sprains and pinch points workers would otherwise be exposed to Chipper feeding is mechanized keeping workers away from chipper infeed. Roadside restoration needs are minimized when equipment is kept on road	Sennebogen reaches 80% of work from shoulder. Grapple saw is most productive to complete ash removals. Reaching from roadside limits on-site travel time. Grapple on existing excavator provides the power to lift & load logs into chipper Chipper on wheels eliminates need for loading on low boy. Disc style whole tree chipper handles larger diameter logs and keeps pace with Sennebogen. Produces 120 cu yd/hour (semi-tractor load) 5x faster than current bucket crew Equipment combination uses 3 staff vs. 5 for current bucket crew = \$320 savings/day	Sennebogen Grapple Saw: \$570,000 purchase or \$28,000 rental Dymax 360 Hydraulic Rotation Grapple: \$39,463 Bandit 1855 Disc style whole tree chipper on wheels: \$230,400	\$0	Sennebogen: If using contractor for >13 days/month, equipment rental is cheaper. Purchase of unit is paid in 274 days (\$1080/day) or 20 months (\$41,600/month) contracting. Dymax Purchase is paid for with 247 hours contracting equipment (\$160/hour) Bandit: Purchase is paid for with less than 14 months contracting equipment (\$16,800/month)	
	13	Build larger chip bed for dump trucks	Reduces frequency of dump trucks leaving site by increasing capacity	Construct a removable bed with high sides and lid to insert into dump beds to handle larger volume of chips	Improves efficiency of debris disposal Reduces downtime each time crew leave site Removes easily out of dump when dump will be used for other jobs	None	Reduces frequency of leaving work site to dump chips Keeps debris disposal crew productive longer between dumping	Use materials on hand	\$5 for loading into dump each day	Immediate	
	14	Rent horizontal grinder (~1-2 two weeks/yr.) Dispense chips directly into semitrailer for disposal	Log disposal	When site is near yard, transport logs to yard to process all at once	Can be more efficient than chipping large logs on site Horizontal grinder will not get enough use to warrant purchase, but rental makes economic sense	None	Can handle a lot of debris in a short amount of time Allows trees that won't fit through a chipper to be disposed	\$5,000/week rental vs. \$500,000 purchase	\$0	Horizontal grinder: Weekly rental is \$23,800 less expensive than contracting for 1 week Purchase is paid off in 17.3 straight weeks of use	
	Equipment maintenance	15	Bench grinder for garage 3 sets of chains for each saw 1 extra bar for each saw	Employees didn't know how to sharpen chainsaws properly/ used dull chainsaws Variable results with individuals using hand file in field Lost time in field sharpening saws	Provide more efficient tools for sharpening Train employees on chain sharpening Sharpen & maintain tools at end OR beginning of day	Employees using saws should know how to sharpen them without damaging them Will improve efficiency Reduce downtime from damaged equipment or equipment maintenance	N/A	Minimizes downtime in field Ensures proper sharpening and most efficient use of chainsaws Swapping chains in the field takes less time than sharpening with a hand tool Saves \$15+ each time a saw a saw would have been sharpened in field	Oregon 620-120 Hydraulic Assist Bench Grinder \$459 Chains \$25-35 Bars \$35-40	\$0	6 months
	Communication	16	Headsets communication system Compatible forestry helmet	Field adversities to communications	Provide headsets to all tree crew members	Improves communication for efficiency and safety Enhances training and mentorship by allowing for more frequent and thorough communication during operations	Enables better information flow Tighter communication can make a difference between an accident, a near miss, and prevention altogether	Improve quality of communication Minimize time lags caused by miscommunication/ slowed communication	Speak Easy Actio Pro- C \$280 each	\$0	6-12 months

Appendix D. Gap Analysis and ROI - Phase I Summary

Current Process

- ODOT bucket crew with brush chipper
 - 5 Crew members (1 cutting in bucket with chainsaw, 4 ground crew members pulling brush and manually feeding chipper)
 - Production rate = 30 trees/day
 - Labor cost = \$800/day
 - Cost per tree = \$26.67
 - Safety concerns
 - Labor intensive
 - Slips, trips and falls
 - Pinch points and back strain
 - Cuts and limb loss
 - Hazards from falling tree parts

Recommended Process

- Purchase Equipment:
 - Sennebogen 718 E Grapple Saw Truck, \$570,000
 - Dymax 360 Hydraulic Rotation Grapple: \$39,463
 - Bandit 1855 Disc style whole tree chipper on wheels with Kelsa loader: \$230,400
 - Equipment is not sole source distributor
- 3 crew members (1 cutting in saw truck, 1 in midsize excavator, 1 operating chipper)
- Production rate = 150 trees/day
- Labor cost = \$480/day
- Cost per tree = \$3.20
- Safety and Efficiency Benefits
 - Large pieces can be taken down in less cuts increases production
 - Pieces are held by grapple and placed neatly for chipper loading
 - Workers are in enclosed cabs reducing exposure to weather or site safety risks
 - Workers are not exposed to cutting implements
 - Work is less labor intensive
 - Production rate increases 5x, leaving less hazards on right-of-way
 - Uses 2 less crew members

Equipment Purchase Return on Investment Comparisons

- Approach 1 compares to contracting out work:
 - Contractor uses Sennebogen and Bandit 21xp chipper @ \$92,400/month
 - Equipment purchase will be paid off in 9 months of contracting
- Approach 2 compares to ODOT crew with current equipment:
 - Current process is too slow leaving hazards on right-of-way too long and work is dangerous for crews with current setup
 - Equipment purchases will be paid off in 47.7 weeks (11 months) based on reduced labor & increased production

Outcome

- Equipment benefits all species that need clearing, not just ash
- ODOT can reduce backlog leaving less hazards on roadsides
- Equipment is safer for employees to use
- Equipment pays for itself in less than 1 year based on decreased labor and increased production

Appendix E. Equipment Cost Quotes

Model: _____ SENNEBOGEN 718 M "E"
Customer: _____ Ohio Department of Transportation
Page: _____ Page 1 of 7
Date: _____ Tuesday, June 08, 2021

Prepared for: **Ohio Department of Transportation**

SENNEBOGEN 718 M "E series"



(Picture may show optional equipment or similar model)

Engine

- ▶ Cummins QSB4.5 diesel engine (4 cylinder) with direct injection, water cooled (TIER 4f emission)
- ▶ Engine output 160 HP (119 kW) @ 2,200 rpm
- ▶ Turbo Intercooler & water cooler hydraulically driven, reversible
- ▶ Automatic idle-stop control and eco-mode for diesel engine
- ▶ Air pre-cleaner integrated

Hydraulic System

- ▶ Computer free, state-of-the-art load-sensing with flow-on-demand control
- ▶ Hydraulic cooler hydraulically driven, reversible
- ▶ Hydro-Clean filtration system with water absorption and contamination indicator
- ▶ Additional hydraulic package, including extra variable displacement pump (50 GPM / 3,625 PSI)
- ▶ Biodegradable hydraulic oil (PANOLIN HLP Synth 46)

Upper Carriage & Swing System

- ▶ Torsion free, precisely machined upper carriage frame
- ▶ High torque axial piston swing motor
- ▶ Large dimensioned, internal teeth swing bearing
- ▶ Automatic central lubrication system for upper carriage and swing bearing
- ▶ Handrail on top of upper carriage
- ▶ Fire extinguisher set (1x cab, 1x storage compartment)
- ▶ One rotating beacon on top of the cab
- ▶ Light Package consisting of: 2x integrated in the cab roof, 1x LED on top of the cab, 2x in frame
- ▶ Jump start connection easily accessible

Operator's Cab "maXCab"

- ▶ Hydraulic elevating cab system "E270" (elevation: 8'8") plus 30° tilting angle for better visibility
- ▶ Catwalk with handrail beside cab
- ▶ "maXCab" with sliding door and door window as sliding window, sunshade, floor mat
- ▶ Automatic climate control with AC, heater and defroster
- ▶ AM/FM radio with CD player, MP3 and Bluetooth
- ▶ SENCON visual and acoustic diagnostic system for monitoring all essential machine functions
- ▶ Air suspended and adjustable operator's seat incl. armrests, seat heater, headrest, seat belt
- ▶ Camera system with display in cab (2 cameras, right side and back)
- ▶ Skylight of bullet proof glass, fixed glass
- ▶ Windscreen wiper for skylight with washer system
- ▶ Cab front windscreen in bullet proof glass version, fixed glass plus windscreen guard
- ▶ Spare Parts catalogue (1x print / 1x digital)
- ▶ Operator's & Maintenance manual incl. hydraulic & electric schematics (1x print / 1x digital)

Model: SENNEBOGEN 718 M"E"
 Customer: Ohio Department of Transportation
 Page: Page 3 of 7
 Date: Tuesday, June 08, 2021

Working Equipment

- ▶ K13T - special material handler boom with telescopic stick (6'8"), maximum reach 43'
- ▶ Boom cylinder equipped with safety check valves and end position dumping
- ▶ Attachment open/close and rotate hydraulic circuits and lines installed up to the end of the stick
- ▶ Additional Light Package consisting of: 2x LED on the boom

Under Carriage

- ▶ Rubber tired under carriage MP21E with 4-point stabilizers
- ▶ Automatic unlock of oscillating axle if upper carriage in longitudinal direction to under carriage
- ▶ Single air tires 600/50 – 22.5, 4 units
- ▶ Steering via joy stick with steering-direction control for change of driving direction
- ▶ All wheel drive via variable hydraulic motor with 2-stage shift transmission
- ▶ Protection guard for under carriage to protect transmission, hydraulic motor and drive shafts
- ▶ 2-circuit servo brake system with additional safety brake
- ▶ Centralized lubrication points (front & rear) for lubrication of under carriage components
- ▶ Audible travel alarm while driving machine (forward & backward)
- ▶ Tool box w/ basic tools, stick pin, grease gun, wheel chock, etc.

Attachments

- ▶ Rotator / tilter mounted at the end of the stick
- ▶ Grapple saw Sennebogen / SS550 – saw bar 35.4"

for further technical information or options please refer to the technical literature



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 Under our policy of continuous improvement, we reserve the right to change specifications and design without prior notice. The illustrations may show optional equipment and/or different series
 718 Quotation ODOT

MACHINE QUOTATION



Model: SENNEBOGEN 718 M"E"
Customer: Ohio Department of Transportation
Page: Page 4 of 7
Date: Tuesday, June 08, 2021





Model: SENNEBOGEN 718 M "E"
Customer: Ohio Department of Transportation
Page: Page 5 of 7
Date: Tuesday, June 08, 2021

COMMERCIAL CONDITIONS

Scope of supply

SENNEBOGEN LLC in cooperation with its local distributor will supply the complete machine as described in the technical specification.

Pricing

SENNEBOGEN 718 M "E" Tier 4f series according to scope of supply & technical specification excluding sales tax

Machine price for base unit (per unit) US\$ 570,000.00

Price Includes (2) Two Uptime Kits



New ChickFilA.ttf

At least (3) Days of operator familiarization on site

*** Customer is responsible for paying sales tax.**

Payment terms

100% through Sennebogen Capital financing.

Delivery time

SENNEBOGEN LLC in cooperation with its local distributor will deliver the machine within a to be determined delivery time, after receipt of the written purchase order and final clarification of the technical specifications. The exact delivery time is pending on transport permits, availability at time of receipt of purchase order and subject to prior sale. Delivery time as of today, 3-6 weeks after order date.

Warranty:

SENNEBOGEN warrants all machines for a period of twelve (12) months or 2,000 hours of operation whichever occurs first according to the latest edition of the SENNEBOGEN LLC warranty manual;

Validity

The commercial conditions and technical specifications are valid for delivery before December 31, 2021. Later deliveries are subject to price adjustments.

Further terms

The commercial conditions are according to the SENNEBOGEN LLC general terms and conditions of sale. All applicable federal, state and local taxes are not included. Prices and delivery are subject to prior sale. In case of processing the machine purchase order or rental through SENNEBOGEN's local distributor, the distributor's general terms and conditions apply.

Quotation accepted by:.....

Name:.....

MACHINE QUOTATION



Model: _____ SENNEBOGEN 718 M "E"
Customer: _____ Ohio Department of Transportation
Page: _____ Page 6 of 7
Date: _____ Tuesday, June 08, 2021

Title:.....

Date:.....



DETAILED EQUIPMENT QUOTE

JUNE 25, 2021

SALESPERSON: Chris Morgan
 CUSTOMER CONTACT:

QUOTE PREPARED FOR:

DOT CO EQUIPMENT MANAGEMENT
 1620 W BROAD ST
 COLUMBUS, OH 43223
 P: 614-351-2828

FACILITY QUOTED FROM:

1500 Industrial Parkway, Brunswick, OH
 44212
 Branch: (330) 225-6511
 Mobile: (419) 261-9630
 Email: cmorgan@southeasternequip.com

QUOTE INFORMATION:

Account Number: 3001123

Eq # / Item #	Product Description	Hours	Product Notes	Total Price
	Rotation kit to fit a Kobelco SK140SR LC-5 installed. For rotation on a 360 degree log grapple and to tilt helac power tilt on ditching bucket. Price includes installation at Southeastern Brunswick location shop. Price also includes quick couplers to fit the Helac and attachments to be purchased. 30 day lead time on rotation kit			\$15,000.00
Total Price				\$15,000.00

NOTES:

EQUIPMENT WARRANTY AND DELIVERY INFORMATION:

Warranty Type:
 Warranty Detail:

Delivery Method:
 Delivery Date:
 Delivery Info:

*All information and prices are subject to change prior to signed sales order. Description, specifications, hour meters and other information may differ from actuals. Any finance information presented on this quote is not a promise to finance or a guarantee of rates.



DETAILED EQUIPMENT QUOTE

TRADE-IN EQUIPMENT:

Year	Serial #	Manufacturer	Model	Trade-In Allowance
Total Trade-In Estimate				0

Finance Rate Options (Estimate Only)			
	Months	Rate	Estimated Cost
Term 1		%	
Term 2		%	
Term 3		%	
Term 4		%	
Term 5		%	

QUOTE TOTALS*	
Total Equipment Price	\$15,000.00
Estimated Trade-In Allowance	\$0.00
Trade-In Difference	\$15,000.00
Applied Rent	
Carrying Charge	
Fuel, DEF & Other	
Freight/Trucking	
Title and License Fees	
Total Trade Payoff	\$0.00
Total Price Before Tax	\$15,000.00
Sales Tax	
FET Tax	
Total Amount Due	\$15,000.00
Down Payment	
Estimated Balance Due	\$15,000.00

*All information and prices are subject to change prior to signed sales order. Description, specifications, hour meters and other information may differ from actuals. Any finance information presented on this quote is not a promise to finance or a guarantee of rates.

