Understanding the True Cost of Snow and Ice Control

Parsons Brinckerhoff

research for winter highway maintenance

Project 98247/CR10-03
January 2014

Pooled Fund #TPF-5(218)
www.clearroads.org

PARSONS BRINCKERHOFF

Understanding the True Cost of Snow and Ice Control

A Clear Roads Research Project: 10-03

CLEAR ROADS

January 29, 2014

Submitted by:
Parsons Brinckerhoff
510 First Avenue North, Suite 550
Minneapolis, MN 55403
(612) 371-0443

Technical Report Documentation Page

<table>
<tr><td colspan="2">1. Report No.</td><td colspan="2">2. Government Accession No</td><td colspan="2">3. Recipient's Catalog No</td></tr>
<tr><td colspan="4" rowspan="2">4. Title and Subtitle
Understanding the True Cost of Show and Ice Control
A Clear Roads Research Project: 10-03</td><td colspan="2">4. Report Date
January 29, 2014</td></tr>
<tr><td colspan="2">5. Performing Organization Code</td></tr>
<tr><td colspan="4">7. Authors
Andrew Cadmus & David Rose</td><td colspan="2">8. Performing Organization Report #</td></tr>
<tr><td colspan="4" rowspan="2">9. Performing Organization Name & Address
Parsons Brinckerhoff, Inc.
510 First Avenue North, Suite 550
Minneapolis, MN 55403</td><td colspan="2">10. Purchase Order No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
98247</td></tr>
<tr><td colspan="4" rowspan="2">12. Sponsoring Agency Name & Address
Clear Roads Pooled Fund
Minnesota Department of Transportation
395 John Ireland Blvd
St. Paul, MN 55155-1899</td><td colspan="2">13. Type of Report & Period Covered
Final Report, 2012-2014</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="6">15. Supplementary Notes</td></tr>
<tr><td colspan="6">16. Abstract
Understanding the True Cost of Snow and Ice Control (10-03) was a Clear Roads research project to identify methods to better manage winter maintenance, identify the cost of winter maintenance, and more effectively communicate its true cost. Through the analysis of existing state winter maintenance data and research, this project resulted in a report documenting the research results and recommendations for improved data collection, and the True Cost Tool. The True Cost Tool is innovative Excel based tool that can be used to collect winter maintenance data, store data entered for future analysis, and provide quick estimates and comprehensive summaries of costs by lane-mile and level of service achieved on maintained roadways. It also has supporting tools that allow users to compare storm events and costs, and supports what-if scenario testing. This tool is a prototype of a proposed future web-based tool for broader use.</td></tr>
<tr><td colspan="3">17. Key Words
Winter; Maintenance; Show; Ice: Data; Financial; Model; Best Practices; Storm Data; Clear Roads; Cost; Cost Analysis.</td><td colspan="3">Distribution Statement
No restriction. This document is available to the public through the Clear Roads Organization and the Minnesota Department of Transportation.</td></tr>
<tr><td colspan="2">19. Security Classification (this report)
Unclassified</td><td colspan="2">20. Security Classification (this page)
Unclassified</td><td>20. No. of pages
28</td><td>21. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Report of completed page is authorized

Table of Contents

1 Introduction

Understanding the True Cost of Snow and Ice Control (10-03) is a Clear Roads research project to identify methods to better manage winter maintenance, identify the cost of winter maintenance, and more effectively communicate its true cost. State Departments of Transportation (DOT) across the country have experienced stagnant or declining road maintenance budgets, while costs have continued to increase. In addition, many DOTs have been confronted with a policy and fiscal environment in which it is imperative to provide timely storm data and winter maintenance costs.

Clear Roads initiated this research project to mitigate these challenges through:

1. Having more data driven management – linking the level of effort or work performed to the results and Level of Service (LOS) achieved.
2. Improving efficiency and effectiveness of winter maintenance efforts – measuring efficiencies to make comparisons across regions/states and identify best practices.
3. Better understanding and communicating costs of keeping roads open and to a specific level of service – providing critical information to policy makers to support decisions.

To achieve these objectives, the research team evaluated available data from several states in order to establish a strategy for identifying the cost of work performed during a storm event. Linking the work performed to the level of service achieved during a storm event would provide valuable data on which to base decisions, identify efficiencies, and more easily communicate the true cost of winter maintenance.

During the evaluation of state data, gaps were identified that prevented the research team from linking the cost of work performed during a storm event to the level of service achieved. This is because many state DOTs have separate financial and maintenance management systems that track costs and work performed in different ways. While the financial systems track cost incurred by an agency, it does not typically track materials, equipment, or labor in a way that can be linked to a storm or roadway. Maintenance Management Systems may track work orders and quantities for materials and equipment, but do not always tie the actual work performed directly to the financial system.

These data gaps provided the research team an opportunity to evaluate the data collection efforts of state DOTs, and recommend improvements. Maine's data set was selected for this case study due to relative completeness of data and consistent participation on the team (Section 2 of this report). The review of Maine's sample data resulted in a number of recommendations for all states which includes: a checklist for data collection, recommendations for recording data, and an overview of how data should be stored in a relational database for analysis (Section 3 of this report).

Though the data gaps limited the team's ability to fully achieve all three objectives above based on historical data, the team developed an innovative tool that can be used to achieve the objectives as new data is collected. The True Cost Tool is an Excel based tool that supports data collection, stores data entered for future analysis, and provides quick estimates and comprehensive summaries of costs by lane-mile and LOS achieved. It also has supporting tools that allow users to compare storm events and costs; and supports what-if scenario testing. This tool is discussed in detail in Section 4 of this report.

