

Measuring the Efficiencies of Tow Plows and Wing Plows

Final Report



research for winter highway maintenance

University of California, Davis

**Project 1034818/CR19-03
December 2021**

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16. Abstract As agencies consider purchasing new types of snowplow equipment, it is important that they understand the trade-offs between equipment costs and potential gains in efficiency. Both tow plows and plows with wings represent a greater up-front investment but are designed to allow a plow operator to clear more snow in a single pass than a standard front plow, potentially providing efficiencies in terms of plow cycle time, labor and equipment allocation, operating costs, increased level of service, and more. This project assessed the efficiency benefit of variable plow width equipment with respect to lane clearing capabilities for typical highway configurations and developed tools for DOT decision-making and procurement, including a Decision Support Tool and user's guide and a Best Practices Guide. These tools will support DOT procurement and operational planning with respect to the designated plow types. The tools will also assist in identifying the best roadways and geometries for deployment and in analyzing cost of ownership and return on investment. Both tools are available at https://clearroads.org/project/19-03/ . This final report documents the methodology for creating these tools.			
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MEASURING THE EFFICIENCIES OF TOW PLOWS AND WING PLOWS

Task 9: Final Report

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LIST OF ABBREVIATIONS

AHMCT	Advanced Highway Maintenance and Construction Technology Research Center
CR	Clear Roads
DOT	Department of Transportation
DST	Decision Support Tool
MnDOT	Minnesota Department of Transportation
UCD	University of California, Davis

EXECUTIVE SUMMARY

Measuring the Efficiencies of Tow Plows and Wing Plows is a Clear Roads (CR) consortium Department of Transportation (DOT) pooled fund research project. This research is being performed by the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center at the University of California, Davis. This final report summarizes the information gathered in the following research tasks:

- Task 1: Literature and Product Review
- Task 2: Survey of Practice
- Task 3: Recommendations and Test Plan (Roadway Types/Geometries)
- Task 4: Simulations (Roadway Types/Geometries)
- Task 5: Peer Review of Simulation Results
- Task 6: Methodology for Efficiency Analysis
- Task 7: Decision Support Tool
- Task 8: Best Practices Guide
- Task 10: Decision Support Tool User's Guide

Because the Decision Support Tool (Task 7) and User's Guide (Task 10) and the Best Practices Guide (Task 8) are the main deliverables of this project and the prior tasks have been documented in corresponding interim or summary reports, this final report is brief, focusing on documenting the methodology for creating those deliverables. AHMCT is also preparing a final closeout webinar and a PowerPoint™ file to support presentations at conferences or national and regional meetings by Clear Roads members regarding the findings and recommendations resulting from this project.

Task 1 and Task 2 reviewed literature, products, and surveys from participating DOT members. Task 3 developed recommendations and a test plan for the research effort. Task 4 began core tool development efforts, yielding a Microsoft Excel™/VBA tool to support simulation of cost efficiencies for varying allocations of plow types and road configurations. This tool was presented to the CR panel members who provided their review via teleconferences to AHMCT in Task 5. Task 6 yielded metrics to expand the simulation tool of Task 4 into the Decision Support Tool (DST) developed in Task 7. The DST, the primary product of this research, expands upon the plow efficiency methodology developed and reviewed by the CR subcommittee in the simulation and other preceding tasks, especially Task 6. The DST provides DOTs with an innovative method for quantifying plow configuration efficiencies and true costs throughout the life cycle of the equipment. These two cost analyses run together utilizing a common set of plow type and cost data in an Excel application. The DST output assists DOTs in calculating a return on investment of the designated plow types based on their state-specific costs and plow configurations. The DST incorporates modifications based on suggestions made by the subcommittee reviewers in Task 5. Task 8 provides background information on tow and wing plows, operational considerations of the target plow configurations, and most importantly, a guide to the use

of the DST. Task 10, Decision Support Tool User's Guide, was added to the scope at the request of the Clear Roads subcommittee. The intent was detailed documentation on how to use the DST.