Columbus Equipment Company
 2323 Performance Way Columbus, Ohio 43207
 614/443-6541

BRANCHES AT:
 COLUMBUS, OHIO 43207 RICHFIELD, OHIO 44286 MASSILLON, OHIO 44846
 2329 Performance. 614-443-6541 3942 Brecksville Rd. 330-669-6681 2200 Venture Cr SE 330-833-2420
 TOLEDO, OHIO 43615 CADIZ, OHIO 43907 ZANESVILLE, OH 43701
 25000 WILLIAMS ST 419-531-7101 290 Old Steubenville 740-942-8871 818 LEE ST 740-455-4036
 CINCINNATI, OHIO 45241 DAYTON, OHIO 45424 PIKETON, OHIO 45661
 712 SHEPHERD AVE 513-771-3922 7870 NEW CARLISLE PIKE 937-879-3154 3668 US 23 South 740-789-3757

DATE
 June 22, 2021

SOLD TO
 Ohio Department of Transportation
 ADDRESS
 1980 West Broad Street
 CITY
 Columbus, OH 43223

SHIP TO - Same as Sold To unless noted below
 ODOT District 3
 808 Kochheiser Rd W,
 Mansfield, OH 44904

CUSTOMER'S NUMBER 67517	VIA	FOB Mansfield, OH	SPECIAL INSTRUCTIONS
----------------------------	-----	----------------------	----------------------

DESCRIPTION	UNIT PRICE	TOTAL PRICE
New Order Rotobec 4042HD Log Grapple and RT322 Rotator		\$13,090.00
Quick Adaptor Plate Yoke MM		\$4,151.00
Freight to Mansfield, OH		\$700.00
(Customer may provide valid tax exempt certificate, Columbus Equipment is not responsible for tax liability)	SALES TAX	Exempt
	TOTAL	\$17,941.00

TERMS
 Customer to pay upon receipt of invoice

This order is taken subject to the approval and acceptance by an officer of the Columbus Equipment Company at Columbus, Ohio. Vender is not to be held liable for any delays in shipment, damage en route or any damages of any nature caused by riots, strikes, floods, fire, acts of God, or any cause beyond the vendor's control.
 The quoted price on this order is subject to increase without notice by the amount of any sales or excise tax that may be imposed by the federal, state or local Government, or by the amount of any price increases imposed by the manufacturer or supplier.
 Possession of goods & chattels described above is not to be considered evidence of ownership, but it is expressly agreed that the title of all said property is to remain with the vendor until full amount of purchase price is paid.

SALESMAN
 Bob Stewart

CUSTOMER'S SIGNATURE



Ed Dodak
 6750 Millbrook Rd.
 Remus, MI 49340
 USA
 989-561-2270 (Phone)
 989-561-2273 (Fax)
www.banditchippers.com

QUOTATION			
Quote #	Quote Created	Last Updated	Salesperson
132865	September 27, 2021 12:00 PM by Bandit Industries, Inc.	September 27, 2021 12:00 PM by Ed Dodak	Ed Dodak
CUSTOMER:		BILL TO:	SHIP TO:
Ohio Dot District 3 906 Clark Ave Ashland , OH 440855 USA 419-281-0513 (Phone)		Ohio Dot District 3 906 Clark Ave Ashland , OH 440855 USA 419-281-0513 (Phone)	Ohio Dot District 3 906 Clark Ave Ashland , OH 440855 USA 419-281-0513 (Phone)
MODEL 2090 (20" DRUM STYLE) TOWABLE WHOLE TREE CHIPPER			
Qty	Part #	Description	Base Price
1	MODEL-2090	Model 2090 - (20" Drum Style) Towable Whole Tree Chipper	\$ 121445.00
STANDARD EQUIPMENT			
Qty	Part #	Description	Price
1	STANDARD	Slide box feed system with (2) horizontal feed wheels, top feed wheel is 32" long X 27" diameter and bottom feed wheel is 32" long X 10 5/8" diameter.	\$ 0.00
1	STANDARD	Wide profile, tapered infeed hopper with 30" solid infeed pan	\$ 0.00
1	STANDARD	37" Diameter x 24" wide drum with replaceable holders and (4) 5/8" X 5 1/2" X 12 1/8" dual edge bolt-on knives	\$ 0.00
1	STANDARD	In-line hydraulic pressure check system (Gauge is included)	\$ 0.00
1	STANDARD	Hydraulic lift cylinder - utilizes a hydraulic cylinder to raise or provide down pressure for the top feed wheel (controlled via radio remote control)	\$ 0.00
0	STANDARD	60 gallon steel fuel tank with magnetic drain plug, lockable filler cap, and aluminum sight gauge	\$ 0.00
1	STANDARD	Round control bar - located around top and sides of infeed hopper with 3 control positions (forward / stop / reverse)	\$ 0.00
1	STANDARD	60 gallon steel hydraulic tank with magnetic drain plug, lockable filler cap, aluminum sight gauge, mesh screen strainer and gate valve	\$ 0.00
1	STANDARD	Radio remote control with tether back-up. Remote controls the following functions: (discharge functions, feed system forward/reverse, yoke up/down, throttle, and engine kill switch). (Only standard on non cab and loader units)	\$ 0.00
1	STANDARD	270 degree hydraulic swivel discharge with hydraulic up/down chip deflector (Features a high angle discharge radius) - discharge can be raised / lowered with manual side crank	\$ 0.00
1	STANDARD	Clean out and inspection door on discharge bottom	\$ 0.00
1	STANDARD	Bandit 5 year "GUTS" warranty Warranty Includes: Bandit slide box feed system, including all fabricated components related to this system. Bandit disc/drum assembly, including all fabricated components related to the disc/drum. *Limitations and exclusions may apply. Please speak with your Bandit representative for additional details. Warranty is not transferable.	\$ 0.00
1	STANDARD	Hydraulic tongue jack	\$ 0.00
1	STANDARD	Clean out trap door located underneath bottom feed wheel	\$ 0.00
1	STANDARD	10,000# heavy duty hand crank jack with spring return pad	\$ 0.00

1	STANDARD	Banded chipper drive belts (adjustable via a sliding engine system)		\$ 0.00
1	STANDARD	Spanish & English combination safety decals		\$ 0.00
1	STANDARD	12 volt system with rubber mounted LED taillights, 6 prong replaceable coiled power cord & protected heavy-duty wiring with junction box, and LED clearance lights with reflectors.		\$ 0.00
1	STANDARD	(1) weatherproof machine manual (includes safety, operation and parts sections) also (1) engine and clutch manual is included if applicable		\$ 0.00
1	STANDARD	Engine disable plug for hood locking pin-preventing engine from operating without pin in place		\$ 0.00
1	STANDARD	10 pound fire extinguisher		\$ 0.00
1	STANDARD	Bandit control panel (Includes reversing auto feed with panel to display engine gauges, fuel level and engine hours)		\$ 0.00
0	STANDARD	Loader not included		\$ 0.00

PAINT

Qty	Part #	Description	Unit Price	Total
1	333-32273	Standard Imron Industrial Urethane Bandit Yellow Specified: Black	\$ 0.00	\$ 0.00

CAB/LOADER

Qty	Part #	Description	Unit Price	Total
1	OPTION-920-5000-33	Kesla 500 Series Loader controlled via radio remote control (Towable units includes: hydraulic oil cooler, 60 gallon hydraulic tank, dual rear hydraulic stabilizers and storage grapple barrel located on tongue. HD infeed with solid infeed tray is also included).	\$ 71285.00	\$ 71285.00

ENGINE

Qty	Part #	Description	Unit Price	Total
1	990-RC1393-974	Cummins QSL9, 350 horsepower engine without clutch- Tier 4 FINAL (Includes 2 year / 2,000 hour engine warranty)	\$ 69535.00	\$ 69535.00

CONTROL SYSTEM AND ENGINE INSTALLATION

Qty	Part #	Description	Unit Price	Total
1	937-6000-67	Bandit control panel with reversing auto feed for Cummins 350 horsepower diesel engines (Includes 1,400 CCA battery with battery box) - Track or Loader Machine	\$ 8350.00	\$ 8350.00

CLUTCH

Qty	Part #	Description	Unit Price	Total
1	937-1016-27	NACD 14T over center clutch for Cummins engine	\$ 3250.00	\$ 3250.00

FEED SYSTEM

Qty	Part #	Description	Unit Price	Total
1	OPTION-920-5000-	Hydraulic Flow Controls	\$ 925.00	\$ 925.00

AXLE

Qty	Part #	Description	Unit Price	Total
1	990-100712	Tandem 12,000 pound spring axles with electric brakes	\$ 1275.00	\$ 1275.00

TIRES/RIMS

Qty	Part #	Description	Unit Price	Total
1	990-100731	(4) 235/75R 17.5" tires mounted on HD gray rims (Tandem 8,000 pound axles on up)	\$ 0.00	\$ 0.00

FENDER

Qty	Part #	Description	Unit Price	Total
1	STANDARD-937-5	Tandem axle steel fenders	\$ 0.00	\$ 0.00

HITCH

Qty	Part #	Description	Unit Price	Total
1	990-100931	3" pintle hitch with safety chains, slip hooks, and 7 prong replaceable coiled power cord (Includes grapple barrel on whole tree chipper models)	\$ 0.00	\$ 0.00

ADD-ON OPTIONS

Chipper Discharge Transition

Qty	Part #	Description	Unit Price	Total
1	OPTION-937-0501-	Clean out and inspection door on transition	\$ 175.00	\$ 175.00

Extended Warranties

Qty	Part #	Description	Unit Price	Total
1	900-9950-10	5 year / 6,000 hour Warranty (QSL9 Cummins Engines) - Parts and labor coverage only	\$ 4075.00	\$ 4075.00

Fuel And Hydraulic Tanks

Qty	Part #	Description	Unit Price	Total
1	OPTION-920-5000-32	80 gallon steel fuel tank with magnetic drain plug, lockable filler cap, and aluminum sight gauge	\$ 375.00	\$ 375.00

DIRECT SALE TOTALS

Total Unit Price:	\$ 280690.00
Factory Direct Discount :	- \$ 54570.00
Freight/Shipping Charges:	\$ 1300.00
Total Direct Sale Price:	\$ 227420.00

COMMENTS

Billing Note

By Ed Dodak on 05/07/2021 08:16 PM

Bandit 1 Year Warranty

SIGNATURE

The Buyer, whose name and address appears above, agrees to purchase from the Seller, whose name and address appears above, the above equipment at the prices stated and upon the terms and conditions of this agreement.

X

Signature

Date

Appendix F. Safety Training Agenda

ODOT Customized Draft Agenda

Agenda times and order are subject to change

Day 1: Electrical Safety

Classroom Instruction with Materials and Audio Visuals

- 7:30 am Introductions and Course Overview
- 8:00 am Morning Stretches and Close Call Discussion
- 8:15 am Industry Safety Statistics
Who's Getting Hurt?
How Are They Getting Hurt?
Incident Video Analysis
- 9:00 am Electrical Safety Regulations: ANSI Z133
Electrical Hazards (Section 4)
Direct Contact, Indirect Contact, and Step Potential
Minimum Approach Distance
Dielectric tool inspection, testing and care
DIG: De-energize, Isolate, Ground
- 10:00 What is Electricity?
Understanding Electricity on a Molecular Level
How magnets produce electricity
Simple Circuits
How Electricity is Measured: Amps, Volts, Ohms
- 11:00 am Morning Q & A Session
- 11:30 am **LUNCH**
- 12:30 Dam to Doorbell
How electricity is generated, transmitted, and distributed
How to Recognize an Electrical Hazard: common electrical hardware
- 1:15 pm The effects of electricity on the Human Body
Video: Tim's Story
Resistance Burns!
- ##### Field Instruction and Demonstration and Participation
- 1:30 pm Emergency Response
With and without Electrical Hazard
How to perform an Aerial Rescue (Z133 Annex F)
Don't Become a second Victim
Self-Rescue from energized equipment
- 2:15 pm Student Rescue Practice and evaluations
- 3:15 pm Electrical Hazard Testing
(50 question MC/TF)
- 4:00 pm Afternoon Q & A Session
- 4:30 pm End of Day 1

ODOT Customized Draft Agenda

Agenda times and order are subject to change

Day 2: Pruning & Felling

Field Instruction and Demonstration and Participation

- 7:30 am Stretching and Review of Day 1
- 7:45 am General Safety Requirements (Z133-Section 3)
Emergency Response
Job Briefings
3-way Communication
PPE
- 8:15 am Tree Pruning Principles
Pruning with a purpose (thinning, deadwood, clearance, etc.)
Where to make the cut and how will the tree respond (CODIT)
Pruning Tools (conductive vs insulated)
- 9:00 am Chainsaw Use and Maintenance (Requires a chainsaw, chain, and files)
Z133 Requirements (Section 6.3)
Preventing Kickback
Review Safe Operating Procedures
Matching the bar and chain (pitch vs gauge)
Sharpening and Tensioning the Saw Chain
- 9:45 am The 5 Step Felling Plan (requires at least one tree to fell)
1) Assessment and Site Analysis (will it fit?)
2) Determining the Lean (forward, backward, side)
3) Planning the Escape Route
4) Setting up the Hinge using a Notch
5) Back Cut/ Bore Cut and Trigger
- 10:30 am Removing Limbs and Bucking Logs (felled tree)
Understanding Tension and Compression Wood
- 11:00 am Morning Q & A Session
- 11:30 am Lunch
- 12:30 pm Students Notch and Bore Cut practice/ evaluation
- 2:00 pm How to install tag lines and create mechanical advantage
Throwball use
Knots (Running Bowline, Butterfly, Bowline on a bight, prussik)
Fiddle Blocks, Pulleys, and Port-a-wraps
- 3:00 pm Team Felling Assessment (requires multiple trees to fell)
Crew members will break into teams and perform an inspection, install tag lines, and fell their assigned tree using practices discussed throughout the day.
- 4:00 pm Afternoon Q & A Session
- 4:30 pm End of Day 2

ODOT Customized Draft Agenda

Agenda times and order are subject to change

Day 3: Rigging/Cleanup

Field Instruction with Demonstration and Participation (*aerial lift and chipper required*)