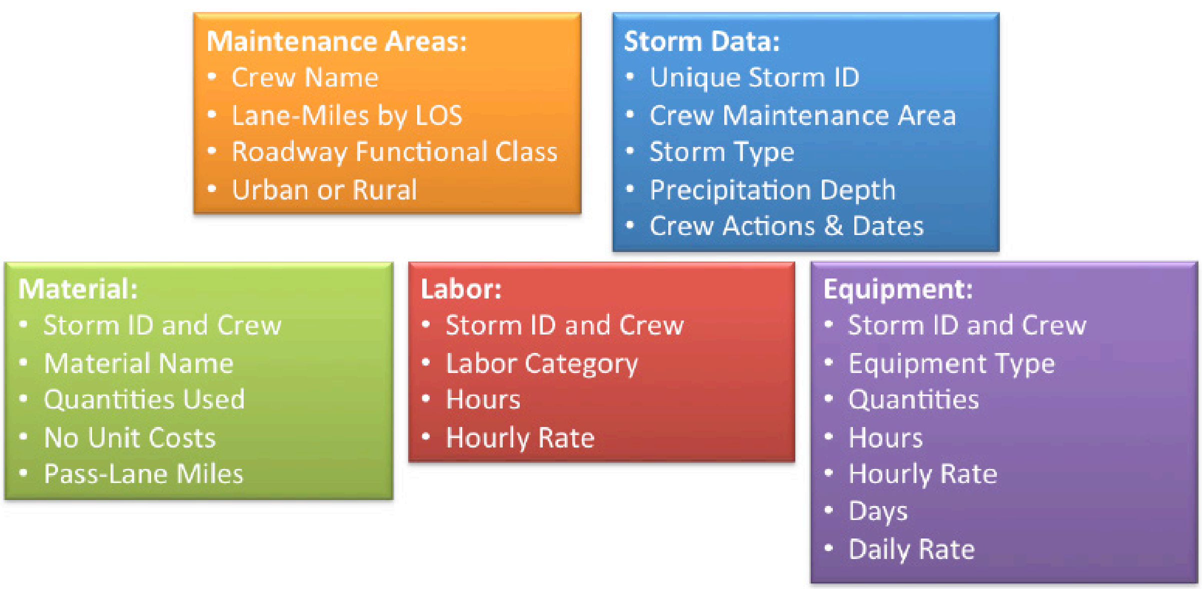
Due to the data gaps identified during this study, the True Cost Tool and supporting data recommendations in this report are only the first steps in accomplishing all of the objectives the Clear Roads Team developed. Next steps include:

1. Develop Data Collection Methodology
2. Develop Web-Based Tool
3. Perform Data Collection by States
4. Consolidate Data and Do Statistical Analysis
5. Compare Aggregated Data
6. Draw Conclusions and Present Result

2 Initial Data Review & Analysis

In collaboration with Parsons Brinckerhoff, the Clear Roads Team analyzed data from its member states in order to establish a strategy for identifying the cost of work performed during a storm event and link the work performed to the level of service achieved. To facilitate the analysis, the Clear Roads Team included a panel of winter maintenance professionals including active state DOT representatives from Kansas, Maine, Massachusetts, Minnesota, Utah, Virginia, Washington, and Wisconsin. These DOTs provided winter storm maintenance and cost data with varying levels of detail. Of the states that provided data, Maine shared the most comprehensive dataset. The data set included extensive expenditure data for calendar year 2011 along with storm data, work plans, and material application guidelines. Although Maine's dataset had a large number of storm events with many details, it was still insufficient to link work performed and costs to level of service achieved. Figure 1 below is a representation of Maine's data set and how it is organized. This discussion below includes an analysis of Maine's data, descriptions of how it is organized, and conclusions regarding its use in this research project.

Figure 1 - Maine's Data Set



2.1 Current Data Set

Maine provided several Microsoft Excel files containing data extracted from various databases. This format provides the team with a high degree of flexibility; however, Microsoft Access or other database files would also suffice. For the purposes of the analysis, the team organized the data into categories: Maintenance Areas, Storm Data, Materials, Equipment, and Labor.

Maintenance Areas:

The Maintenance Database file contains data that uniquely identifies a crew maintenance area and quantifies total miles of roadway, lane-miles by LOS category, whether the area is urban or rural, roadway functional class, and jurisdiction.

Contents: The content of the file is sufficient to provide data needed for maintenance area analysis.

Data Integrity: All data in this file is objective and quantifiable.

Format: The format of this data is sufficient for analysis.

Storm Data:

This file contains data regarding each winter storm that impacted the state. Each storm has a unique storm identification number and each line item has the region name and crew name needed to specifically identify the impacted area and who completed the work. Further, storm data includes an open field description, storm type, precipitation depth, start and end dates, crew action taken, and the start and end dates of the action.

Contents: The content of the file is sufficient to associate a storm to the impacted region. However, the duration of the storm in hours would provide significant benefits. The cost of a storm is likely to be related to its intensity, so using the combination of precipitation amount and duration may provide important insights into costs.

This file should also include the pass lane-miles by level of service category. This data is critical to calculating the cost of a lane-mile for a particular level of service category.

Data Integrity: Some storm start and end dates are multiple months apart, which may be due to the fact that the dates are based on when the storm charge code is opened and closed. As a result, the closing of a storm account is somewhat subjective and may be prone to error. For cost analysis the storm start/end date and time would provide more benefit than charge code opening/closing date.

The field for storm 'description' may be valuable for management to understand unique challenges or situations for a particular storm, but the field cannot be used in an analysis due to its unrestricted format. Many crews use their own format to input quantities used, temperatures, and/or precipitation type. If these crews find this information valuable, separate and structured data fields should be provided to capture this information. The description field should only be used for data that cannot be input in a standardized way.

The 'storm type' field allows users to input multiple precipitation types in one field. While the selection is structured, the concatenation of these storm types creates analytical challenges. It is usable, but we recommend either having a separate field for each storm/precipitation type or requiring the user to only select the most prominent condition.

Format: The format of this data is sufficient for analysis, however, revising the structure of 'storm type' and providing additional fields to structure the information crews are placing in the 'description' field would improve the format for the desired analysis.

Materials:

The "MATS" database export file contains quantities of materials used by crew for each storm event and total material cost. However, the file does not contain the unit costs of each type of material or subtotals for material costs, leaving the file incomplete for documenting these costs. The file also contains more than just material data, it also includes total pass lane-miles (not broken out by LOS category), total labor cost, and total equipment cost. While these additional data points are valuable, they may be more appropriately placed in a different file with additional details.

Contents: The content of the file alone is insufficient for an analysis of material costs. Unit costs are needed to break down the total material costs. Fortunately, Maine was able to provide unit costs for specific materials in separate files allowing us to roughly associate costs.

Data Integrity: All data in this file is objective and quantifiable. Material unit costs should be integrated to ensure data integrity.

Format: The format of this data is sufficient, but the integration of unit costs would improve usability.

Equipment

Maine's database has a custom query tool for extracting equipment class, unit costs, and quantities, organized by crew number and storm number. Furthermore, this file contains pass lane-miles for each equipment class and piece of equipment, which is extremely detailed and useful. However, it does not relate the pass lane-miles to LOS. This data only allows us to relate equipment costs to storm events.

Contents: The file contains all the information needed to relate labor costs to crews and storms. However, it does not allow us to relate pass lane-miles and cost to LOS.

Data Integrity: All data in this file are objective and quantifiable.