OVERVIEW

PROBLEM

The fundamental tool used by DOTs nationwide to clear snow build-up on highways is a snowplow blade attached to a heavy-duty dump truck. The plow is most commonly mounted to the front of the truck, but underbody and even rear-mount plows are also used. The clearing width of these basic plows when angled is constrained by the legal width restriction for vehicles driving on the highway. Extending the clearing width of a plow truck is the obvious method to increase the efficiency and reduce the cost of highway snow clearing operations. A wide range of plow attachments have been developed that extend well beyond the legal width limit while operating in the plowing work zone and retract to legal width limits when the vehicle is out of the work zone. These extendable plow attachments add significant system cost and weight and further complicate the operation of the plow truck. Therefore a determination must be made whether the additional clearing capability justifies the costs of adding extendable plows to a standard plow truck, and, if so, what is the most appropriate attachment for the specific application. In the current research, the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center developed a Decision Support Tool (DST) and corresponding Best Practices Guide for snow-clearing DOTs to determine if, when, and where DOTs should procure and use more advanced variable-width plows.

OBJECTIVES

The objective of this research was to develop a guide for assessing the costs and benefits of investing in the addition of advanced plowing products to DOT plow truck configurations. This project had two primary goals. First, the research assessed the efficiency benefit of variable plow width equipment with respect to lane clearing capabilities for typical highway configurations. Second, this research developed tools for DOT decision-making and procurement, including a Decision Support Tool (DST) and a Best Practices Guide, which will be helpful in procurement decisions and use of such plows. The DST and Best Practices Guide are the main deliverables of this project. These tools will support DOT procurement and operational planning with respect to the designated plow types. These tools will also assist in identifying the best road areas and geometries for deployment and in analyzing cost of ownership and return on investment.

SCOPE

There are a wide array of innovative variable-width commercially-available plow products. This research applies to most of these products, but attention was focused on the effectiveness of seven specific variable plow width configurations suggested by the Clear Roads (CR) project committee:

1. Conventional-width front (head or underbody) plows (base case for comparison).
2. Front plow with a right- or left-side wing plow.
3. Double wing plow.

4. Single-direction tow plow.
5. Bidirectional tow plow (assessing both right- and left-side deployments as well as operational efficiencies gained from the equipment's flexibility).
6. Single-direction tow plow combined with a wing plow.
7. Telescopic head plow.

The data sources used in this report, Best Practices Guide, and DST were based on a literature review, committee input, DOT survey, and product manufacturer recommendations. The DST is DOT-specific, interactive, and input-dependent for improved accuracy. The data relates to roadway classifications and geometries, operational considerations, and measures of efficiency including level of service and cost. The primary objective in the analysis was to optimize single-pass lane clearing capability.

BACKGROUND

CR member DOTs, with Minnesota DOT (MnDOT) as the lead, are interested in examining the benefit/cost relationship of using advanced snowplows vs. the baseline standard front plow. The current research investigated this efficiency, including lane-clearing capabilities vs. equipment costs. While more expensive than conventional front (head) plows alone, the addition of telescoping plow, wing plow, and tow plow truck accessories allows more snow to be cleared for each pass, potentially providing an overall reduction in operating costs, better labor and equipment allocation, and increased level of service. There is presently an abundance of innovative commercially available products designed specifically to extend the lane-clearing capability of a conventional DOT plow truck. Each of these products has application-specific operational advantages and disadvantages. When DOTs select which plow attachments to deploy, they have a wide range of unique parameters to consider. Since the marketplace for snowplow products is expanding rather than converging on a small set of successful designs, a more sophisticated method of identifying the most efficient and appropriate plow equipment designs is essential for the foreseeable future.

RESEARCH METHODOLOGY

This research moved beyond current theoretical understanding of tow plow and wing plow efficiencies by gathering information on their efficiency in real-world application. A systematic approach was developed which characterizes the utility of advanced extendable plow equipment. The approach focused on the lane clearing capabilities of plow width products and not on the comparative effectiveness of the wide array of available products. The snow state DOTs include many different climate regions with distinct road conditions. Individual plow products and configurations are optimized based on snow/ice conditions, which vary widely depending on regional climate conditions. Accordingly, the plow performance and efficiency varies dramatically depending on the application. Examination based on a broad overall average efficiency rating, which ignores pavement and snow conditions, is not necessarily useful. Since the fundamental requirement is that a plow has to cover the roadway before the efficiency of that plow can be considered, examining the best means of covering the roadway with plows is the most important metric. Once the plow coverage has been optimized, specific performance

enhancing countermeasures, such as blade type, plowing speed, blade down-pressure, and moldboard benching design can be augmented to meet specific regional requisites. State-specific issues like these could be examined in future research and surveys of DOT winter maintenance practitioners in multiple states. The current research focused on lane clearing capability based on analysis and modeling. The developed model was incorporated into a spreadsheet tool, the DST, which can assist in selecting which type of plowing equipment to deploy.