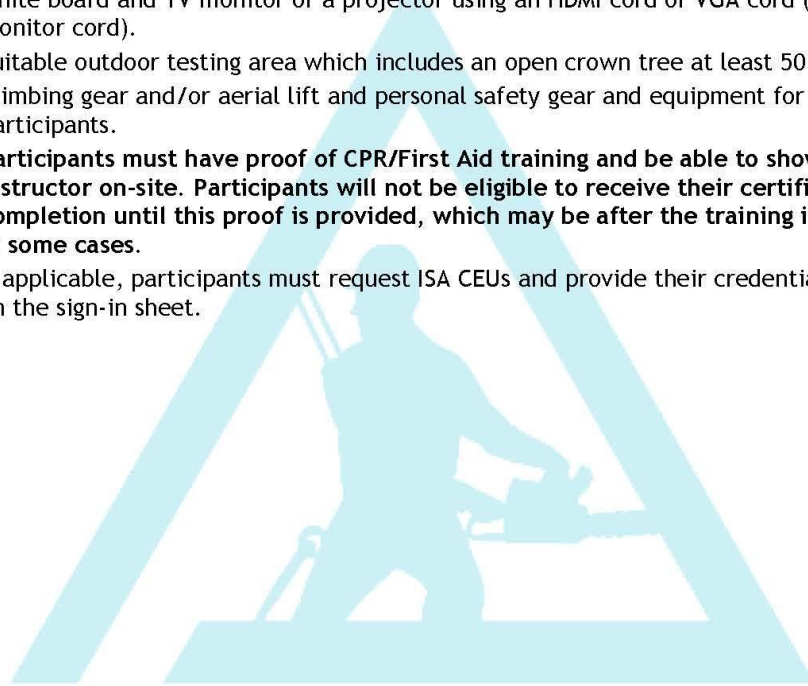
- 7:30 am Stretching and Review of Day 2
- 7:45 am Site Assessment, & Job Briefing
- 8:00 am How to perform a daily aerial lift and chipper inspection
- 9:00 am Rigging Related Work Practices
 - Establishing a drop zone and debris staging area
 - Three-way communication
 - Emergency Contingency Plan
 - Work Positioning and escape routes
 - Housekeeping and rope management
- 9:30 am Understanding Forces in Rigging
 - Doubling Effect and Mechanical Advantage
 - Static vs Dynamic Forces
 - Workload Limit, Breaking Strength, and Cycles to Failure
 - Green Log Weight Chart
- 10:00 am Rigging without hardware (minimalist approach)
 - Rope Selection, knots, and friction control
 - What can I do with one (1) rope? (butt hitch, tip tie, speed line)
 - What can I do with two (2) ropes? (zip line, load transfer, spider rigging)
- 11:00 am Morning Q & A Session
- 11:30 am **Lunch**
- 12:30 pm Building Rigging Systems
 - Positive Rigging (rigging point above the load)
 - Negative Rigging (rigging point below the load)
 - Utilizing mechanical advantage and progress capture
 - Floating anchor points
 - Setting systems from the ground
 - Simple vs Complex Designs
- 1:30 pm Team rigging assessment
 - Crew members will break into teams to discuss their rigging plan and the equipment needed to achieve plan, then execute plan.
- 3:15 pm Safe chipper operation
 - Z133 requirements (section 8.7)
 - Chipper wench precautions and best practices
 - Site Clean - up
- 4:00 Afternoon Q & A Session
- 4:30 End of Day 3

ODOT Customized Draft Agenda

Agenda times and order are subject to change

The host is asked to supply the following:

- Classroom space to seat all participants comfortably and allow them to see and hear without obstruction. Table seating is best. The classroom should contain a chalk or white board and TV monitor or a projector using an HDMI cord or VGA cord (blue PC monitor cord).
- Suitable outdoor testing area which includes an open crown tree at least 50' tall.
- Climbing gear and/or aerial lift and personal safety gear and equipment for the participants.
- **Participants must have proof of CPR/First Aid training and be able to show the instructor on-site. Participants will not be eligible to receive their certificate of completion until this proof is provided, which may be after the training in question in some cases.**
- If applicable, participants must request ISA CEUs and provide their credential number on the sign-in sheet.



ACRT
ARBORIST TRAINING

Appendix G. Site Assessment Form

Intended User: Work Planner, Tree Foreman

This document is intended to be used by the work planner as a quick reference when inspecting a site to aid in ensuring a more complete and thorough assessment. It is useful as a checklist in gathering information for a baseline that, in conjunction with the decision tree, will guide the planning of what equipment, job setup configuration and by what process a given tree or trees in the right-of-way (ROW) ought to be removed. Standards of safety and efficiency have been key parameters considered in establishing the work plan for this job. This document, when complete, is to be passed along to the tree foreman intended to execute the work.

Work Planner Name:

Date:

Location:

Ex. mm, direction, cross street

Number of Lanes _____

Speed limit _____Mph

MOT Needed:

Scope of Work:

Workload Volume/Estimated Crew Hours on Site:

Equipment Needed:

Ex. bucket truck, chipper

Additional Equipment and Tools required:

Ex. mobile traffic lights, cribbing, mud mats, extra ropes

Obstacles identified:

Utility Lines Mailbox Fence Driveway House Guard Rail
 Soundwall

Road Signs Nearby Construction

Other: _____

Hazards identified:

Wire fencing Barbed wire Bee nest Rocks

Poisonous Plants (ivy, giant hogweed) Trash Uneven ground

Other: _____

Plan to manage exposure to hazards:

Emergency Response: 911

Nearest Hospital Address and Phone:

Ground Conditions:

Slope Aspect: _____

Snow/Ice Standing Water Gravel Concrete/Asphalt
 Soft Shoulder

Percent Slope: <10 10-25 25-50 50-75 75-100 >100

How to Estimate: Percent slope is determined by estimating the change in elevation vertically and dividing that by the linear distance that the change in elevation occurs. For example, a slope that has 8 feet of rise over 16 feet of run would yield $8/16=0.50$ or 50 percent slope; 8 feet of rise over 8 feet of run is $8/8=1$ or 100 percent slope.

Surrounding Environment:

Short vegetation (<12in) Tall vegetation Dead vegetation Wet Ditch
 Dense Saplings (< 4in) Shrub/Pines Pole Timber Mature timber
 Vines

Tree Conditions:

Decay (woodpecker, fungi, rot)

Level: 1 2 3 4 5 6 (circle all that apply)

1: Tree is declining (leaves still present) 2: Recently died (no leaves but fine twigs present)

3: Fine twigs missing/losing strips of bark 4: Branches missing; most of bark gone

5: Few branches; no bark 6: Significant softened wood in trunk

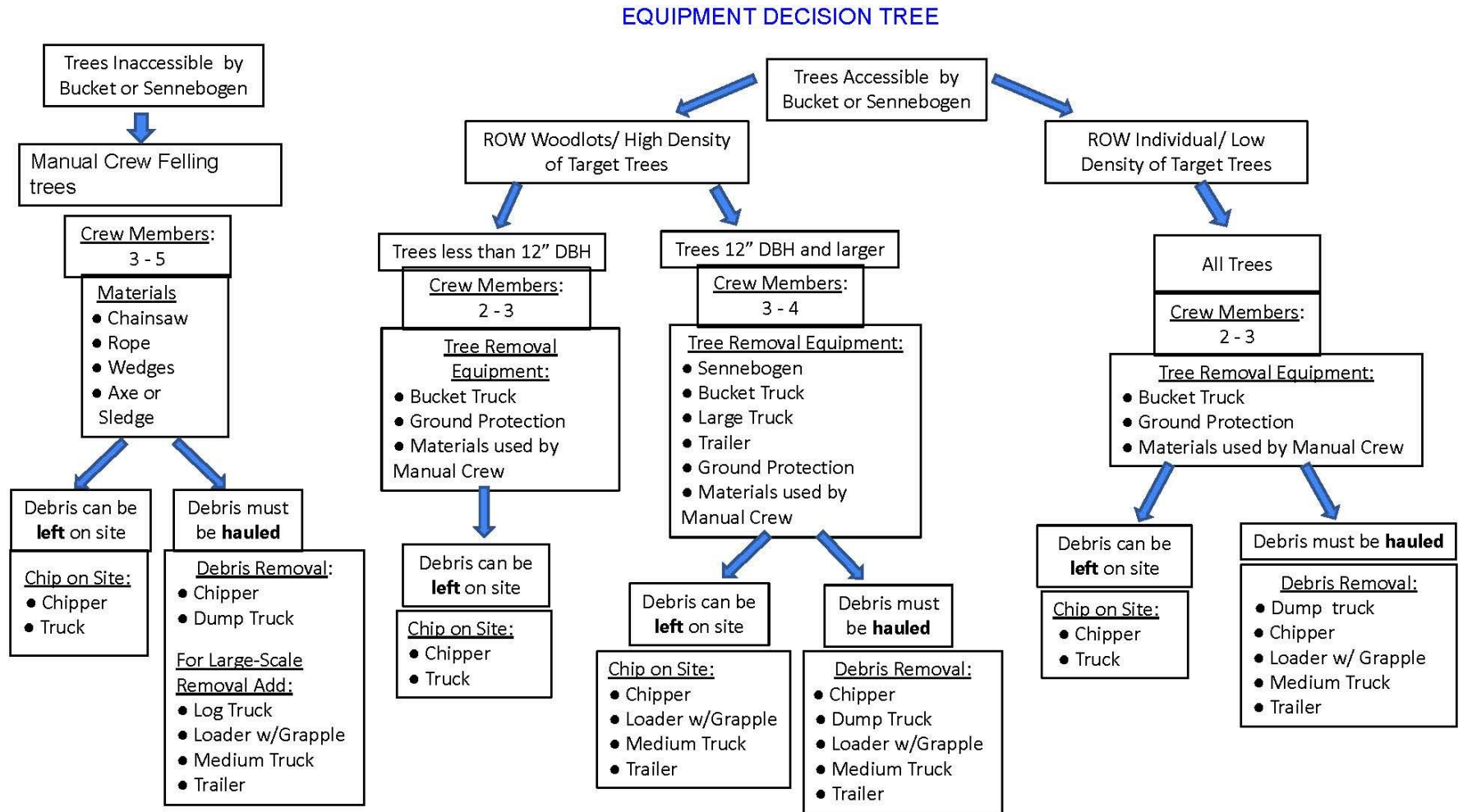
Hollow Cavity Hollow Tree Dead Large Limbs Broken Limbs

_____ Tree DBH (single tree or average of trees) _____ Tree Height

_____ Distance from Edge of Road

Draw a Sketch:

Appendix H. Equipment Decision Tree



Appendix I: Phase II Field Test Setup and Site Details

November 2021 field test

Overview

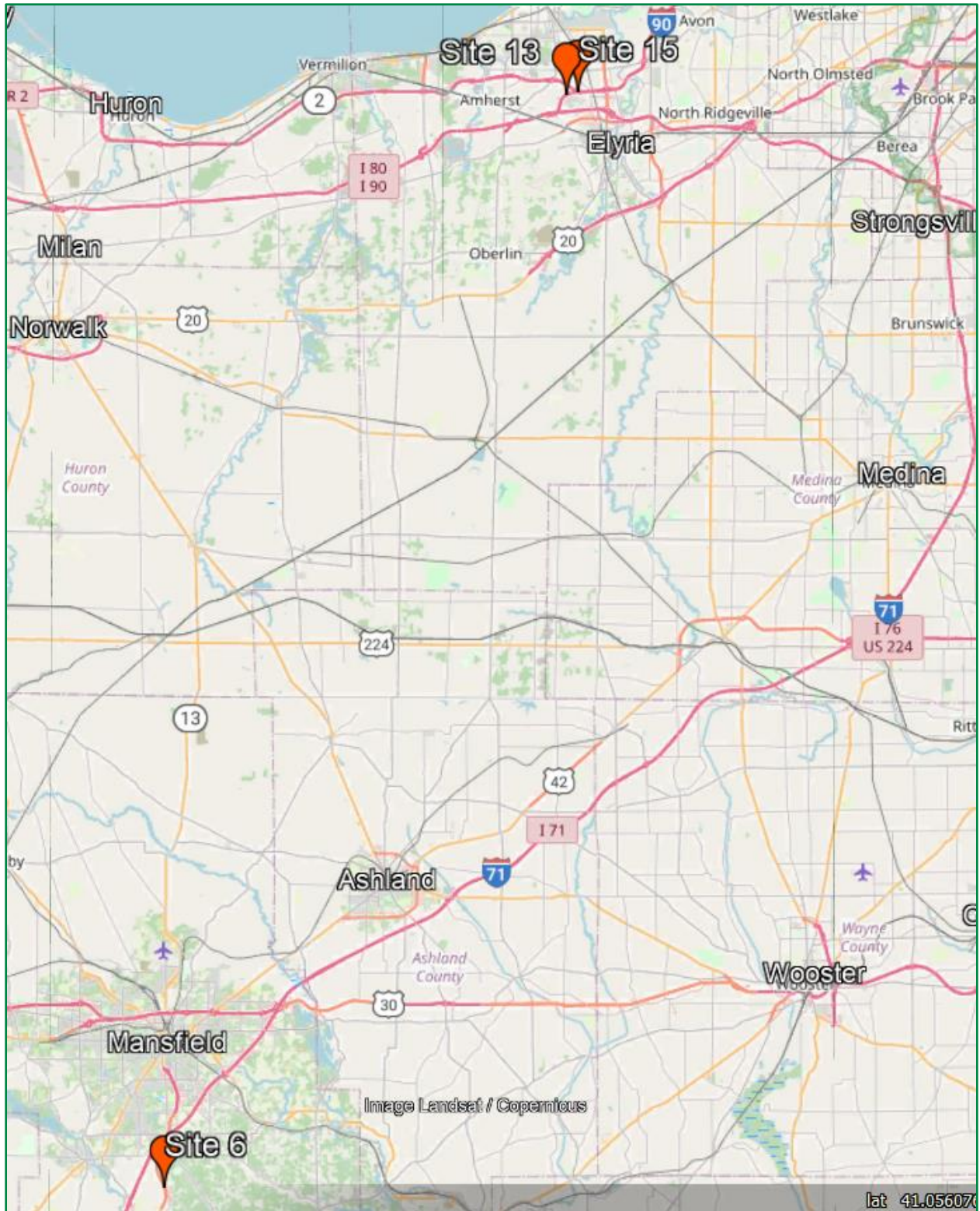
DRG observed dead tree removal and debris handling procedures of three crews across three sites in Richland and Lorain counties on November 4th-6th, 2021. Each day, two crews were observed removing trees along adjoining linear plots (see “Plot and test details” below). The sites were set up for each crew to have the same volume of biomass. The three crews were originally planned to represent three different treatments based on equipment setup and training levels of workers:

- Proposed Treatment 1 - A “Control” crew out of the Richland County garage consisting of five crew members, which utilized ODOT’s current tree removal equipment combination - an Altec LR760-E70 Bucket Truck for tree cutting and removal, Morbark Beaver M14R brush chipper used in conjunction with a ground crew handling debris, and a dump truck to remove the chips as needed for the site.
- Proposed Treatment 2 - A “Trained bucket” crew out of the Lorain County garage consisting of three crew members, which utilized the same equipment as the “Control crew” but were planned to attend the third-party safety training and the DRG efficiency workshop.
- Proposed Treatment 3 - A “Sennebogen” crew which was made up of experienced bucket truck operators selected to be part of a dedicated crew to operate the Sennebogen 718E and would ultimately run the Rotobec 4042HD grapple and Bandit 2090 whole tree chipper when they arrived.