Format: The format of this file is simple and easy to use in analysis.

Labor:

The "FACT2" database file contains all labor, overhead, training, benefits, and overhead costs. Additionally, it contains total costs for salt, sand, rental of equipment, fuel, and other miscellaneous items. This data is organized by crew maintenance area, but does not relate expenses to specific winter storm events. As a result, it could not be integrated with the other aforementioned datasets. After conversations with Maine's database programmers, they were able to provide a new file through a custom query which provided labor class, hours, hourly rate, unique storm number, and unique crew number. This data enabled us to directly relate labor costs to storm events.

Contents: The customized file contains all the information needed to relate labor costs to crews and storms.

Data Integrity: All data in this customized file are objective and quantifiable.

Format: The format of this customized file is simple and easy to use in analysis.

2.2 Conclusions

Overall, Maine's data is comprehensive, but lacks two critical links. Primarily, it lacked data to directly link assumptions regarding the number and intensity of storms to cost, and directly link level of service to lane-mile costs. These objectives required historic data regarding the lane-miles of work performed (pass lane-miles), level of service accomplished during a storm event, and storm characteristics. Since there were not any data collected regarding the number of pass lane-miles of work accomplished by level of service during a storm event, and storm characteristic data were incomplete or inconsistent, it was not possible to determine the relationship between LOS, storm intensity, and cost. This analysis illustrates the strength and limitations of Maine's dataset and uses this data as reference point for recommendations.

3 Data Collection

The team learned several lessons from the initial analysis of data sets from surveyed DOTs. Primarily: "What data should be collected?" and "How should the data be stored in order to facilitate data analysis?" Below are a list of recommendations for all DOTs, a checklist of data fields recommended for collection, and an illustration of a sample database for storing this data.

3.1 Recommendations for All States

The following is a list of recommendations to improve data collection and support the linking of the following data: storm event, work performed, cost, and level of service achieved. The linking of this data will allow analysis necessary to reach the original objectives of this research study.

- Assign a unique identification number to each winter storm.
- Assign a unique identification number to each region and crew.
- Ensure that all costs and data fields are relatable per storm event:
    - If a unique storm identification number is assigned to an event at the regional or crew level, this can act as the key relating tables. In other words, all costs and work should be assigned to the storm identification number.
    - If a unique storm identification number is not specific to a region and crew (used to describe a storm passing over multiple regions/crews), then storm, crew, and region must all be used. In other words, all costs and work should be assigned to a storm number, crew number, and region number.

- Record storm characteristics uniformly.
    - Crew region area
    - Precipitation amount
    - Precipitation type
    - Duration of storm in hours
    - Date and time storm begins
    - Pavement temperature (optional)
    - Air temperature (optional)
    - Accumulation (optional)
- Reduce the use of unstructured fields so that data can easily be sorted and analyzed. Create unique and structured fields for each type of data.
- Record the number of lane-miles in the crew area by LOS desired.
- Record the pass lane-miles accomplished during each storm event by LOS category. Relating this data to equipment and material used would be ideal.
- Record unit costs, quantities and total costs of labor, equipment, and materials.
- As expenses are recorded, assign them to a storm number, and crew/region number. The combination of storm, crew, and region will become the key linking these different types of data if recorded in separate tables.
- Don't concatenate data fields.

3.2 Checklist

Below is a checklist of data fields identified as necessary to accomplish the objectives of this research project. Variations in terms, and specific characteristics may be necessary to accommodate other DOTs' needs. For example, Maine charges equipment use on both an hourly and daily basis. Other states may only use one method. Similarly, Maine uses Regions and Crews to divide its maintenance areas while other DOTs may use Districts or Counties.

Table 1: Data Checklist

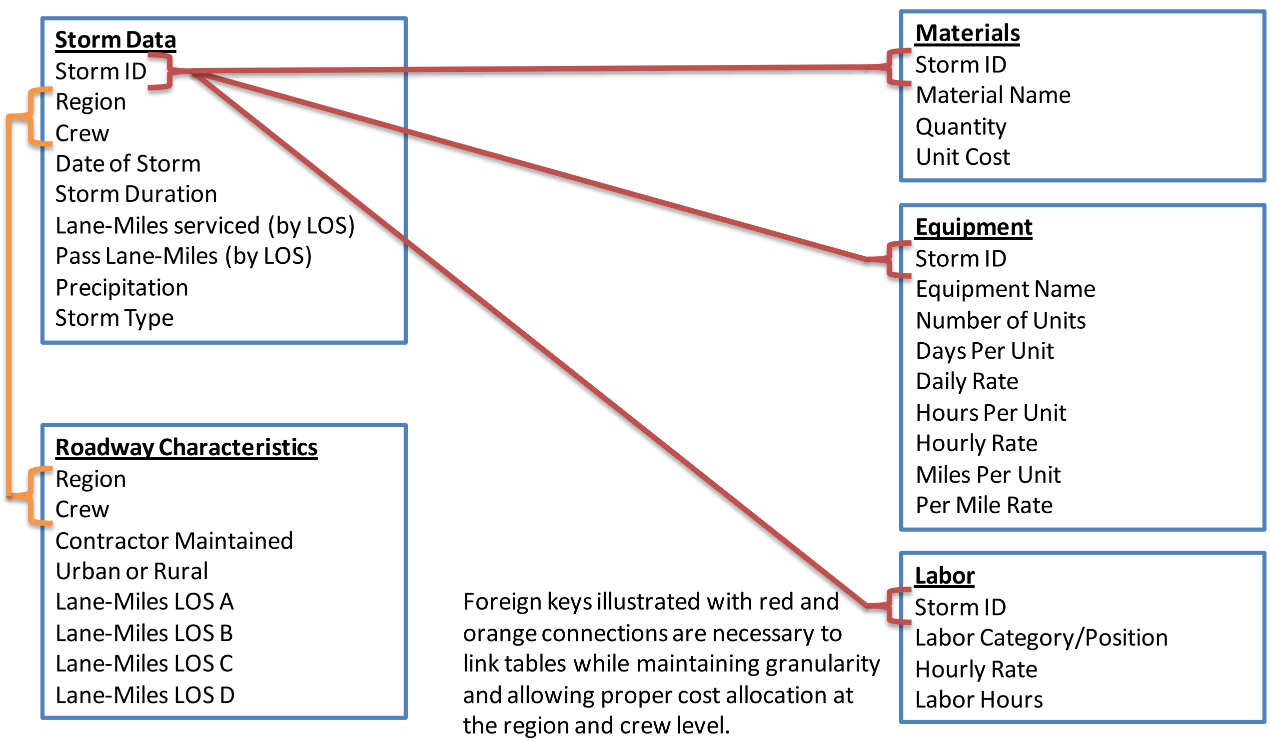
Variable	Unit	Check
Storm Characteristics		
Storm ID Number	Name	☐
Date of Storm	mm/dd/yyyy	☐
Lane-Miles Serviced (By LOS Classification)	Lane-miles	☐
Pass Lane-Miles (By LOS Classification)	Lane-miles	☐
Storm Duration	Hours	☐
Precipitation (equivalent liquid)	Inches	☐
Storm Type (predominant type)	Type	☐
Roadway Characteristics		
District Identification Number	Number/Code	☐
Crew Identification Number	Number/Code	☐
Contractor Maintained	Yes/No	☐
Urban vs. Rural	Urban/Rural	☐
Lane Miles (By LOS Classification)	Lane-miles	☐
Materials		
Material Name	Name	☐
Quantity	Unit	☐
Unit Cost	Dollars	☐
Equipment		
Equipment Name	Name	☐
Number of Units	Count	☐
Days per Unit	Days	☐
Hours per Unit	Hours	☐
Daily Rate	Dollars	☐
Hourly Rate	Dollars	☐
Miles per Unit	Miles	☐
Per Mile Rate	Dollars	☐
Labor		
Labor Category/Position	Name	☐
Hourly Rate	Dollars	☐
Number of Positions	Count	☐
Labor Hours	Hours	☐