REPORT STRUCTURE

Tasks 1-6 have been documented in prior interim reports or summary internal CR panel reports. These tasks will be briefly summarized herein. More detailed information will be provided for the DST (Task 7), the Best Practices Guide (Task 8), and the DST User's Guide (Task 10).

TASK 1: LITERATURE AND PRODUCT REVIEW

OVERVIEW

AHMCT performed a literature search of domestic and international in-progress and completed research that describes relevant aspects of the use of tow plows and wing plows.

In the associated product review, AHMCT assembled basic information about each of the plow configurations to be tested, including any relevant documentation available from vendors (product specifications, guidance for use, manufacturer videos, etc.). AHMCT also identified key data needed for Task 7, including average purchase price and other costs.

METHODOLOGY

This task involved a literature search using Google Scholar and similar publication database search tools. AHMCT also visited manufacturer web sites for product information. The literature review included the following top-level topics:

- Snowplow Route Optimization
- Snow Clearing Best Practices
- Snowplow Benefit/Cost
- Plow Extension Equipment

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 1: Literature and Product Review," interim report, Clear Roads project 19-03, June 29, 2020

TASK 2: SURVEY OF PRACTICE

OVERVIEW

AHMCT performed a survey of practice as part of the current research project sponsored by the Clear Roads Pooled Fund. The purpose was to gather information on advanced snow plowing technologies and evaluation of their plowing efficiencies. The survey examined the costs of operation of six specific plow types. The six plow types included a conventional single plow truck, wing plows, three types of tow plows, and a telescoping head plow; a seventh plow type (double wing plow) was added as an outcome of Task 5. The goal was to identify successful snow clearing application techniques to incorporate into a Best Practices Guide and to support development of a DST. The DST is a key project deliverable that enables DOTs to analyze and calculate optimum plow configurations for specific plowing routes based on the most efficient application of the seven plow types.

METHODOLOGY

AHMCT developed a 15-question survey, which was distributed on August 10, 2020. There were 15 responses, one of which was an internal test. The responders and quantities were:

- (1) Greg Waidley (CR project manager)
- (1) Montana
- (1) Pennsylvania
- (1) Delaware
- (4) Wyoming
- (1) Kansas
- (1) Nevada
- (3) Idaho
- (1) Connecticut

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 2: Survey of Practice," interim report, Clear Roads project 19-03, September 1, 2020

TASK 3: RECOMMENDATIONS AND TEST PLAN (ROADWAY TYPES/GEOMETRIES)

OVERVIEW

A primary objective of the current research was to develop a Best Practices Guide for deploying tow plows and wing plows on specific roadway types and geometries. Task 3 of this study developed preliminary recommendations that identify the roadway types and geometries where the use of accessory plow configurations could increase efficiencies beyond the use of a standard front plow and highlight limitations where these configurations may be less efficient. These preliminary recommendations were formed by surveying snow state DOTs, then normalizing the responses to create a framework for the analytics developed to characterize plow efficiency metrics. The preliminary recommendations formed the basis for developing an analytical model for evaluating the efficiency of selected plow configurations on various roadway types and geometries.

METHODOLOGY

Based on the results from the literature search and the snow state DOT survey, preliminary recommendations and a test plan were developed for evaluating the efficiency of the six plow types selected in Task 2 when deployed on various roadway types and geometries. The literature search presented several state DOT empirical plowing efficiency reports based on seasonal plowing data. These reports are useful since they catalog how a successful agency fulfills their duty to maintain a passable highway system given available resources. However, these reports do not frame the data in any quantitative measure of efficiency that is comparable to alternative plowing methods or equipment, which is a goal of this study. Without a basis of systematic analysis, data from one case study is a poor predictor of any other slightly dissimilar operation. Consequently, the test plan for this study focused on the development of a systematic method of analyzing DOT snow plowing operational data and creating a framework for uniform quantitative plowing efficiency metrics. From this, agencies would be able to describe actual plowing routes of their choosing based on experience. Then, utilizing the analytical model, the agency can calculate a predicted plow cost efficiency for the prospective deployment of any combination of the six plow configurations of the agency's choosing. This enables an agency to evaluate cost efficiencies of various deployments of existing plow equipment and also investigate the potential performance of plow equipment not already in their fleet. In this way, an agency can determine what is the most cost efficient plow deployment configuration for a specific plowing route by calculating and comparing the cost of different plowing configurations.