However, due to equipment procurement difficulties and logistical issues in setting up training workshops during Covid 19, Proposed Treatments 1 and 2 were identical in terms of equipment and training levels. Treatment group 3 utilized a Sennebogen 718E, but in conjunction with the original Morbark Beaver M14R brush chipper and dump truck setup. Additionally, crew sizes differed from what was originally proposed (see “Plot details” below).

Plot Details

Overview Map of Fall Testing Locations



Day 1: Thursday, 4 November 2021

“CONTROL” (BUCKET TRUCK 1) CREW = RICHLAND CREW

- Site 6, Richland County, Belville, SR-13 (S-bound), **Plot 1**
- Proposed Crew Size = 5; Actual Crew Size = 5

- Starting Point
 - 40.660246°, -82.514327°
 - State MM: 111
 - County MM: 8.31
- Ending Point
 - 40.658983°, -82.513870°
 - State MM: 110.91
 - County MM: 8.22
- Plot Length: 482 ft.
- Tree Count: 31
- Biomass: 10883.5
- Slope from Road= -32°
- Max Distance from Road: 32 ft.
- Known Obstacles: Guardrail, & Large Sinkhole with Pipe



“TRAINED” (BUCKET TRUCK 2) CREW = LORAIN CREW

- Site 6, Richland County, Belville, SR-13 (S-bound), **Plot 2**
- Proposed Crew Size = 3; Actual Crew Size = 4

- Starting Point
 - 40.658938°, -82.513860°
 - State MM: 110.91
 - County MM: 8.22
- Ending Point
 - 40.658526°, -82.513725°
 - State MM: 110.88
 - County MM: 8.19
- Plot Length: 153 ft.
- Tree Count: 20
- Biomass: 2684.15
- Max Distance from Road: 32 ft.
- Known Obstacles: Guardrail, & Large Sinkhole with Pipe

- Site 6, Richland County, Belville, SR-13 (N-bound), **Plot 3**
- Proposed Crew Size = 3; Actual Crew Size = 4

- Starting Point
 - 40.648823°, -82.514618°
 - State MM: 110.19
 - County MM: 7.5
- Ending Point
 - 40.652035°, -82.512946°
 - State MM: 110.43
 - County MM: 7.74
- Plot Length: 1,256 ft., Slope = -32°
- Tree Count: 25
- Combined Biomass w/ Plot 2: 9446
- Slope from Road= -32°
- Max Distance from Road: 32 ft.
- Known Obstacles: Guardrail & Gas Line Marker



Day 2, Friday, 5 November 2021

“CONTROL” (BUCKET TRUCK 1) CREW = RICHLAND CREW

-Site 13, Lorain County, Elyria, 1-90 (W-bound), **Plot 4**

- Proposed crew size = 5; Actual crew size = 5

- Starting Point:
 - 41.401991° , -82.152540°
 - State MM: 143.85
 - County MM: 11.34
- Ending Point
 - 41.400415° , -82.155931°
 - State MM: 143.66
 - County MM: 11.15
- Plot Length: 1087 ft.
- Tree Count: 24
- Biomass: 14571.5
- Slope from Road= -10°
- Max Distance from Road: 42ft.

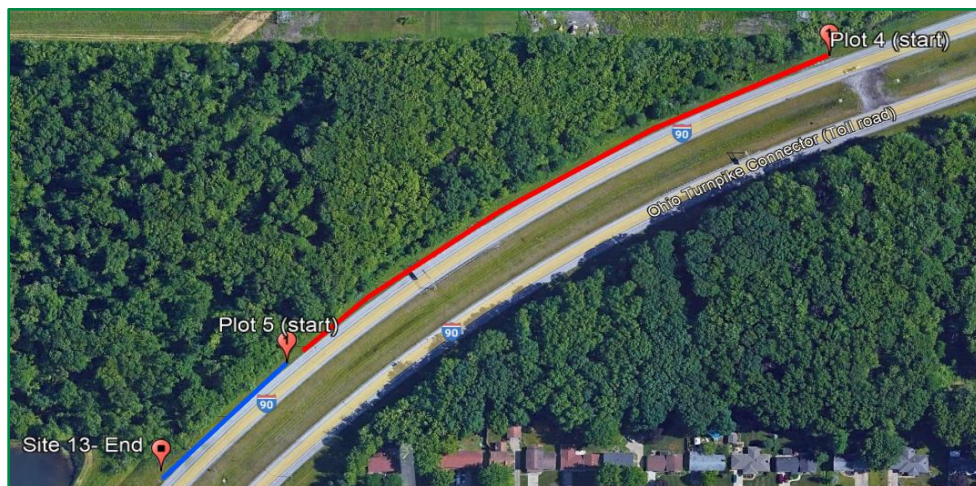
Known Obstacles: Guardrail, Concrete Barrier, & Light Post

SENNEBOGEN CREW out of Lorain Garage

- Site 13, Lorain County, Elyria, 1-90 (W-bound), **Plot 5**

- Proposed Crew Size = 3; Actual Crew Size = 6

- Starting Point
 - 41.400366° , -82.156001°
 - State MM: 143.66
 - County MM: 11.15
- Ending Point
 - 41.399770° , -82.156816°
 - State MM: 143.6
 - County MM: 11.09
- Plot Length: 312 ft.
- Tree Count: 61
- Biomass: 17444.7
- Slope from Road= -10°
- Max Distance from Road: 42
- Known Obstacles: Guardrail, Concrete Barrier, & Light Post



Day 3, Saturday, 6 November 2021

SENNEBOGEN CREW out of Lorain Garage

- Site 15, Lorain County, Elyria, SR-2/ I-90 (E-bound) **Plot 6**

- Proposed Crew Size = 3; Actual Crew Size = 4

- Starting Point
 - 41.403506°, -82.143149°
 - State MM: 167.85
 - County MM: 11.01
- Ending Point
 - 41.40321°, -82.141498°
 - State MM: 144.0
 - County MM: 11.09
- Plot Length: 448 ft.
- Tree Count: 28
- Biomass: 17377.05
- Slope from Road= -5°
- Max Distance from Road: 60
- Known Obstacles: None

“TRAINED” (BUCKET TRUCK 2) CREW- LORAIN CREW

- Site 15, Lorain County, Elyria, SR-2/I-90 (E-bound) **Plot 7**

- Proposed Crew Size = 3; Actual Crew Size = 4

- Starting Point
 - 41.40321°, -82.141498°
 - State MM: 144.0
 - County MM: 11.09
- Ending Point
 - 41.403272°, -82.140466°
 - State MM: 144.8
 - County MM: 11.97
- Plot Length: 300 ft.
- Tree Count: 31
- Biomass: 11010.35
- Slope from Road= -5°
- Max Distance from Road: 60
- Known Obstacles: None



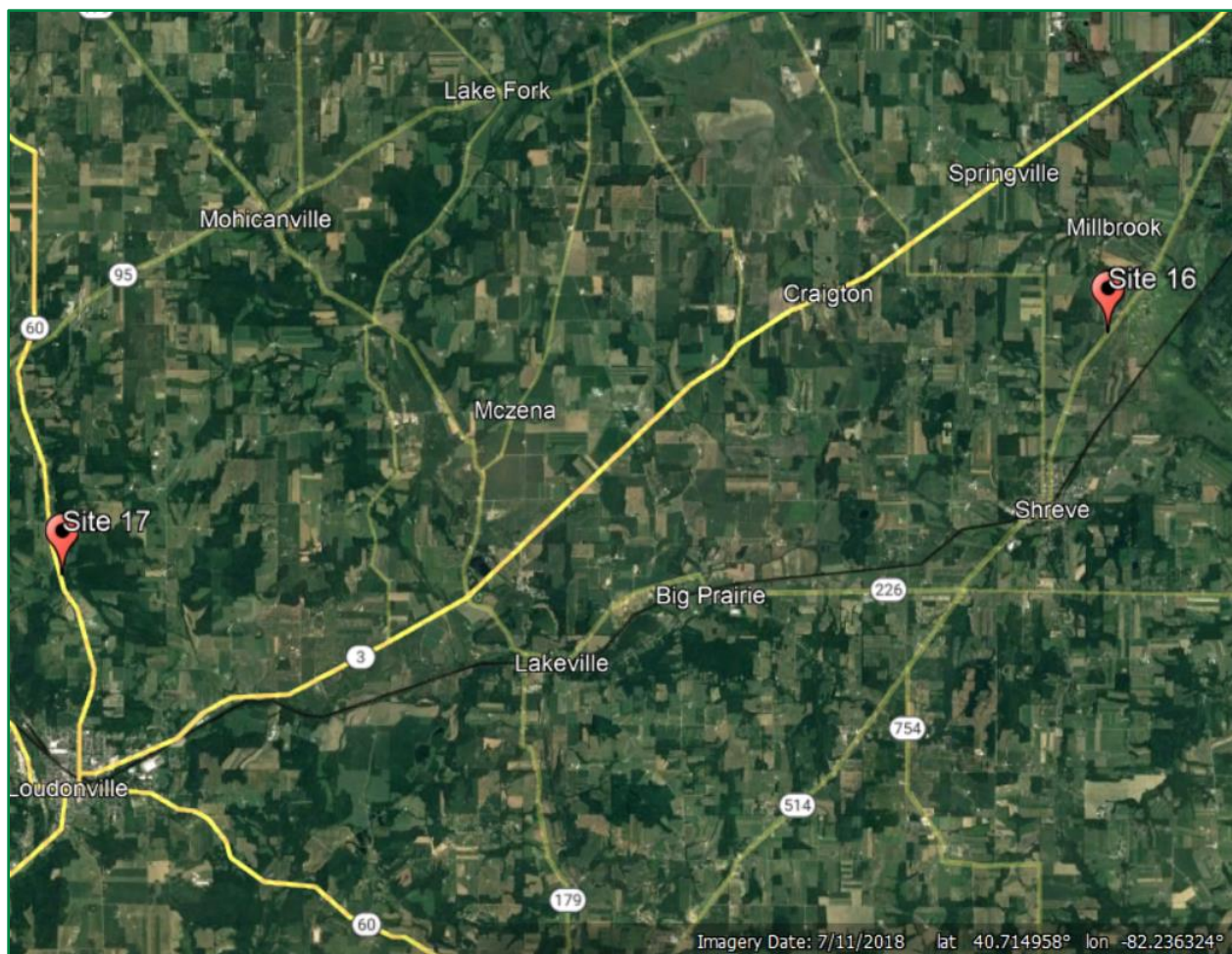
July and August 2022 Observations and Field Test

Overview

After a tornado damaged and felled trees, DRG observed hazard tree removal and debris handling procedures of the Sennebogen 718E out of the Wayne and Ashland County ODOT garages across two sites in Wayne and Ashland counties on July 6th, 7th and August 11th, 2022. The Sennebogen 718E was on-site during all three dates, but the Bandit 2090 whole tree chipper with Kelsa loader was only on-site on July 6 and August 11 due to being jammed early in the day on July 6. The Rotobec 4042HD grapple was not used at either site but was in use clearing tree debris in another area affected by the storm. At site 16, due to the large volume of debris leaving a hazardous condition at an active work site, the material was not able to be inventoried. Due to the chipper being jammed on July 6th and 7th, DRG staff did not collect tree removal counts and only gathered observational data from crew observations and interviews to assess overall changes to work safety and efficiency. Tree removal/process data was able to be collected on August 11th at Site 17 as the chipper was operational.

Plot Details

Overview Map of Summer Testing Locations



Day 1-2: Wednesday & Thursday, 6-7 July 2022

SENNEBOGEN 718 CREW = WAYNE CREW

-Site 16, Wayne County, Shreve, SR-226 (S-bound), **Plot 1**

- Proposed Crew Size = 3, Actual Crew Size = 4

- Starting Point
 - 40.711051°, -82.009395°
 - State MM: 9
 - County MM: 4
- Ending Point
 - 40.709744°, -82.010730°
 - State MM: 9
 - County MM: 4
- Plot Length: 600 ft.
- Max Distance from Road: 30 ft.
- Known Obstacles: Ditch
- Notes
 - Clean up from a summer storm
 - Various species of trees
 - Was not able to get DBH and accurate count of trees due to the large volume of debris and downed trees



Day 3: Thursday, 11 August 2022

SENNEBOGEN 718 CREW = ASHLAND CREW

-Site 17, Wayne County, Loudonville, SR-60 (N-bound), **Plot 1**

- Proposed Crew Size = 3; Actual Crew Size = 4

- Starting Point
 - 40.669598°, -82.234484°
 - State MM: 3
- Ending Point
 - 40.670625°, -82.234677°
 - State MM: 3
- Plot Length: 380 ft.
- Max Distance from Road: 40 ft.
- Known Obstacles: Ditch, culverts, memorial
- Notes
 - Clean up from a summer storm
 - Various species of deciduous trees



Appendix J: Phase II Data Analysis Methodology

November 2021 Field Test Comparisons

DRG compared the productivity and costs across treatment groups for the November 2021 observations, the August 2022 Sennebogen 718E observation, and a contractor observation (VanCuren Services, Inc.). Different metrics were used to represent productivity or cost based upon available data for each data collection event and/or source. To compare productivity across treatment groups for the November 2021 field tests, DRG compared removal and process rates of tree biomass. Removal rates account for trees that were cut down, whereas process rates include trees that were both taken down and chipped or processed in some other fashion. Since biomass data was available for all plots during November 2021 field tests, this was utilized to measure productivity rather than just trees removed because it accounts for differences in effort needed to remove trees of varying sizes. Additionally, hours of on-site work were included in the denominator because the amount of time each crew was on-site removing trees varied.

Biomass was calculated as:

$$\text{Biomass (ft}^3 \text{ of tree material)} = \Sigma(\text{Tree height} * \text{DBH})$$

DRG calculated removal and process rates of each crew as:

$$\text{Removal rate} = \frac{\text{Biomass (ft}^3 \text{ of tree material) removed}}{\text{hours of on – site work}}$$

$$\text{Process rate} = \frac{\text{Biomass (ft}^3 \text{ of tree material) processed}}{\text{hours of on – site work}}$$

To compare costs, DRG first calculated the total on-site labor cost of active crew members (crews which were on-site for the duration of the work and contributed to the tree removal). Including only active employee hours also removed some error that could have been associated with including employees on-site that either did not contribute to the work or were on-site for only part of the tree clearing work. Since the amount of time each crew was on-site varied, DRG converted each cost to an efficiency metric by dividing the total on-site labor costs by the total biomass removed during the workday to make these costs more comparable across treatments. Following this comparison, daily equipment costs were then added to the labor cost to get a total cost for the day's work. DRG calculated the cost efficiencies for each crew as:

$$\text{Cost Efficiency (Labor only)} = \frac{\text{On – site Labor Cost}}{\text{ft}^3 \text{ Biomass removed}}$$

$$\text{Cost Efficiency (Labor and Equipment)} = \frac{\text{Total Cost}}{\text{ft}^3 \text{ Biomass removed}}$$

For all November 2021 comparisons of productivity and cost efficiency, DRG tested whether statistically significant differences existed among treatment groups utilizing one-way analysis of variance (ANOVA) in R. If differences existed, pairwise differences between each treatment group were tested utilizing Tukey's honest significant difference (Tukey HSD) test in R. For a breakdown of equipment costs used in this analysis and others, see Table 2 in Appendix L.