3.3 Sample Relational Database

To effectively manage the data identified in the checklist, the data should be stored in a manner that facilitates future analysis. A relational database can serve as a means of storing data effectively. The following illustrates one way to relate storm and roadway characteristics to costs. The sample database below creates a framework to store, view, and analyze data collected. It attempts to simplify the complex data most DOTs collect to illustrate the relationships necessary for the data analysis required to meet the objectives of this research project.

Ideally, a unique storm ID would be assigned for each storm event within in each region and crew area. This was the assumption in designing the database below. However, if a Storm ID is not unique to an event, region, and crew, all three would need to be recorded within each table. It is also assumed that the table "Roadway Characteristics" is a static table of data describing each region, and thus is not necessary to relate directly to Storm ID, but instead links to the Storm Data table.

Figure 2: Sample Relational Database



4 Tool Development

As stated earlier, many states have separate financial and maintenance management systems that track costs and work performed in different ways. While the financial systems track cost incurred by an agency, it does not typically track materials, equipment, or labor in a way that can be linked to a storm or roadway. Maintenance Management Systems may track work orders and quantities for materials and equipment, but don't always tie the actual work performed directly to the financial system.

The intended purposes of these two systems are different, and don't provide a comprehensive perspective on storm maintenance costs. Further, they are often not readily accessible with timely information during or immediately after a storm event. Existing systems do not typically have the ability to quickly estimate the cost of a storm, create what-if scenarios to predict how unit cost changes may affect annual budgets, and do not effectively summarize data to identify cost drivers. Additionally, DOTs desire to better understand their winter maintenance costs and trends across regions and states in order to identify cost effective policy improvements or LOS adjustments.

4.1 Objective

The objectives of this tool are listed in Table 2. All objectives are marked as met ✓, partially met ~, or require more data to be met ■. Some of the original objectives required historical data that was not available; this limitation is further discussed in the Data Analysis and Limitations section below.

Table 2: Objectives Accomplished

Clear Roads Objective	True Cost Tool
(A) Perform what-if scenario testing on unit costs	✓
(B) Communicate cost drivers to policy-makers and the public	✓
(C) Allow managers to better understand and manage costs	✓
(D) Compare winter maintenance costs across storms, districts or regions, and states	✓
(E) Facilitate evaluation of cost effectiveness of winter maintenance policies	~
(F) Compare contracted vs. state maintenance	✓
(G) Compare winter maintenance costs across time	✓
(H) Directly link assumptions regarding the number and intensity of storms to cost	■
(I) Directly link levels of service to lane-mile cost	■

4.2 Data Analysis and Limitations

As mentioned earlier, the Clear Roads Team met many of the original objectives, however due to data limitations, two were not achieved: 1) to directly link assumptions regarding number and intensity of storms to cost and 2) to directly link level of service to lane-mile costs. Both of these objectives required the analysis of a large datasets from multiple states in order to identify patterns and a statistically significant relationship between variables.

Historical data collected by each state were consistent with their individual needs; therefore, no two states had similar datasets. Work plans varied widely in scope across states as did definitions of level of service and other data fields. Additionally, data within some states were collected inconsistently rendering it unreliable.

Maine provided extensive expenditure data, and while the expenditure and storm data were useful for much of the analysis, inconsistent or incomplete data prevented the Team from achieving some objectives. The team was unable to (1) directly link assumptions regarding the number and intensity of storms to cost and (2) directly link LOS to lane-mile costs. These unmet objectives require historic data regarding the lane-miles of work performed (pass lane-miles), level of service accomplished during a storm event, and storm characteristics. Since there were not any data collected regarding the number of pass lane-miles of work accomplished by level of service during a storm event, and storm characteristic data were incomplete or inconsistent, it was impossible to find a reliable relationship between LOS, storm intensity, and cost.

With these data limitations, a tool was developed to meet the remaining achievable objectives. This tool was also created with the ability to collect and save the data needed to fill in the current data gaps so that the previously unmet objectives can be addressed in the future. It is believed that with this data generated over a season, and across multiple states, all the remaining objectives could be met in a future research study.

Clear Roads Objective	True Cost Tool
(H) Directly link assumptions regarding the number and intensity of storms to cost	■
(I) Directly link levels of service to lane-mile cost	■

4.3 Proposed Approach Overview

With the known data limitations, two approaches were proposed: a Bottom-Up approach and a Top-Down approach. Two prototype models were developed to demonstrate each approach and their results. This allowed the Clear Roads Team to evaluate each approach based on their priorities and provide the research team with additional direction. These prototype models were developed as described below:

Top-Down Approach

The Top-Down approach uses historical data to identify trends in costs through a statistical analysis which is then applied to predict future costs. Independent and dependent variables were identified in order to construct a regression model and determine the relationships between inputs. An independent variable is a data field which does not change as a result of other data; e.g. precipitation amount or temperature. A dependent variable is a data field which may change as other variables change: e.g. material cost or labor hours. One advantage of this approach is that it captures the effect of variables that were not specifically recorded in the dataset. For example, the prototype model has a field for "Type of Storm" in which the user can specify whether the precipitation was wet or dry snow. If a storm with dry snow typically incurs additional costs due to drifting, the cost associated with drifting will be captured within the variable "Type of Storm" without having to have an additional variable specifically for drifting. Through the use of high level metrics, the prototype model's inputs can be simplified while still generating accurate results. Given adequate data, this approach has the best chance of meeting all of the Team's objectives by statistically relating cost to labor, equipment, materials, storm characteristics, and possibly policies.