One of the primary goals of this research was to develop preliminary recommendations of roadway types and geometries where the use of tow plows and wing plows is expected to increase and decrease plowing efficiencies. The test plan selected to best accomplish the evaluation plowing efficiencies for various plow types is based primarily on clearing a plow route consisting of various roadway geometries. One of the most consistent DOT survey responses received in this study was the importance of matching

plowing equipment clearing width to roadway geometry. Clearing the width of the roadway is the primary concern, and plowing efficiency is a key dependent factor in any plowing operation. Deploying the minimum amount of resources to maintain the travel way is an essential best practice because it translates into more of the roadway being cleared with a given set of resources, thereby delivering a higher level of service. Good plowing practices may have less to do with how a DOT utilizes a particular plow type and more about constructing the most efficient snow clearing operations based on roadway geometry. The test plan was to develop a methodology that provides a means for an agency to enter plowing routes consisting of various roadway geometries, plowing strategies, and plow types, after which the analytical model translates these parameters into a cost that can be compared to other deployment configurations to establish a quantitative measure of efficiency.

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 3: Recommendations and Test Plan," interim report, Clear Roads project 19-03, November 19, 2020

TASK 4: SIMULATIONS (ROADWAY TYPES/GEOMETRIES)

OVERVIEW

The goal of this task was to develop a computer simulation that calculates the plowing efficiency of the deployment of six plow types (later seven) as related to clearing common roadway types and geometries. The measure of plow efficiency is based on the CR advisory subcommittee-approved comparative efficiency model described in detail in Task 3. The final simulation tool enables DOT users to compare the capabilities of seven plow configurations to clear a specific plow route ranked by their predicted operating costs (efficiency). The scope of this project is to develop a method of quantitatively comparing the efficiencies of the seven designated plow types; the goal is not an expert system that recommends specifically how an agency should deploy plow equipment to clear snow from their highways. The subcommittee and the researchers agree the individual DOTs are best equipped to make such decisions.

METHODOLOGY

The simulation analysis is plow type and plow route-specific. A plow route, in general, consists of an innumerable amount of independent variables, but from the perspective of snow clearing efficiency, the user need only define a few key attributes. The plow route can be represented simply as a set of key roadway geometrics (Nodes) to be cleared, connected by uniform sections of roadway (Segments). The simulation algorithm solves for the necessary plow type(s) or a combination of plow types to clear the entire width of the route at its widest and calculates the corresponding operating cost. The plow operating cost is based on procurement and daily operating costs. The final simulation tool links to data libraries that define the plow equipment performance and cost parameters for the seven plow types as well as specific plow route roadway geometries. The libraries contain default data for all seven plow types and important roadway geometries, all of which can be customized to correspond with DOT-specific parameters. The simulation tool was developed in Microsoft Excel™/VBA.

PRIOR REPORT

Duane Bennett and Ty Lasky, “Measuring the Efficiencies of Tow Plows and Wing Plows - Task 4: Simulation (Roadway Types/Geometries),” plow efficiency simulation report, Clear Roads project 19-03, January 28, 2021

TASK 5: PEER REVIEW OF SIMULATION RESULTS

OVERVIEW

AHMCT provided a copy of the completed simulation tool program to the Clear Roads project subcommittee DOT members for review on March 4, 2021. AHMCT also conducted an online demonstration of the simulation program to instruct the subcommittee on how to use the program and to provide an overview of program's outputs. Several subcommittee DOT state representatives volunteered to serve as peer reviewers to confirm that the simulation results represent what would be expected to occur under real-world operating conditions. AHMCT provided individualized demonstration sessions to each of three requesting state DOT expert groups. AHMCT worked to resolve any concerns identified during these peer review sessions and incorporate acquired information into continued plow measurement of efficiency program development.

METHODOLOGY

The three individualized simulation tool demonstrations conducted with subcommittee DOTs included representatives from the Montana Department of Transportation (MDT), the Idaho Transportation Department (ITD), and the Rhode Island Department of Transportation (RIDOT). The Task 5 report includes a list of comments received that related directly to simulation program development. The list in this report is not the full set of generalized questions or comments discussed in the initial presentation and the individualized DOT demonstration sessions. The simulation tool demonstration review comments can generally be categorized as being related to simulation program use issues, simulation program output methodology, or the overall project objective expectations. The program modifications requested in Task 5 comments included adding two additional wing plow configurations and adding a double wing plow type to the multi-directional plow configuration and cost data libraries.