August 2022 Field Data Comparisons

Potential increases in productivity and or cost efficiency since November 2021 were explored by comparing process rates, removal rates, and costs for the August 2022 observation to the mean values for each November 2021 treatment group. Since many of the trees processed during the August 2022 Sennebogen 718E observation had fallen from the storm or were felled before DRG was on-site, process rates were compared in the first analysis rather than removal rates (Figure 12). Process rates were calculated in the same fashion as the November 2021 field tests. Similarly, to productivity, cost efficiency was calculated utilizing the same formulas above, but with process rates used instead of removal rates, again due to the lack of removal data for the August 2022 observation.

As an alternative productivity comparison, removal rate (as trees removed per day) for all November 2021 and August 2022 observations were also compared (Figure 13). As mentioned, many trees were felled before DRG was on-site for the August 2022 Sennebogen 718E observation. Given the observed speed of the cutting mechanism of the Sennebogen (2-3 cuts to take down larger trees), DRG assumed that all trees processed could have theoretically been removed during the time DRG was on-site. Note that since the August 2022 Sennebogen 718E data is only from a single observation (i.e., sample size = 1), those values were not included in any statistical analysis. Instead, the relative percent differences between November 2021 mean values and the August 2022 values were calculated for comparison.

Gap Analysis

DRG compared the productivity (trees removed/day) of an experienced contractor crew operating a Sennebogen 718E (VanCuren Services, Inc.) to that of an experienced bucket truck crew (Davey Tree, Inc.) using a brush chipper. The increase in productivity experienced by the trained Sennebogen contractor crew was compared to the increase in productivity experienced by the August 2022 ODOT crew utilizing a Sennebogen 718E and Bandit 2090 whole tree chipper. The percent increases in productivity were calculated as follows:

$$\% \text{Productivity increase (ODOT)} = \frac{\text{Trees removed/day (Sennebogen crew)} - \text{Trees removed/day (bucket crew)}}{\text{Trees removed/day (bucket crew)}} \times 100$$

$$\% \text{Productivity increase (contractor)} = \frac{\text{Trees removed/day (Sennebogen crew)} - \text{Trees removed/day (bucket crew)}}{\text{Trees removed/day (bucket crew)}} \times 100$$

The cost efficiency of ODOT crews across all observations was also compared to estimated cost efficiency of hiring a contractor (VanCuren Services, Inc.). Given that height and DBH measurements were not available for contractor observations to calculate biomass, DRG estimated cost efficiency for all ODOT crews based upon the count of trees removed. Since the contractor cost estimates assume 8-hour workdays for all employees, ODOT costs were also estimated assuming 8-hour workdays for this comparison. As such, cost efficiency for all ODOT observations and the contractor observations were calculated as follows:

$$\text{Cost Efficiency (Labor and Equipment)} = \frac{\text{Total Weekly Cost}}{\text{Trees removed per week}}$$

Similarly, to the August 2022 Sennebogen 718E observations, the contractor estimates are only a single observation (i.e., sample size = 1), therefore no statistical analysis were conducted on these contractor comparisons. Instead, DRG calculated the relative percent differences between the contractor rates and ODOT rates from November 2021 and August 2022.

Return on Investment (ROI) estimates

The annual ROI is the percentage of the total cost of the new equipment that would be paid off each year from cost savings. The annual ROI for the crews operating a Sennebogen 718E were estimated based upon observed productivities and costs during November 2021 and August 2022 field observations. ROI calculations assumed that ODOT would conduct 26 weeks of tree removal work per year given the federally endangered bat cutting restrictions.

Annual ROI estimates and its components were calculated as follows:

$$\text{Cost savings per tree} = \text{Total cost/tree (bucket)} - \text{Total cost/tree (Sennebogen)}$$

$$\text{Weekly production increase} = \frac{\text{Trees removed/week (Sennebogen)} - \text{Trees removed/week (bucket)}}{\text{week (bucket)}}$$

$$\text{Annual ROI} = \frac{((\text{Cost savings per tree} * \text{Weekly production increase}) * 26)}{\text{Total cost of new equipment}} \times 100$$

Note that in calculating the cost savings and production increase components of the ROI, the total cost/tree for bucket truck crews utilized the average total cost/tree (\$32.52) and average trees removed/week (153.75) observed during November 2021 field tests, rather than the estimated Total Cost/tree given in the Phase I recommendation documents (\$26.67/tree and 150 trees/week). Total costs include both labor costs and equipment operating costs. Note that we did not have a daily equipment operating cost for the Bandit 2090 chipper used during the August 2022 Sennebogen observation, so the operating cost for the Morbark chipper was substituted in its place. Also, the “total cost of new equipment” in the ROI formula denominator only includes the total cost for the new equipment being used during the observations. For example, “total cost of new equipment” for the November 2021 ROI calculation only included the cost of the Sennebogen 718E since that was the only new piece of recommended equipment present.

Appendix K: Phase II Field Test and Gap Analysis Detailed Results

Table 1. Raw tree removal and process data from November 2021 and August 2022 field tests. Plots 2 and 3 were part of the same sample for site 6 and thus were combined for all analysis. NOTE: Removed trees for August 2022 is less than trees processed because most trees had fallen from the storm or were cut down for initial road clean up before DRG was on-site.

Date	Site	Plot	Treatment	Active Crew	Removed Count Ash	Removed Count All trees	Processed Count Ash	Processed Count All trees	Removed Biomass (ft ³) Ash	Removed Biomass (ft ³) All trees	Processed Biomass (ft ³) Ash	Processed Biomass (ft ³) All	Job Length (Hrs.: Min)
11/4/21	6	1	Bucket 1	5	28	31	16	19	9471.5	10883.5	7503.5	8915.5	5:32
11/4/21	6	2	Bucket 2	4	16	20	16	20	2425.65	2684.15	2425.65	2684.15	1:35
11/4/21	6	3	Bucket 2	4	15	15	0	0	6823	6823	0	0	2:48
11/5/21	13	4	Bucket 1	5	23	24	23	24	12471.5	14571.5	12471.5	14571.5	4:59
11/5/21	13	5	Sennebogen	6	39	61	39	61	13597.2	17444.7	13597.2	17444.7	4:52
11/6/21	15	6	Sennebogen	4	15	43	1	13	4980.8	17377.05	220	7025.5	2:51
11/6/21	15	7	Bucket 2	4	12	33	4	5	5270.65	11010.35	1711.95	2031.95	2:43
8/11/21	17	1	Sennebogen	4	2	10	2	74	800	5720	800	16740	4:59

November 2021 Field Test Crew Comparisons

Productivity

November 2021 field tests indicated that the average production rates for the crew utilizing a Sennebogen 718E were higher than the production rates for the bucket truck crews. The average biomass removal rate (tree biomass (ft³) removed/hour of total on-site work) of the crews using a Sennebogen (4840 ft³/hour; Figure 1) was 65% greater than the removal rate of the faster of the bucket crews (2940 ft³/hour; Figure 1). Similarly, process rates were also higher for the crew operating a Sennebogen, with the average biomass process rate (tree biomass (ft³) processed/hour of total on-site work) (3020 ft³/hour; Figure 2) being 33% greater than that of the faster bucket crew (2270 ft³/hour; Figure 2). There were no statistically significant differences across treatment groups.

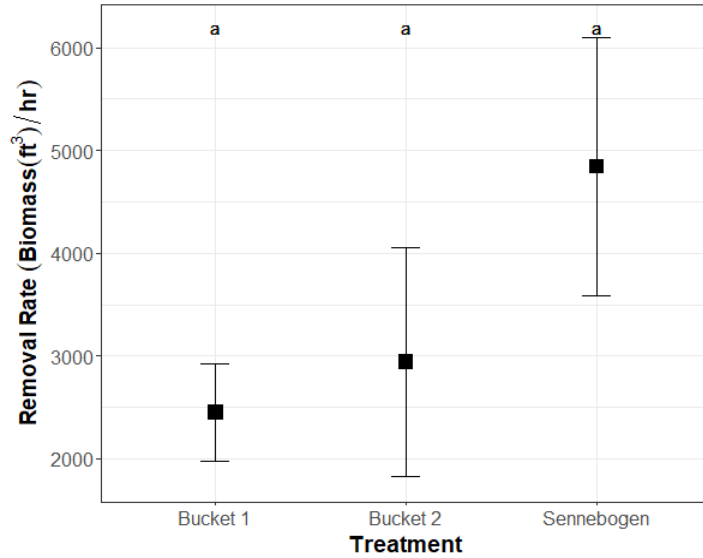


Figure 1. Average biomass removal rate (biomass (ft³) removed/hour) for each treatment group during November 2021 field tests. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p-values <0.05).

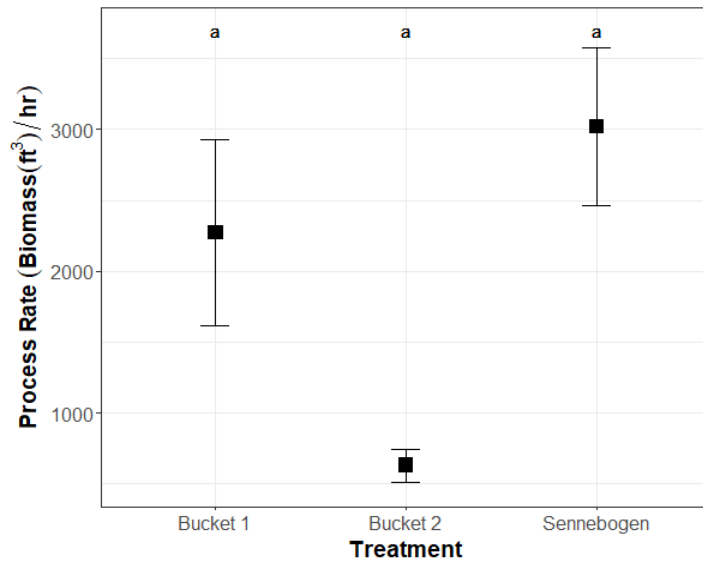


Figure 2. Average biomass process rate (biomass (ft³) processed/hour) for each treatment group during November 2021 field tests. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p-values <0.05).

Cost Efficiency

November 2021 field tests indicated that the on-site labor costs for the crew utilizing a Sennebogen 718E with a brush chipper and dump truck were less than the on-site labor costs for the bucket truck crews for each cubic ft. of biomass removed. All labor cost estimates assumed a \$20/hour rate for all employees. The average on-site labor cost/ ft³ of biomass removed for the crews operating a Sennebogen 718E (\$0.0233/ft³ of biomass removed; Figure 3) was approximately 27% lower than the average on-site labor cost/ ft³ of biomass removed for the most cost-efficient bucket truck crew (\$0.0318/ ft³ of biomass removed; Figure 3). However, when accounting for the operating cost of each piece of equipment, average total cost/ ft³ of biomass removed for the crews with a Sennebogen 718E (\$0.075/ ft³ of biomass removed; Figure 4) was 33% higher than that of the most cost-efficient bucket crew (\$0.0564/ ft³ of biomass removed; Figure 4, on the next page). There were no statistically significant differences across treatment groups.

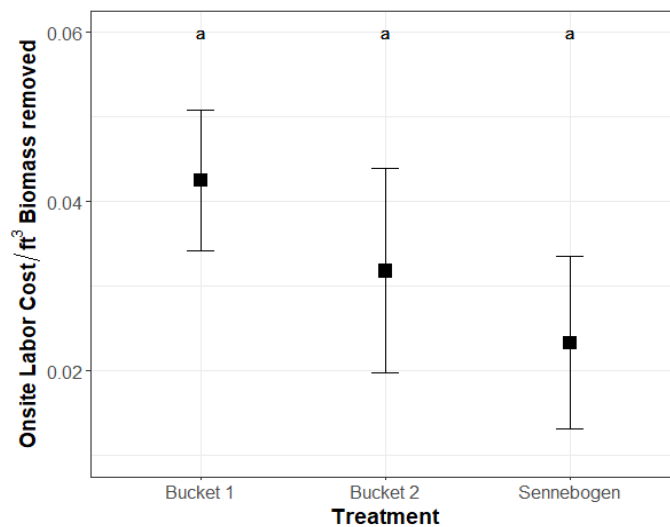


Figure 3. On-site labor cost/ ft³ of biomass removed for each treatment group during November 2021 field tests. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p-values <0.05).

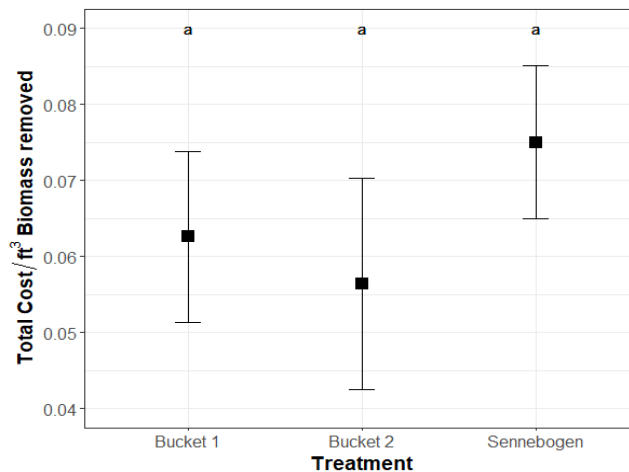


Figure 4. Total cost (on-site labor cost and equipment cost)/ ft³ of biomass removed for each treatment group during November 2021 field tests. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p-values <0.05).

August 2022 Field Test Crew Comparison

Productivity

The August 2022 field test of the crew using the Sennebogen 718E and Bandit 2090 whole tree chipper indicated that process rates (tree biomass (ft³) processed/hour of total on-site work) increased when compared to November 2021 process rates of the crew operating the Sennebogen 718E with a brush chipper and dump truck. The August 2022 crew process rate (3360 ft³/hour; Figure 5) was 11% higher than that of the average November 2021 Sennebogen 718E crew process rate (3020 ft³/hour), and 48% higher than the process rate of the faster bucket truck crew from November 2021. Removal rate of trees also increased for the August 2022 observation. The removal rate of the August 2022 crew using the Sennebogen 718E and Bandit 2090 whole tree chipper (75 trees/day) was 44% greater than the average removal rate (52 trees/day) for the November 2021 crew operating the Sennebogen 718E with a brush chipper and dump truck (Figure 6).