As developed, the Top-Down approach was calibrated with Maine's expenditure data and yielded a comprehensive cost estimate per lane-mile with minimal inputs.

Table 3: Top-Down Approach

Top-Down Approach Inputs & Outputs
Inputs
Region
Percent of the Route that is Urban
Winter Severity Index
Month
Storm Precipitation Depth
Storm Duration
Ground Temperature
Type of Storm (Wet snow, dry snow, etc.)
Total Lane-miles Serviced
State or Private Contractor Service
Lane-miles Serviced by LOS
Outputs
Total Labor Cost by Lane-Mile
Total Equipment Cost by Lane-Mile
Total Materials Cost by Lane-Mile
Total Cost by Lane-Mile
All of the Above by LOS Category
State vs. Contractor Cost

The gray inputs and outputs would only be available if sufficient historical data were presented (currently not available). Additionally, this model requires calibration using a state's historical data. If this methodology were selected, additional historical data would need to be collected for each state, as discussed in the Data Analysis and Limitation section of this report.

Bottom-Up Approach

The Bottom-Up approach is different than the Top-Down as it does not use historical data to predict future costs. Instead it requires inputs of unit costs and quantities to estimate the cost of a storm. This method requires that the user be familiar with the amount of work needed to complete winter maintenance tasks and has data on the amount of work or work standard to be accomplished. By multiplying user defined data by unit costs, total costs of materials, equipment, and labor are calculated.

The Bottom-Up approach yields a robust cost estimate tool that is capable of modeling multiple maintenance scenarios. The output of this tool includes a clear breakdown of costs by category and cost per lane-mile for any described service area. Cost drivers are easily identified, and the user can change individual items to perform what-if analyses. This is valuable in the analysis of historical storm costs once data is available or understanding how unit cost changes can affect future storm costs. A significant advantage of this tool is that it does not need to be calibrated for a specific state. However, the cost estimate is highly dependent on the accuracy of numerous user inputs.

Preferred Approach

After presenting both models to the Clear Roads Team, the Bottom-Up approach was selected as the preferred methodology given the data available to a majority of the states. The Clear Road Team believes that the Bottom-Up approach will be more useful than the Top-Down approach during storm events. After storm events have occurred and the data has been entered into the tool, the tool can serve as a platform for quickly creating an estimate of costs, what-if scenarios for future storms, identifying cost drivers, and analyzing effects of unit cost changes. The Clear Roads Team also identified uniform data collection as a priority so that states can share data and future analyses can meet remaining objectives. As a result, the Team requested that the Bottom-Up approach be combined with a way to collect data required to perform the analysis discussed in the "Data Analysis and Limitations" section of this report. This data entry tool will gather the necessary inputs in a standardized format so that all of the objectives can be met in a future study.

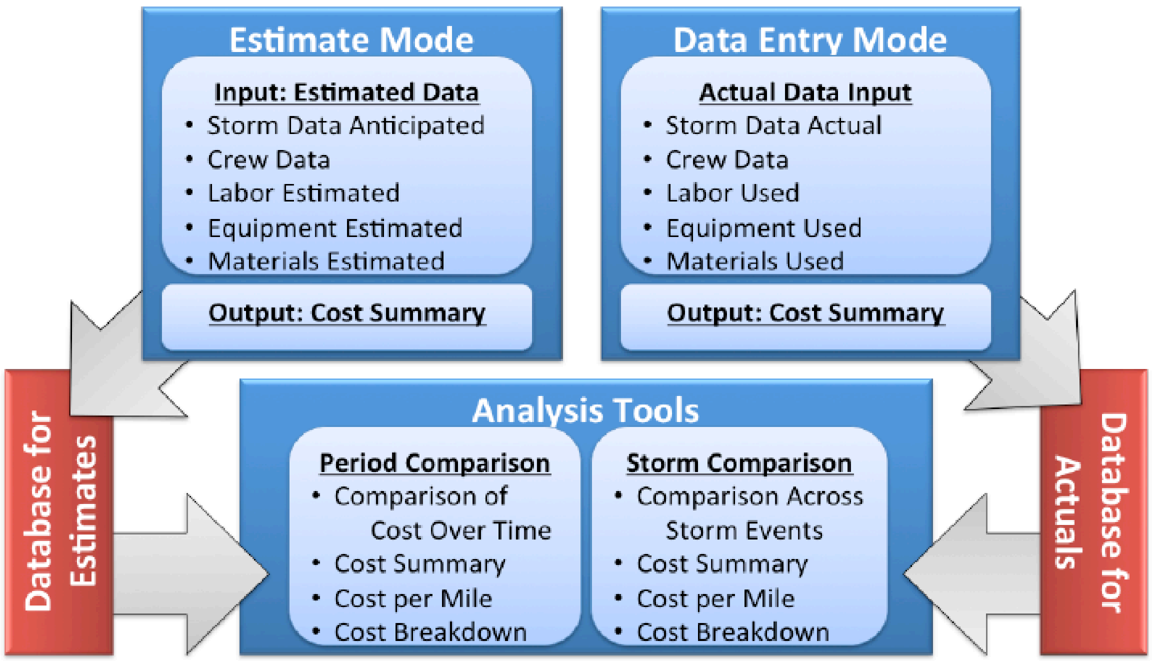
4.4 True Cost of Winter Maintenance Estimate & Data Entry Tool

The True Cost Tool was developed through an interactive and iterative process of prototype tool development and evaluation by the Clear Roads Team. The resulting tool is flexible and can:

- Accommodate any storm type, equipment, materials, and labor category without calibration
- Save storm data to a database
- Estimate storm costs with user defined data
- Perform what-if analyses by varying inputs
- Assist users with identifying cost drivers
- Produce storm report summaries to communicate costs
- Compare storm costs and characteristics
- Assist users with evaluating impacts of policies on cost
- Compare storms across time periods
- Compare storms across contract types

To achieve the objectives of the study, the True Cost Tool has two modes: (1) Estimate Mode, and (2) Data Entry Mode. There are also two analysis tools provided: (1) Storm Comparison Tool, and (2) Period Comparison Tool. These four features are illustrated in Figure 3 and discussed in detail below relative to the Team's objectives.