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 5: Peer Review of Simulation Results," plow efficiency simulation report for completed Tasks 5-7, Clear Roads project 19-03, April 1, 2021

TASK 6: METHODOLOGY FOR EFFICIENCY ANALYSIS

OVERVIEW

The goal of this task was to expand the fundamental plow efficiency methodology to incorporate as many identified key operational considerations of plow efficiency as possible into the efficiency analysis. As defined in this study, plow efficiency is characterized as a comparison among seven designated plow types, with a standard 12-foot front plow as a baseline value. Comparing actual or hypothetical plowing efficiencies enables DOTs to easily visualize their most efficient strategies to deploy plow resources, which could then be translated into cost savings.

METHODOLOGY

Task 6 focused primarily on ensuring the four project designated plowing metrics were incorporated into the efficiency analysis:

1. Time
2. Level of service
3. Labor allocation/optimization
4. Width of pavement cleared in a single pass

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 6: Methodology for Efficiency Analysis," plow efficiency simulation report for completed Tasks 5-7, Clear Roads project 19-03, April 1, 2021

TASK 7: DECISION SUPPORT TOOL

OVERVIEW

The primary deliverable in Task 7 was the development of a Decision Support Tool (DST) in the form of an Excel program that calculates both plowing efficiencies based on real world plowing data and the life cycle costs of plow configurations. The DST expands upon the plow efficiency methodology developed and reviewed by the CR subcommittee in the simulation and other preceding tasks, especially Task 6. The DST provides DOTs with an innovative method of quantifying both plow configuration efficiencies and the true costs of plow configurations throughout the equipment life cycle. These two cost analyses run together using a common set of plow type and cost data in an Excel application. The DST output assists DOTs with calculating a return on investment of the designated plow types based on their state-specific costs and plow configurations. The DST also incorporates modifications based on suggestions made by the subcommittee reviewers in Task 5.

METHODOLOGY

The DST combines two algorithms: (1) the measure of plow efficiency algorithm that calculates cost efficiency by the plow configuration required to clear the full width of a user-specified plow route, and (2) the life cycle cost algorithm that evaluates the cost of plow types throughout the equipment life cycle.

The DST outputs two related calculations. The primary output is the measure of plow efficiency in relation to clearing a specific plow route. The secondary output calculates an Average Life Cycle cost categorized by plow type. These calculations share data contained in plow equipment cost and performance libraries, but some of the data in these libraries is specific to one calculation or the other. The User Interface (UI) home screen of the DST application displays the outputs and various key data values to provide a quick reference to the calculation basis.

The DST program uses the same methodology and algorithm as the Simulation Tool program. The extended capabilities of the DST consist primarily of program modifications that incorporate new requisite features from Tasks 5, 6, and 7. The program modifications requested in Task 5 comments included adding two additional wing plow configurations and adding a double wing plow type to the multi-directional plow configuration and cost data libraries. The primary program modification required by Task 6 was calculating plow route loop times. This change required the addition of average plow speed data in the plow performance data library. Together with the defined plow route combined segment length, the DST computes the average plow route loop time for the user-defined route. The primary program modifications required in Task 7 was the addition of a plow life cycle comparison calculation to the UI.

The plow life cycle comparison automatically estimates the average life cycle cost of each plow type for a user-customizable time period. The plow life cycle cost is useful when calculating a DOT's return on investment as to where to deploy the six designated plow types, and provides an estimate of any

practicable efficiencies related to the investment. To make life cycle (LC) cost comparisons between plow types that may have different service lives, a common frame of reference needs to be established. The DST uses a time-of-use reference frame. This assumes the different plow types are used the same amount over the season, which will not typically be the case. However, generally when DOTs make comparison judgements to decide between purchasing and/or deploying one plow type over another, they often make that judgment in respect to its utility to clear the same plow route(s) assuming the service time interval. The DST program uses the same approach. The LC analysis is based on a common time-of-use reference frame represented as the total number of days used in a normalized equipment life. In this way, the calculated LC average cost values for each plow type can be directly compared.

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 7: Decision Support Tool," plow efficiency simulation report for completed Tasks 5-7, Clear Roads project 19-03, April 1, 2021

TASK 8: BEST PRACTICES GUIDE

OVERVIEW

Task 8 developed a Best Practices Guide to aid state DOTs in determining where to best deploy various plows and configurations to optimize cost-effectiveness and other efficiencies. This Best Practices Guide, a key deliverable for this research, serves as a companion to the DST developed in Task 7.

The Best Practices Guide is available at <https://clearroads.org/project/19-03/>.