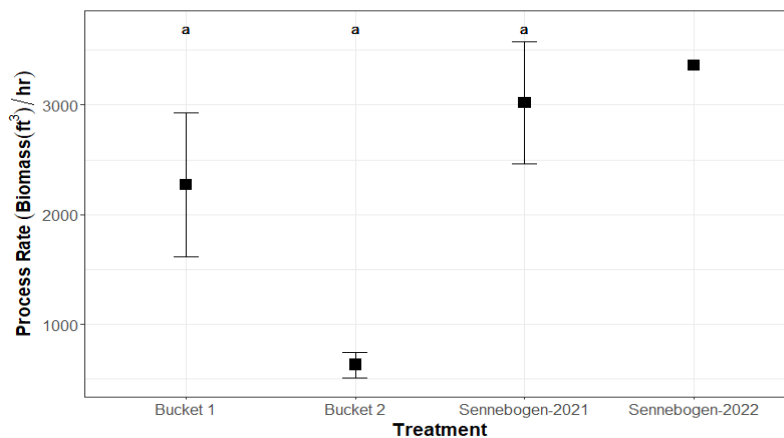


Figure 5. Average biomass process rate (biomass (ft³) processed/hour) for each treatment group during November 2021 field tests and August 2022 Sennebogen test. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p -values <0.05). NOTE: Since there is only one observation for Sennebogen-2022, there is no standard error associated with this mean and it was not included in any statistical analysis.

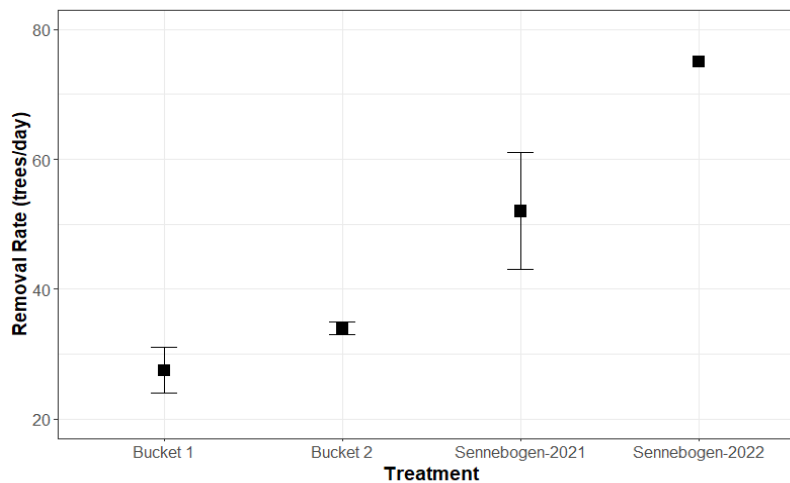


Figure 6. Average daily tree removal rate (trees/day) for November 2021 field tests and the August 2022 Sennebogen 718E observation. Error bars are standard errors around the mean values. Since sample size = 1 for the 2022 ODOT Sennebogen 718E observation, that mean does not have a standard error, therefore no statistics were run for this comparison.

Cost Efficiency

The August 2022 field test of the crew operating the Sennebogen 718E and Bandit 2090 whole tree chipper also revealed an increase in cost efficiency when compared to November 2021 tests operating a Sennebogen 718E with a brush chipper and dump truck. All labor cost estimates assumed a \$20/hour rate for all employees. The on-site labor cost/cubic feet of biomass processed for the 2022 crew (\$0.0238/ft³ biomass processed; Figure 7) was approximately 28% lower than the average on-site labor cost/ft³ of biomass removed for the 2021 crews (\$0.033/ft³ biomass processed; Figure 7). This increase in cost efficiency continues to hold true even when accounting for equipment costs. The total cost/cubic feet of biomass processed for the 2022 crew (\$0.0775/ft³ biomass processed; Figure 8) was 37% lower than the average for the 2021 crew (\$0.123/ft³ biomass processed; Figure 8).

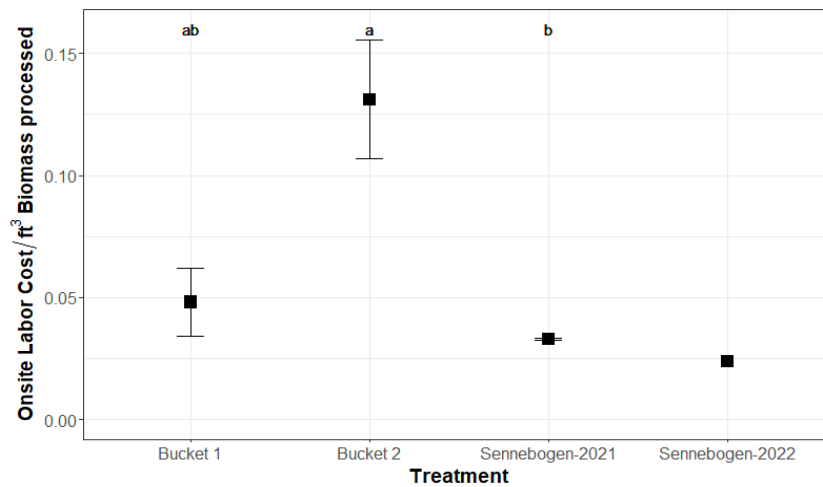


Figure 7. On-site labor cost/ft³ of biomass processed for each treatment group during November 2021 field tests and August 2022 Sennebogen 718E observation. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p-values <0.05). NOTE: Since there is only one observation for Sennebogen 718E-2022, there is no standard error associated with this mean and it was not included in any statistical analysis.

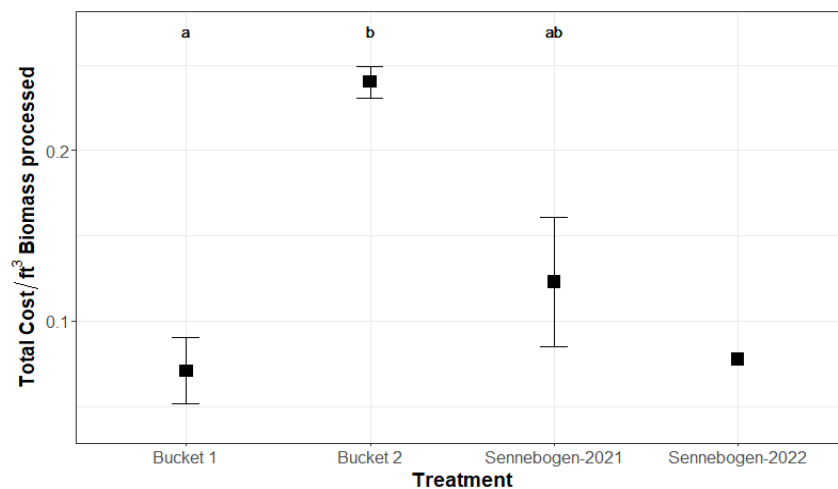


Figure 8. Total cost (on-site labor cost and equipment operating cost)/ft³ of biomass processed for each treatment group during November 2021 field tests and August 2022 Sennebogen 718E observation. Error bars are standard errors around the mean values. Different letters above each treatment group indicate statistically significant differences across groups (Tukey HSD test; p-values <0.05). NOTE: Since there is only one observation for Sennebogen 718E-2022, there is no standard error associated with this mean and it was not included in any statistical analysis.

Gap Analysis

Productivity

When comparing an experienced Sennebogen 718E crew (VanCuren Service, Inc.) to that of an experienced bucket truck crew (Davey Tree, Inc.), the experienced Sennebogen crew's productivity (trees removed/day) was 114% higher than that of the experienced bucket truck crew (Figure 9). In making this same comparison for the ODOT crews, the August 2022 ODOT crew utilizing a Sennebogen 718E and whole tree chipper was 118% higher than the November 2021 ODOT crews utilizing bucket trucks and brush chippers (Figure 9).

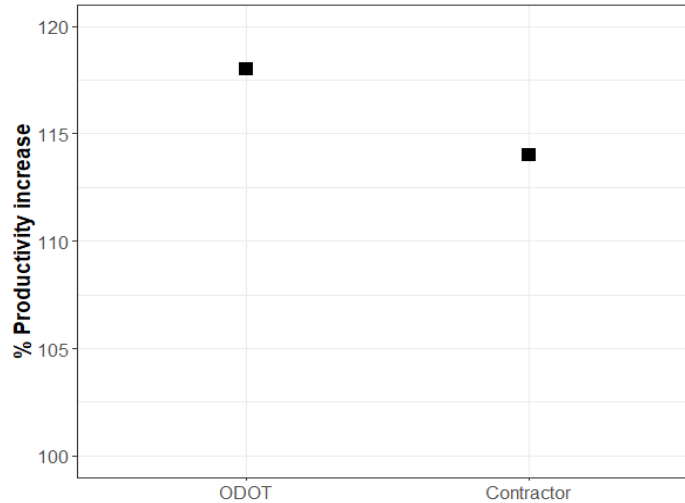


Figure 9. % Productivity (trees removed/day) increase between crews operating a Sennebogen 718E and Bandit 2090 whole tree chipper and crews operating forestry bucket trucks for both ODOT and experienced contractor crews.

Cost Efficiency

The cost efficiency of the August 2022 crew utilizing a Sennebogen 718E and Bandit 2090 whole tree chipper (total cost (labor and equipment)/tree removed) was greater than that of treatment groups during November 2021 field tests, and greater than contractor cost efficiency. All ODOT labor cost estimates assumed a \$20/hour rate for all employees. Total cost/tree removed for the August 2022 crew was \$20.53/tree (Figure 10), which was 30% lower than the contractor crew cost efficiency (\$29.50/tree; Figure 10) and was 22% lower than the most cost efficient of the November 2021 ODOT crews (\$26.20/tree; Figure 10).

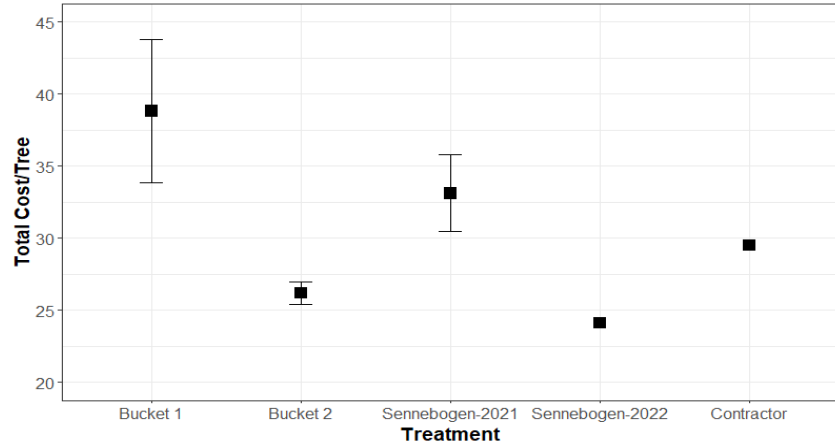


Figure 10. Total cost/tree removed across all November 2021 treatment groups, the August 2022 Sennebogen 718E observation, and for contractor cost efficiency. Error bars are standard errors around the mean values. Since sample size = 1 for the 2022 ODOT Sennebogen 718E observation and contractor estimate, those means do not have standard errors, and no statistics were run for this comparison.

Return on Investment (ROI)

ODOT’s potential annual return on investment (ROI) for new equipment purchased for tree removal (assuming 26 weeks of tree removal work) when based on ODOT Sennebogen 718E crew costs and productivity in November 2021 was 0.25% (Figure 11). The annual return on investment based on ODOT Sennebogen 718E crew costs and productivity for an August 2022 observation increased nearly 35 times to 8.65% (Figure 11). This would result in a time to return on investment of approximately 11.5 years assuming 26 weeks of tree removal work/year.

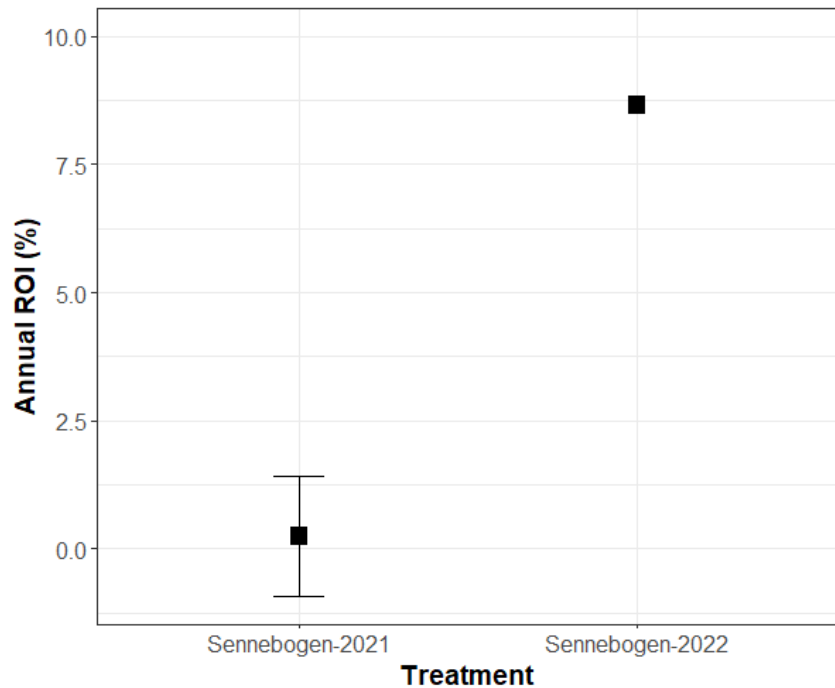


Figure 11. Annual ROI based on November 2021 crew costs and August 2022 crew costs utilizing a Sennebogen 718E. ROI calculations assumed 26 weeks of tree removal work/year. Equipment costs used in the ROI calculations only include costs for new equipment that was used during the observation (e.g., Sennebogen 718E for the November 2021 crew, and Sennebogen 718E and Bandit 2090 chipper for the August 2022 crew).

Contractor and ODOT Storm Event Response Cost Comparison

The total cost of loaded labor and daily operating costs of equipment for ODOT during the storm event cleanup in Wayne County from June 15, 2022, to August 5, 2022 (\$278,320.01) was nearly double the total cost of labor and equipment operating costs for a contractor crew to conduct the work (VanCuren Services, Inc.) (\$154,875) (Figure 12). Although the ODOT equipment operating costs were 74% lower than that of a contractor (Figure 13), there was a substantial difference in labor costs that caused the discrepancy. ODOT loaded labor costs over the 35-day storm event cleanup (\$246,815.86) was 7.8 times greater than the labor costs for contracting out the work to VanCuren Services, Inc. for the same period (\$31,640) (Figure 14). These results further demonstrate that the size of the crew that accompanies the ODOT crews utilizing the Sennebogen 718E are either too big, or a lack of efficiency of the crews is contributing to longer hours and increased costs for ODOT.