Figure 3: Overview of the True Cost Tool



Estimate Mode

The Estimate Mode is used to estimate a storm's cost with imperfect data, perform what-if analyses, and explore cost drivers. The variables for the estimate are illustrated in Table 4, and include storm characteristics, estimated quantities for labor, equipment, and materials, and estimated unit costs. The inputs are then used by the tool to calculate storm costs which are summarized on the output sheet. The input pages and final summary sheet can also be easily printed. After an estimate has been completed, the user has the option to save the data into a database so that it can be accessed at a later date and compared to other actual or estimated costs.

The Estimate Mode can be used to estimate a forecasted storm, or obtain an estimate of a current/recent storm for which the official data is not yet available. Furthermore, a user can input a previous storm's data and change unit costs or quantities to observe how they affect total costs. In this way, a user can create what-if scenarios. For example, if a DOT received a new bid for salt unit costs for the next season, the winter maintenance manager could test how the new unit costs would have affected total costs of previous storms. Additionally, the maintenance manager may decide to create scenarios in which the DOT supplants some salt use with plowing to determine if the total costs could be reduced. The ability to quickly perform what-if analyses can improve a winter maintenance manager's ability to manage and understand cost drivers, evaluate bids, and better communicate the effects of changes to others.

Clear Roads Objective	True Cost Tool
(A) Perform what-if scenario testing on unit costs	✓

Table 4: List of Variables in Tool

Variable	Type of Variable	Unit
Assumptions		
Storm ID Number	Input	Name
Private Contactor	Input	Yes/No
Maintenance Area Lane-miles	Input	Lane-miles
Urban vs. Rural	Input	Urban/Rural
Lane-miles Serviced	Input	Lane-miles
Pass Lane-miles Accomplished	Input	Lane-miles
Storm Characteristics		
Storm Duration	Input	Hours
Precipitation	Input	Inches
Storm Type	Input	Type
Materials		
Quantity	Input	Unit
Unit Cost	Input	Dollars
Materials Cost	Output	Dollars
Equipment		
Number of Units	Input	Count
Days per Unit	Input	Days
Hours per Day	Input	Hours
Daily Rate	Input	Dollars
Hourly Rate	Input	Dollars
Miles per Unit	Input	Miles
Per Mile Rate	Input	Dollars
Equipment Cost	Output	Dollars
Labor		
Hourly Rate	Input	Dollars
Positions on Crew	Input	Count
Number of Days on Job	Input	Days
Hours Worked per Day	Input	Hours
Labor Costs	Output	Dollars
Total Cost		
Total Cost of Maintenance	Output	Dollars
Cost per Crew Maintenance Area Lane-miles	Output	Dollars
Cost per Lane-miles Serviced	Output	Dollars
Cost per Pass Lane-mile	Output	Dollars

Data Entry Mode

The Data Entry Mode is used to enter actual storm characteristics, resource quantities, and unit costs. Data in this mode should only be entered after a storm event has been cleared and all quantities and unit costs have been realized. As with the Estimate Mode, data can be saved into a separate database for actual data. Reports can be generated from this mode which combines storm characteristics with labor, equipment, and materials, unit costs, and quantities to better communicate the true cost of winter maintenance to management, decision-makers, and the public. Cost drivers will also become apparent through the cost breakdown summary, helping managers better understand and manage costs. Furthermore, this data will enable both direct storm comparisons and aggregate storms comparisons across time and contract types.

Clear Roads Objective	True Cost Tool
(B) Communicate cost drivers to policy-makers and the public	✓
(C) Allow managers to better understand and manage costs	✓

Storm Comparison Tool

The Storm Comparison Tool allows for the retrieval of saved storm event data and displays them side-by-side. The tool can retrieve estimates from either the Estimate Mode database or the Data Entry Mode database, allowing for the comparison of what-if scenarios and/or actual storm event data. The comparison of storm events allows the user to hone in on cost differences and identify the cause. For example, comparing similar storms in two different regions may indicate that one crew is working more efficiently or has better equipment. Another potential answer could be that one of the crews was a state maintenance crew while the other was a contracted crew. The Storm Comparison Tool does not directly indicate the cause for cost differences, but it provides a framework for a comparative analysis. As more data is recorded in the database, trends will be more easily perceived. However, the data will require further analysis to draw high level comparisons.

Once databases are populated with actual/realized event data, states can share that data with others and compare estimates in a single standard format. The uniformity of the data will enable a robust analysis of all variables collected in the future. Such a study will shed more light on the impact of unit costs and maintenance policies on total costs.

Clear Roads Objective	True Cost Tool
(D) Compare winter maintenance costs across storms, districts or regions, and states	✓
(E) Facilitate evaluation of cost effectiveness of winter maintenance policies	~

Period Comparison Tool

The Period Comparison Tool can also process the rich data saved over time by the Tool to create both annual and monthly summaries; comparing up to four periods at a time. The summaries can be further refined to only display data related to state maintenance crews, contractors, or both.

These summaries will be useful to both managers and policy-makers. This tool allows managers to assess how costs change over time and how different operators (state or contractor) compare at an aggregate level. Examples include changes in labor costs from month to month and side by side comparisons of costs incurred by contractors and state employed crews. These summaries give managers a high level overview of costs and provide a framework for communicating costs to policy-makers.

Clear Roads Objective	True Cost Tool
(F) Compare contracted vs. state maintenance	✓
(G) Compare winter maintenance costs across time	✓

Objectives Met and Limitations

The objective of this tool is to provide agencies with the ability to quickly and easily estimate the cost of a storm. The tool has been designed to show how unit costs affect total costs and to estimate a storm's total cost. Additionally, the tool provides a framework to compare storms and costs across states, contract types, and time. By using the database and summary sheets, cost comparisons can easily be generated and shared with decision-makers, managers, other states, or the public. The True Cost Tool does not forecast costs based on the LOS inputs on the Assumptions sheet. However, these data are instrumental for analysis and comparison of storm events. The collection of this data is critical to future cost analysis. That is, by requiring the user to enter LOS data, future analysis will be able to relate LOS to cost more directly.

4.5 Lessons Learned

State DOTs operate in a fiscally constrained environment where the importance of winter maintenance data has increased. Through this effort, the Clear Roads Team has determined that the reporting of data is a critical aspect for the determination of true winter maintenance costs. Specifically, the Team identified the data needed to evaluate how changes in budgets can impact the level of service DOTs can provide.