TASK 10: DECISION SUPPORT TOOL USER'S GUIDE

OVERVIEW

As the DST was developed and presented to the Clear Roads subcommittee, it became clear that a detailed user's guide would be essential for successful widespread deployment of the DST to multiple Clear Roads DOTs. Consequently, the project subcommittee added a Task 10 to the project scope that creates a DST user's guide. The intent of the user's guide is to enable a DOT user to easily understand the utility of the DST and provide a step by step example of how to utilize the DST to analyze the plowing efficiencies of their specific plowing operations. The Task 10 user's guide consists of an interactive PowerPoint presentation that concisely describes the plow efficiency measurement algorithm, the use of the DST, and how the DST can be utilized to benefit DOT plowing operations. A detailed examination of the DST is available in the Task 7 report: Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Task 7: Decision Support Tool," plow efficiency simulation report for completed Tasks 5-7, Clear Roads project 19-03, April 1, 2021.

METHODOLOGY

The Task 10 DST user's guide was developed to enable a DOT user with highway plowing operations knowledge and access to a specific DOT's plowing operational cost information to conduct various plow route plowing efficiency analyses. The user's guide is a PowerPoint application that uses an interactive multimedia format with action buttons that enables a user to select the areas and depth of information they are interested in viewing. The guide provides a brief overview of the DST, including motivation and benefits. The core of the guide provides text-based description and, where appropriate, accompanying detail videos, for the following aspects of the DST:

- Installation guide
- Adding or revising plow configurations*
- Entering cost information*
- Creating a route*
- Executing a plow route analysis*

AHMCT developed an outline of the user's guide, as well as scripts for the anticipated video segments needed in the user's guide. This draft material was reviewed by the subcommittee, and their feedback was incorporated into the final approach for the user's guide. The subcommittee provided feedback on the draft user's guide. Following this, the subcommittee performed testing of the user's guide efficacy by providing it to uninitiated DOT staff to see if they could install and use the DST. With the resulting feedback from the subcommittee, AHMCT then finalized the user's guide.

PRIOR REPORT

Duane Bennett and Ty Lasky, "Measuring the Efficiencies of Tow Plows and Wing Plows - Decision Support Tool User's Guide," detailed user's guide for completed Task 10, Clear Roads project 19-03, December 31, 2021

CONCLUSIONS AND FUTURE RESEARCH

The fundamental objective of this research was to develop a quantitative measure of plowing efficiency by plow type. A literature search of related research revealed several studies that evaluated a specific DOT's current winter highway maintenance operations. However, references could not be found that attempted to define either a comprehensive measure of plowing efficiency by plow type or establish a methodology for evaluating plowing efficiencies by plow type. Therefore, this research proceeded by creating a suitable measure of plow efficiency by plow type and developing an innovative methodology to quantify the plow efficiencies of dissimilar plow types. The methodology needed a common basis to construct accurate comparisons. Comparisons and trade-offs are key factors to consider when making complex multi-variable decisions, such as deciding which plow type to procure and deploy.

The plow efficiency methodology developed in this study was based on DOT expert subcommittee input. Through a series of program demonstrations, the DOT experts helped to guide the iteration of the methodology into an Excel program that automates the efficiency calculation based on DOT-customizable plow cost and performance data. The final result is the DST, which produces a quantitative comparative measure of plow efficiency for the six designated plow types and a comparative life cycle cost calculation for the four distinct plow types. The DST accuracy is founded on the principles of customizable plow data and normalized comparisons, yielding genuine results that provide a high level of credibility to justify DOT-specific procurement and deployment decisions. A companion Best Practices Guide was also created that describes potential uses of the DST by DOTs to help guide their decision process to enhance their plowing operational efficiencies. When used together, these tools can assist DOTs in qualitatively and quantitatively identifying best road areas and geometries for deployment of tow plows and wing plows and in analyzing their return on investment. Finally, the DST User's Guide will facilitate successful widespread deployment of the DST to multiple Clear Roads DOTs.

Future development of the DST would benefit by the inclusion of roadway surface treatments into the plow efficiency methodology. The application of granular and deice roadway treatments are key factors that DOTs consider when configuring and deploying plow equipment. Some plow types include the capability of transporting and spreading surface treatments, some do not. Vehicle weight, traction, and policies like diminishing loads can guide selection of which plow types to include in the DST efficiency analysis. The scope of this research did not include this key variable. In future work, the DST program could be extended to include a surface treatment metric.



research for winter highway maintenance

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