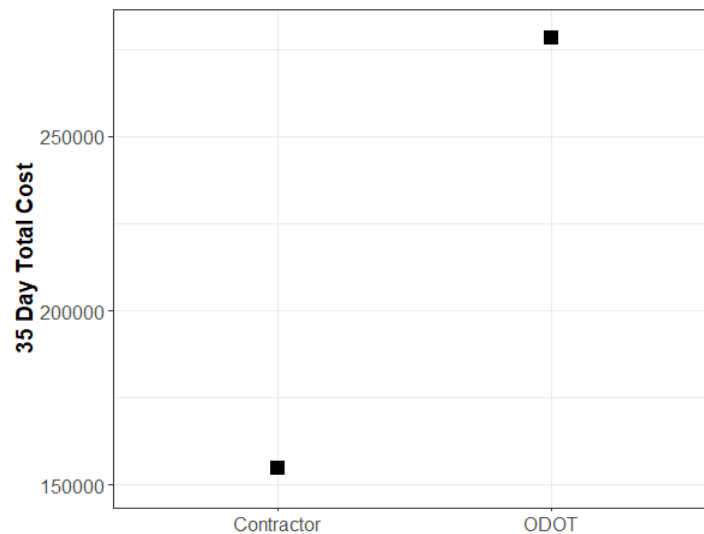


Figure 12. 35-day total labor and equipment operating costs for ODOT crews operating the Sennebogen 718E during the June 15 - August 5, 2022, Wayne County storm event response and estimated contractor (VanCuren) crew total labor and equipment operating costs for 35 workdays.

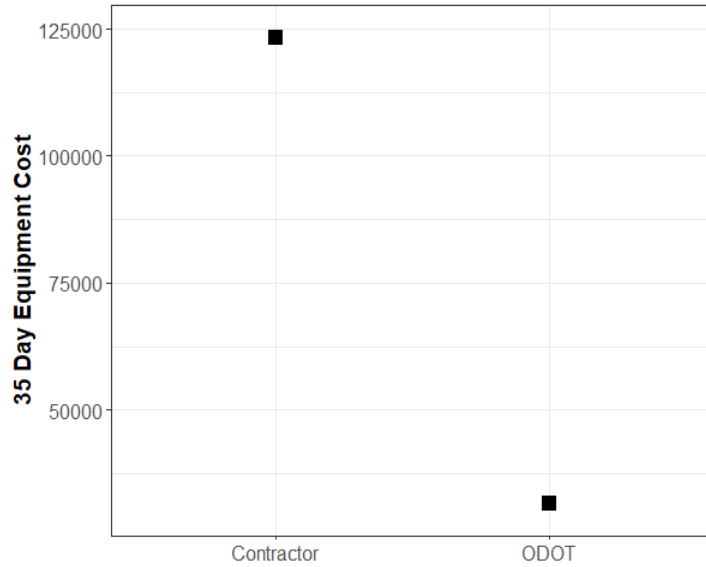


Figure 13. 35-day equipment operating costs for ODOT crews using the Sennebogen 718E during the June 15 - August 5, 2022, Wayne County storm event response and estimated contractor (VanCuren) crew equipment operating costs for 35 workdays.

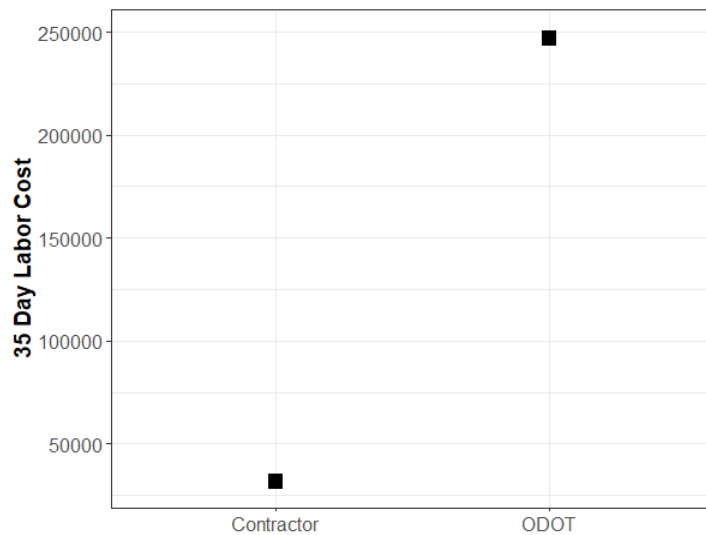


Figure 14. 35-day labor costs for ODOT crews utilizing the Sennebogen 718E during the June 15 - August 5, 2022, Wayne County storm event response and estimated contractor (VanCuren) crew labor costs for a 35-day period. ODOT crew labor costs are the total of loaded labor costs for all crew, and contractor labor costs are the sum of crew billing rates over a 35-day period.

Appendix L: Equipment Costs Table

Table 2. Equipment Cost Table

	Purchase Cost	Daily Cost	#/Days used/week	Weekly and/or total Project Cost
Old Process				
ODOT Crew				
Altec LR760-E70 Bucket Truck	\$157,743.00	\$103.53	5	\$517.65
Morbark Beaver M14R	\$52,000.00	\$50.58	5	\$252.90
dump truck		\$96.37	5	\$481.85
Worker 1	\$20.00	\$160.00	5	\$800.00
Worker 2	\$20.00	\$160.00	5	\$800.00
Worker 3	\$20.00	\$160.00	5	\$800.00
Worker 4	\$20.00	\$160.00	5	\$800.00
Worker 5	\$20.00	\$160.00	5	\$800.00
Total				\$5,252.40
Contractor				
Sennebogen 718E		\$2,080.00	5	\$10,400.00
Bandit 21XP		\$840.00	2	\$1,680.00
2019 Kenworth lowboy for Sennebogen		\$1,125.00	1	\$1,125.00
2020 Kenworth lowboy for Bandit 21XP		\$0.00	1	\$0.00
Worker 1	\$65.00	\$520.00	5	\$2,600.00
Worker 2	\$60.00	\$480.00	2	\$960.00
Worker 3	\$60.00	\$480.00	2	\$960.00
Bandit 21XP Mobilization & Demobilization		\$400.00	2	\$800.00
Sennebogen Mobilization & Demobilization		\$1,800.00	2	\$3,600.00
Total				\$22,125.00
New Process				
ODOT Crew				
Sennebogen 718E	\$570,000.00	\$633.22	5	\$3,166.10
Rotobec 4042 HD grapple for midsized excavator	\$32,941.00	\$174.63	5	\$873.15
trailer for excavator		\$5.00	5	\$25.00
dump truck to haul excavator		\$96.37	5	\$481.85
Bandit 2090 with Kelsa loader	\$227,420.00	\$50.58	5	\$252.90
tandem axil dump truck to toe Bandit		\$96.37	5	\$481.85
Worker 1	\$20.00	\$160.00	5	\$800.00
Worker 2	\$20.00	\$160.00	5	\$800.00
Worker 3	\$20.00	\$160.00	5	\$800.00
Lowboy		\$119.25	5	\$596.25
				\$8,277.10
Storm Event Cleanup 6/15/22 - 8/5/22				
ODOT				
Sennebogen 718E	\$570,000.00	\$633.22	35	\$22,162.70
Bandit 2090 with Kelsa loader	\$227,420.00			\$0.00
Rotobec 4042 HD grapple for midsized excavator	\$32,941.00	\$174.63	13	\$2,270.19
Brush chipper	\$52,000.00	\$50.58	22	\$1,112.76
Forestry bucket truck Equipment		\$103.53	10	\$1,035.30
Dump truck for hauling chipper and chip bed		\$96.37	35	\$3,372.95
Transport vehicle for Sennebogen		\$119.25	13	\$1,550.25
				\$31,504.15

Appendix M: ODOT Crew Observation Questionnaire

Crew Size, Compilation, Efficiency

1. Does each member of the crew demonstrate familiarity/proficiency with equipment being used?
2. Is the crew working efficiently as a team?
3. Does the crew have the proper number of members on-site for the operation?
4. Are there inefficiencies due to crew size (too many or too few) relative to the scope of the work area?
5. Are all crew members staying productive relative to what the crew is doing?
6. What ways could the crew/members be more productive?
7. Take note of the parameters as the day progresses along (changes in temperature, wind speed, traffic patterns, etc.) and try to infer how these changes might affect the site with more and varied types of equipment. What you are observing on that day likely isn't the way it always is.
8. During what repetitive phases of the work tempo does there appear to be the most lag time where production seems to flat line? Some is normal but does it appear excessive?

Equipment

9. What other equipment would make the crew more efficient with less members needed, or less overall hours needed on-site?
10. Are there possible equipment/materials that could be used to aid the job performance? -Salt for traction, mats for wet areas, etc.
11. Are there equipment problems due to the way the equipment is being used?
12. What are the ways the crew could be more efficient to get the work completed?
13. In what condition do the vehicles and machines seem to be in? Do they appear old and worn out or in nice, well-kept condition. How does that match up with crew responses in the interviews?
14. Do the chainsaws appear well kept and in good condition? Are they sharp or dull?
15. Do the chainsaws appear to be used properly? Stance, chain brake use, proper starting techniques, etc.?

Safety

16. Is the crew working safely?
17. What ways could the crew work more safely?
18. Are newer crew members being constructively criticized and educated in what they may be doing wrong or could do better (safer and/or efficiently)?
19. Do employees have proper PPE, footwear, gloves, etc.?
20. How might other work environments affect the operation at present?!! -Heavy snow, ice, mud, slopes, rain, background noise, etc.
21. How might our observation be impacting the site?
22. How are communications amongst the crews/ how familiar are they with one another in knowing how each other works and what signals mean what and to who? - Hand gestures, awareness, eye contact, shouting, etc. (improvements, confusion?)
23. Are any of the workers smokers? Are they smart about it?

Appendix N: ODOT Tree Crew Manager Questionnaire

1. How is it determined which stretch of road crews will focus on for daily operations?
2. Who decides how an ash tree is to be removed? Is that process strictly followed or open to change by another person (i.e., transportation manager, crew foreman, bucket operator)?
3. What additional conditions are considered when working on an ash removal compared to most other species of trees?
4. How is a work plan modified to variances in tree condition (size, shape, and level of decay)? By whom and what process?
5. What conditions determine if you will contract the work out
6. What are ODOT's/your safety standards when working an ash tree?
7. Are you aware of any practices ODOT crews do differently than other companies when removing ash trees and debris?
8. How large are crew operations and do the same guys generally work together day in and out or do crews shift as individuals move around fluidly? Do you work as one large team or break up into several smaller crews of say 3-4 guys clearly performing operations on one specific tree or section of the wood line?
9. Is the process for gathering up equipment efficient? How long would you say it takes crews to mobilize in the mornings?
10. How is site setup and task responsibility determined? By whom and by what process?
11. What is the turnover rate year over year in crew members involved in Ash removal?
12. Is equipment individually assigned or is it communal? Is there personal responsibility and accountability for necessary equipment?
13. Is equipment inspected and serviced in the immediate days (90 days or less) prior to the onset of winter ash removal season?
14. Are there any individual pieces of equipment that have a long-standing history in hindering daily tasks or duties without replacement or repair? Chainsaws that don't perform correctly, chippers that often plug up or have faulty accessories?
15. Are there any additional things (equipment, training protocols, etc.) that you feel would be of great aid in the areas of safety or efficiency to your daily operations?

Appendix O: ODOT Crew Survey Evaluation Score Summary

Table 3. Sum of average scores for each question topic asked to ODOT tree crew members during December 2020 baseline observations, and percent of total possible scores.

Question Topic	Sum of Average Score (All Crew)	Sum of Average Score (Equipment Operators)	Total Possible Score	% Of Total Score (All Crew)	% Of Total Score (Equipment Operators)
Communication	12.21	12.00	16.00	76.34	75.00
Efficiency	8.57	8.17	12.00	71.43	68.06
Equipment Reliability	12.25	11.33	14.00	87.50	80.95
Site Assessment and Job Planning	6.16	6.67	11.00	56.01	60.61
Training/Experience	10.68	10.67	15.00	71.19	71.11
Training/Experience-Ash	6.25	7.33	14.00	44.64	52.38
Totals	58.63	58.50	82.00	71.49	71.34

Table 4. Sum of average scores for each question topic asked to ODOT tree crew members during Summer 2022 field observations, and percent of total possible scores.

Question Topic	Sum of Average Score (All Crew)	Sum of Average Score (Equipment Operators)	Total Possible Score	% Of Total Score (All Crew)	% Of Total Score (Equipment Operators)
Communication	13.50	13.50	16.00	84.38	84.38
Efficiency	10.50	10.00	12.00	87.50	83.33
Equipment Reliability	10.33	10.00	14.00	73.81	71.43
Site Assessment and Job Planning	6.67	6.50	11.00	60.61	59.09
Training/Experience	11.67	12.00	15.00	77.78	80.00
Training/Experience-Ash	7.33	7.50	12.00	61.11	62.50
Totals	60.00	59.50	80.00	75.00	74.38

Table 5. Sum of average scores for each crew observation topic asked of DRG staff observing ODOT tree crews during November 2021 field observations, and percent of total possible scores.

Question Topic	Sum of Average Scores	Total Possible Score	% Of Total Score
Communication	3.50	5.00	70.00
Efficiency	14.50	25.00	58.00
Equipment Operation & Maintenance	13.00	20.00	65.00
Safety	9.00	10.00	90.00
Training/Experience	6.50	10.00	65.00
Total	46.50	70.00	66.43

Appendix P Recommendation Details - Implementation, Benefits, Costs, and Evaluation

Processes:

Work Planning

- Improve work planning and organization with the use of tools used by the work planner to assess whether a site needs to be worked, the priority of the work, the hazards associated with the site and the trees, whether a contractor or ODOT crews should perform the work, and what equipment should be used if performed by in-house crews.
 - The Site Assessment Form and Equipment Decision Tree are good tools to start with and can be modified as needed to become more useful to the work planners (Appendices G and H).
 - These forms should describe site conditions, work goals, personnel and equipment needed, or any other details relevant to the work being conducted.
 - Planning through use of the forms will help communicate to the crews the appropriate equipment to bring to the site, ensuring proper use of equipment available for the day ensuring important pieces are not left behind at the garage. The form will also elucidate how to set up efficiently as well as provide an idea of the volume of work and potential safety concerns. Knowing these things before heading out of the garage will help the tree crews prepare for the day's work more efficiently.
 - This type of planning will reduce the likelihood of crews working sites that are not necessary (no hazard, no additional clearance necessary) and that crews make best use of equipment that gets rotated between the counties such as forestry bucket trucks, Sennebogen 718E, Rotobec 4042HD grapple mounted to excavator, and the Bandit 2090 by working trees that cannot be reached with these pieces of equipment when they are not in the county and by utilizing them every day they are in the county.
 - Costs to conduct these more detailed assessments and completing the forms would be minimal, with each assessment costing an estimated ~\$5 per site and the development of the JPBF forms costing ~\$5 per crew member each day (based on \$20/hour pay rate).
 - This level of organization will pay for itself in short order by preventing the crews from leaving important pieces of equipment behind that must be retrieved and driven out to the site. It will also improve safety by calling out hazardous situations for the crews to be prepared for upon arriving on-site and performing the work. This process will also keep tree removal equipment productive and keep it from sitting idle at sites it cannot be used.