Through this study, the Team discovered that winter maintenance data collection and presentation should be standardized. Currently, the practices employed to report data varies by state and makes analysis and comparison of winter maintenance cost performance difficult. The tool, as described above, provides a framework for standardized data collection and presentation.

To make comparisons between states and to determine how budgets affect the LOS an agency can provide, states will have to collect additional data. Specifically, data regarding the number of lane-miles of work accomplished by LOS (or pass miles) will need to be reported. The True Cost of Winter Maintenance Estimating & Data Entry Tool has been designed to capture the data needed to conduct a rigorous analysis using regression modeling. This will enable the Team to discover the cost per LOS pass lane-miles and give the Team the necessary parameters to evaluate the true cost of winter maintenance per LOS lane-mile.

To compare event costs directly, common units for cost are needed. One of the most effective ways to compare costs is through cost per pass lane-mile (or lane-miles of work performed during a storm event). By determining the cost per pass lane-mile by LOS for many states, best practices and policy decisions can be better analyzed.

5 Next Steps

Due to the limited data, the True Cost Tool is only the first step in accomplishing all of the objectives the Clear Roads Team has developed. Over the course of this research project, the Team has identified a series of steps required to achieve the final objectives. These steps include:

1. Develop Estimation Tool (DONE)
2. Develop Data Collection Tool (DONE)
3. Develop Data Collection Methodology
4. Develop Web-Based Tool
5. Perform Data Collection by States
6. Consolidate Data and Do Statistical Analysis
7. Compare Aggregated Data
8. Draw Conclusions and Present Results

The first two steps have been completed as part of this study. The remaining steps are discussed below.

5.1 Data Collection Methodology

While some states collect the total number of pass lane-miles, they do not include the LOS in the data. The current methodologies employed by states to collect the number of pass lane-miles accomplished should be studied. After the current systems of data collection are understood, a methodology to capture pass lane-miles by LOS data can be developed and shared with all Clear Roads Team members. This uniform methodology will need to be developed so that agencies can easily track and record the number of pass lane-miles by LOS for future analysis. Further, this methodology should be applied to other types of data collection in which integrity may be an issue. For example, if everyone measures precipitation in a different way, the data will not be reliable for comparison.

5.2 Web-Based Tool

The Excel format of the True Cost Tool as developed, is a self contained file and does not facilitate sharing data which can lead to version control problems. It will be necessary to develop a more accessible and robust platform for the tool and database to operate on if the

True Cost Tool is to be used by multiple users within an agency. A web tool will also provide more functionality and a friendlier user interface.

The web-based tool should also integrate a data import feature so that historical data states have already collected can be used. However, if not all data fields are available; the benefits of importing historic data may be limited.

5.3 Data Collection by States

After a web-based tool is developed and made available, states could use the tool to collect data throughout the following winter season. It will be critical to have multiple states with varying contract methods record all data that the tool requests. A comprehensive dataset will produce better and more relevant results once consolidated and analyzed.

5.4 Data Consolidation and Statistical Analysis

After a season of data has been collected, the datasets from multiple states can be consolidated and analyzed. A high-level statistical analysis can be conducted to identify the cost per lane-mile of each LOS category in each state. This will require an analysis of LOS definitions, work plans, and other factors to normalize the data.

5.5 Comparison of Aggregated Data

The aggregated data and results from a regression and relevant statistical analyses will allow for a direct comparison of data across crews, maintenance areas, states, contract types, and time periods. This analysis could answer questions regarding how labor prices vary between states, how differences in equipment impact total cost, and how private contractors and state crews compare. Additionally, further study could provide benchmark data for comparing a DOT's costs. By studying the differences between states, the Team will be able to identify opportunities for cost savings or increased productivity without negatively impacting the level of service. Such an analysis will yield a list of best practices that can be shared will all of the states in efforts to reduce costs and increase efficiency.

5.6 Conclusions and Presentation of Results

The findings from the consolidation of data, statistical analyses, and comparison of data across maintenance areas, states, contract types, and time periods are expected to provide a wealth of information. The team will draw conclusions from the comparisons when possible, identify best practices, and identify trends that maintenance managers may use to improve operational efficiencies or reduce costs. Further, the True Cost Tool should continue to be used so that this analysis can be performed again in the future as more data becomes available. By integrating the True Cost tool into DOTs' winter maintenance practices, states will be able to monitor their costs as they continue to collect data and more accurately estimate future storm costs.

Appendix A User Manual

The objective of this tool is to provide agencies with the ability to quickly and easily estimate the cost of maintenance related to a winter storm and communicate costs to policy makers. There are four components to the True Cost of Winter Maintenance Estimate & Data Entry Tool: Estimate Mode, Data Entry Mode, Storm Comparison Tool, and Period Comparison Tool.

General Information

The excel too works best on Excel versions 2010 and newer, but may be used on earlier versions. Macros must also be enabled for the buttons within the tool to work properly. If macros are turned off, you will get a warning with instructions to enable them.

Estimate Mode

The Estimate Mode is used to estimate a storm's maintenance cost with imperfect data, perform what-if analyzes, and explore cost drivers. To perform such an analysis, data can be entered on the six sheets within this mode and data can be saved after an estimate has been created. The six sheets are as follows:

1. Assumptions – Enter data related to the amount of work, when and where the work is performed and storm characteristics.
2. Materials – Enter data related to material costs
3. Equipment – Enter data related to equipment costs
4. Labor – Enter data related to labor costs
   a. There is a field at the bottom of the sheet that allows users to customize the burdened rate to their agency's definition.
5. Total Cost summary – Contains a summary of all of the costs for the one storm event
   a. There is a field at the bottom of the sheet that allows users to save notes about the storm event.
6. Table of Contents – Enables easy navigation

Data Entry Mode

The Data Entry Mode is used to record actual storm data after a storm has occurred and all costs have been realized. This mode is nearly identical to the Estimate Mode (i.e. it has the same input and output sheets), except that all data saved in this mode populates a database that will be used in a future analysis. Therefore, it is critical that only actual storm data is entered in this mode.

Storm Comparison Tool

The Storm Comparison Tool gives the user the ability to easily compare saved storm events. This feature is useful for analyzing similar storm events, comparing what-if scenarios, and comparing estimates to actual storm events. In this portion of the tool, storm events can be pulled from either the Estimate or Data Entry Mode by using the drop down menus at the top of the sheet. Up to four storms can be compared at the same time.