Training

- Enhance tree worker training by providing documented periodic training refreshers, advanced equipment training, and establishing a mentorship directive.
 - A more structured and sustainable training program needs to be implemented for ODOT tree removal crews to enhance safety and efficiency. Training refreshers need to be given, as well as skill advancement training beyond basic training for all equipment including chainsaws, chippers, bucket trucks, winches, etc.

- Additional training programs are needed for all ODOT tree crews to be able to identify ash trees and those infected with EAB. This will allow for greater identification of potential hazards inherent in working near trees with EAB and will improve efficiency since crew members would not have to rely on others for identification. Crews should become more proficient with chainsaws, cuts, winching, rigging, and chipper use as well as basic operation, maintenance, and safety of the equipment.
- All crew members who use chainsaws and chippers should receive this training.
- For crew members with more tree experience and those with leadership potential, a leadership and associated mentorship program should be developed. The more experienced staff can then act as foremen and will train less experienced crew members. Effective mentoring raises the collective standard competency level.
- Much of this training can be provided via annual week-long training conducted by vendors such as ArborMaster® or ACRT for ~\$28,000 for 20 employees.
- A ROI into this additional training will be seen within 6-12 months.
- There are many maintenance workers across the state that perform tree work periodically. ODOT's maintenance crews have a wide variety of tasks in their job description from snow and ice removal, pothole and guardrail repair, and vegetation maintenance in the form of mowing, herbicide application, and tree trimming and removal. Providing advanced training to all these workers when their workload doesn't focus on tree work for most of the year may seem daunting and unnecessary. From a safety and efficiency standpoint, ODOT's crews need additional training. With most maintenance workers performing chainsaw and chipper work, there are a lot of employees to train. Alternatively, ODOT should create dedicated crews for most of their tree work and focus the advanced training on those workers.
- Evaluate the ROI by looking for increased production (tree count/biomass) and improved safety records to evaluate results of implementation.

Tree Crew Make Up, Schedules, Mobilization, and Setup

- Create specialized crews in all districts that are dedicated to tree work year-round to keep up with workloads and eliminate large backlog of tree work.
 - Dedicated tree crews will become more proficient at the work through familiarity with the equipment and processes. Dedicated crews will not have long breaks between tree workdays as the current crews have. Eliminating the need to get back up to speed at the beginning of the season, doubling the productivity of seasonal crews with the same equipment.
 - Choose employees that are interested, show a skill for tree work, and are not afraid of heights to operate the bucket trucks. Better yet, choose employees with prior professional experience and training with a reputable employer(s) and leadership potential.
 - By utilizing dedicated crews, tree work will be concentrated across less staff, freeing other employees to perform other tasks.
 - There should not be any cost to this recommendation.

- The dedicated crews can utilize bucket trucks when available and needed but should otherwise plan to perform work without the bucket trucks.
- Using tree cutting and disposal equipment can be more dangerous and labor intensive than other maintenance work, so some employees may not be interested in joining the dedicated crews. Employees should be motivated by incentives to join the specialized crews and become bucket operators.
- Having a dedicated tree crew would decrease crew size by two people, saving \$320/day.
- Evaluate the ROI by looking for increased production (tree count/biomass), reduced labor costs per jobsite, and improved safety records to evaluate the results of implementation.
- To mobilize, all tree crews should have a goal for leaving the garage at a certain time in the morning. To help meet this goal and prevent necessary items being left behind, crews should have a checklist of what is needed for each day. Equipment for tree work should be kept in a specific area of the garage or near tree machinery, saving time loading and unloading gear and thus reducing costs associated with mobilization.
 - Having all tools and equipment arrive on-site at an earlier time will allow for a higher production rate.
 - Mobilization improvements are estimated to save \$20/day/person. When carrying out tree removal at a site, work should be set up like an assembly line. For example, set up the bucket truck in front of the chipper. The trimmer should continue cutting while chips are dumped off site.
 - This process will not cost any money and should be implemented in each county immediately.
 - This process should be evaluated by comparing the mobilization time after implementation to the 2-3 hours it took prior to implementation. The decrease in number of trips to bring forgotten items to the field prior to implementation may be harder to measure.
- On-site work should operate like an assembly line with each employee assigned a task, and the tree cutting, and chipping equipment should be operated in unison.
 - This process should be taken whether the crew is a ground crew with saws and a brush chipper, forestry bucket crew with a brush chipper, or the crew using the Sennebogen 718E with Rotobec 4042HD grapple-mounted excavator and Bandit 2090 whole tree chipper.
 - This will reduce the amount of pausing and waiting crew members currently do at each job site while waiting for more material and for safety reasons. This will improve safety by having each member of each crew in the right position and spacing while using their designated equipment.
 - There is no cost to implementing this process. It is common with professional tree crews and promotes safety and efficiency.
 - Evaluate the results by looking for increased production (tree count/biomass) and improved safety records.

Contracting

- Hire contractors for larger or more dangerous jobs to keep up with workload.
 - Ideal jobs for contractors are areas with utility lines as ODOT crews are not qualified to work within MAD, as well as large trees and other trees that can be more difficult or unsafe to remove, and large-scale tree removal operations.
 - Proactively put contracts in place in all districts to prepare for this need.
 - When there is the possibility of needing contract crews to help clear debris from emergency weather events, prepare by asking them to be on standby. This can result in having better responsiveness to clearing activities when the event occurs, rather than waiting for it to happen and being late on the response. There is no cost to asking the contract crew to be prepared, but there will be a cost if they are asked to mobilize for such work.
 - Relying on contracted work in certain situations would be ideal since qualified contractors will have higher production rates and will be qualified to work within MAD of utility lines.
 - Obstacles to implementation are being at the mercy of contractor pricing and availability. This challenge can be difficult to overcome when large storms hit as happened in the summer of 2022. It is wise to maintain some dedicated crews in each district so as not to become entirely dependent on contractors.
 - Evaluate the ROI by monitoring the volume of work performed by contractors and in-house crews and monitoring the volume of work to determine if it is decreasing and if safety incidents are decreasing.

Debris Disposal

- Recirculate the email from June 17, 2016, from ODOT Cost Accounting and Inventory Manager, Brian Church based on a meeting with Chief Legal amongst each county maintenance garage within ODOT. The email reminds county and district level employees that the maintenance operations debris disposal process has been simplified while they await formalized changes in the Ohio Revised Code.
 - Disposal of logs and chips is complicated by the Ohio Revised Code, which makes it complicated to dispose of them in an efficient manner. Staff involved in the project were not aware of the email. The email outlines a simplified process that is more amenable to maintenance operations by removing many of the hurdles and red tape that are in place in the Ohio Revised Code.
 - There is no cost for implementation, and it should be implemented immediately.
 - Using this revised policy will streamline the process for debris disposal and could reduce the costs associated with the process.
 - Garages will be able to more frequently dispose of debris as the revised process does not require as many complicated steps. This will result in less buildup of debris in the garages.
 - Evaluate the ROI by comparing the time and costs associated with the Ohio Revised Code process versus the process outlined in the email from the Finance Department.

Equipment

Equipment Tested During the Study

- Prioritize integrating the equipment purchased for this study (Sennebogen 718E tree handler, Rotobec 4042HD log grapple mounted on midsize excavator, and Bandit 2090 whole tree chipper with Kesla loader) into ash and other species of hazard tree removal work to be completed by ODOT crews. The equipment can also be used for other large scale clearing and debris removal projects if the equipment is available. This equipment combination provides the safest and most efficient option for hazard tree removal by ODOT crews.
 - Proper operation and selection of the right equipment for the job is a key consideration to ensure the safety and efficiency of ODOT workers.
 - The Sennebogen 718E minimizes worker exposure to ash trees by keeping all employees out of the fall zone. It also limits ground personnel on the roadside since its extended reach can work from the road. The Sennebogen 718E can reach 80% of ODOT's ash trees from the road's edge.
 - This ability to reach from the road edge also greatly reduces on-site travel time, and work completed off-road. This reduces environmental damage sustained by equipment driving off road.
 - The Sennebogen 718E's climate-controlled, enclosed, bulletproof cab protects operators much better from falling debris and the elements than an exposed bucket of a bucket truck.
 - The grapple saw on the Sennebogen 718E minimizes safety hazards by holding pieces being cut, rather than dropping them and allowing pieces to shatter and scatter in different directions. The unpredictable nature of the fallen debris can cause injury to ground workers and the traveling public.
 - The operator of the Sennebogen 718E is not near the saw during its operation and only comes in contact with the motionless chain and blade for maintenance purposes. This greatly reduces the potential injuries caused using chainsaws.
 - The Rotobec 4042HD log grapple tool attachment for the excavator can traverse across ditches and effectively lift logs and material over guardrails as needed or move debris down the line to load heavy logs into the chipper. This decreases the risk of strains, sprains and pinch points workers would otherwise be exposed to if moving debris by hand. It also keeps the Sennebogen 718E moving down the roadside cutting without having to slow down to manipulate material for the chipper.
 - The Bandit 2090 whole tree chipper with Kesla loader and remote control is the proper tool to keep up with the size and volume of material the Sennebogen 718E can generate at a site. The Kesla loader can pick up logs and debris organized by the Sennebogen 718E or Rotobec 4042HD excavator mounted grapple and place them in the chute with the use of a remote control. This mechanization keeps workers away from chipper infeed, eliminating the dangers of loss of limbs and life associated with using chippers. The wheeled version of the Bandit 2090 was purchased for the study to eliminate the need for loading on a lowboy. The unit can be towed by a dump truck that would likely be on-site for chip removal anyway.

- Not only does this equipment keep the crews using it safer than the crews with a bucket truck operation but if DRG's recommendations are followed, it will reduce crew size. This would free employees who would otherwise assist on tree removal work to perform other work, thereby reducing the cost of labor on tree removal operations when this equipment is used.
- The combination of equipment will remove trees faster with less cuts in the tree, maneuver the logs and materials to the chipper faster, and chip larger logs than the standard ODOT brush chipper can handle. This will increase the number of trees that can be removed in a day. By completing more work faster in the ROW, ODOT will be able to reduce the backlog of hazardous ash and other species more easily.
- As evidenced by the data analysis conducted during this study, use of the equipment is safer and more efficient than a bucket truck or ground crew. However, ODOT's use of the equipment purchased through this study did not meet the production levels of professional tree workers utilizing the equipment. To increase the production rate and narrow that gap, ODOT will need to implement the processes outlined through this study.
- The largest obstacle for implementation is the combination of equipment purchased as part of the study is far more expensive than the standard forestry bucket truck and brush chipper ODOT usually utilizes for tree removals.
- Overall, this equipment combination of the Sennebogen 718E, Rotobec 4042HD log grapple for a midsize excavator, and the Bandit 2090 whole tree chipper on wheels with Kesla loader and remote control has the potential to be five times faster than ODOT's bucket crews and uses two less staff. This saves approximately \$320/day. The costs for the equipment are as follows:
 - Sennebogen 718E: \$570,000 purchase or \$28,000 rental. An ODOT equipment rental is less expensive than using a contractor with a Sennebogen 718E for more than 13 days/month. Alternatively, purchase of the Sennebogen 718E is paid in 274 days (\$2080/day) or 20 months (\$41,600/month) of contracting.
 - Rotobec 4042HD log grapple and RT322 Rotator Quick Adaptor Plate Yoke (for midsize excavator): \$32,941
 - Bandit 2090 drum style whole tree chipper on wheels with Kesla loader: \$227,420. The Bandit 2090 whole tree chipper is paid for with less than 14 months contracting equipment (\$16,800/month).
- Given the substantial gap between current crew efficiency and potential crew efficiency demonstrated by the ROI analysis and storm response contractor comparison, contracting out tree removal work, particularly for larger jobs, may be the preferred option for ODOT until in-house crews are able to increase productivity and close the gap.
- After additional practice, evaluate performance of the in-house crew compared to the production rate of the contractor to determine if production rates have increased to a level that merits the purchase of additional equipment for another district with high tree density.

- Sennebogen 718E operators and mechanics should complete additional training by Sennebogen LLC at the Sennebogen facility in North Carolina. The training will improve proficiency with operating the machine and its maintenance and troubleshooting.
 - The Sennebogen Training Center is equipped with classroom and hands-on access to full-sized machines. Training is led by highly qualified instructors with several years of practical field experience.
 - Classes and materials are at no cost to customers. The cost would be the labor and travel fees of the participants.
 - These costs would be offset by improved efficiency and being able to operate the machinery better with less problems caused by inexperience and better care and maintenance of the equipment.

Debris Handling

- To further help with debris disposal, DRG recommends that crews construct a removable chip bed with high sides and lid to insert into dump beds to handle larger volumes of chips. This bed can be constructed by utilizing old signs.
 - This will reduce the frequency of leaving work sites to dump chips and keeps the debris disposal crew productive longer between dumping.
 - The cost of this item is the labor and solder for joining the pieces together. The ROI will be achieved in just a couple of days based on the current frequency of emptying the standard dump bed.
 - There are no foreseen obstacles to implementation
 - Evaluate the ROI based on the holding capacity and reduced number of trips to empty a standard dump bed with that of the larger removable dump bed.
- The rental of a horizontal grinder for approximately 1-2 weeks out of the year for districts that perform a lot of tree work but do not have a whole tree chipper may be warranted.
 - Using a horizontal grinder can be more efficient than chipping large logs on-site and allows trees that cannot fit through a chipper to be disposed of.
 - It likely will not get enough use to warrant purchase but rental makes economic sense (\$5,000/week rental vs \$500,000 purchase). Additionally, weekly rental is \$23,800 less expensive than contracting for one week.

Communication

- DRG highly recommends the use of headsets for communication while on-site. DRG observed crews having difficulties communicating by utilizing just raised voices and hand gestures.
 - Headsets will aid in training and mentorship as well make work safer and more efficient by allowing for easier and more frequent communication amongst the crew.
 - ODOT crews were curious about them and enquired DRG about them. Some of the ODOT staff had used them with previous employers and missed the benefits they provided.

- Headsets will improve quality of communication and minimize time lags and potential safety incidents caused by miscommunication. Specifically, DRG recommends the Speak Easy Action Pro-C for \$280 each. DRG estimates a ROI of about 6-12 months for the headsets.
- The ROI can be evaluated by observing the pauses and miscommunication that occurs with hand gestures and shouting needed currently to the frequent and fluid communication of a crew with headsets.