Period Comparison Tool

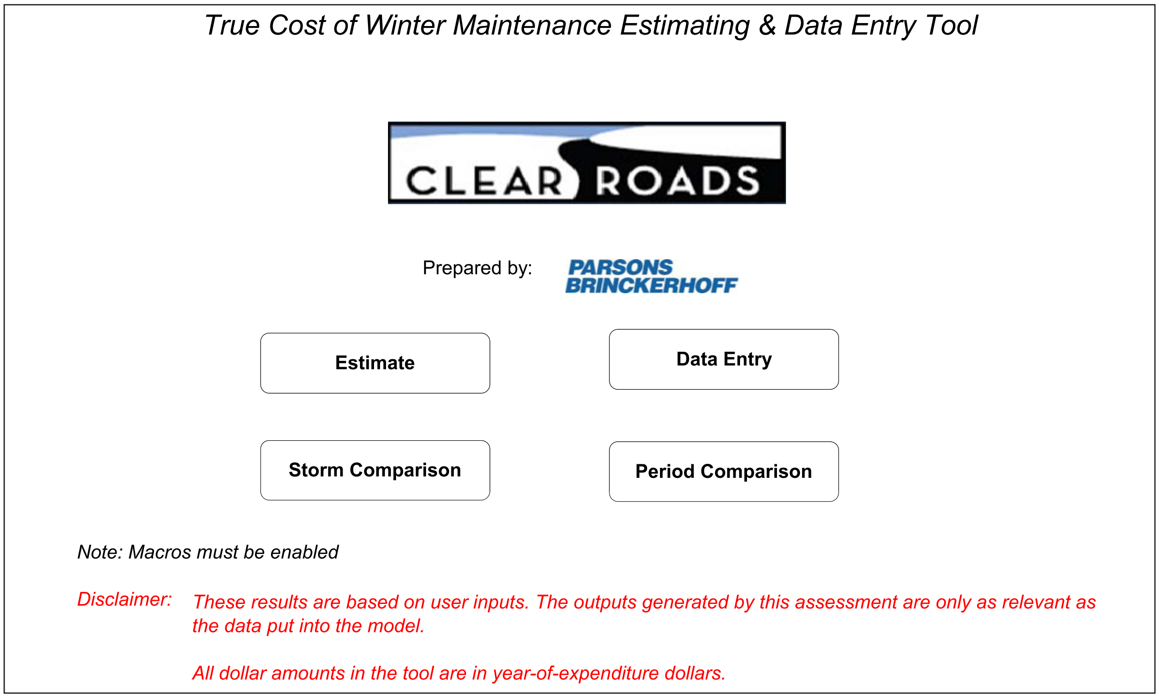
The Period Comparison Tool gives the user the ability to easily compare summary storm data over user defined time periods. This portion of the tool is useful for summarizing historic data, detecting trends, and presenting summary statistics at a policy level. Within this feature only data from the Data Entry Mode may be accessed; however, the data can be divided many ways to isolate variables of interest. The user can select by year and month (or 'all' months) and type of contract. Up to four periods can be compared at the same time.

Data Integrity

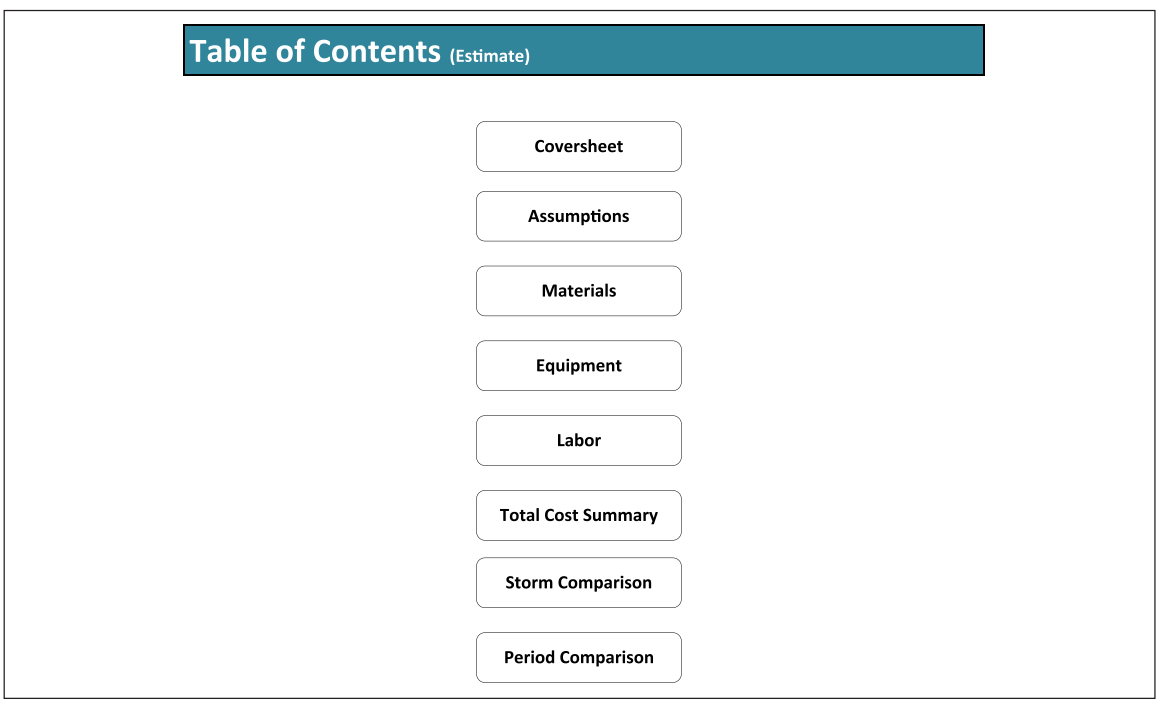
It is critical that consistent and accurate data be used to populate the Data Entry Mode of the tool. Consistent methods in collection of data such as precipitation amounts and temperatures will make comparisons across regions and states possible. It is also important to use the LOS categories as defined in the Glossary of Appendix C.

Appendix B Screenshots of True Cost Tool

Screenshot 1

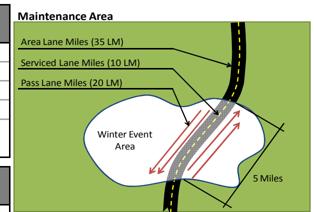


Screenshot 2



Screenshot 3

Instructions	
	Yellow cells are input cells
[Write-In]	White cells with "[Write-In]" can be modified
	Grey cells are not active with specified set of constraints
Grey Text	Grey text is not being used for calculations
Estimation Mode (Estimate)	This mode can be used for estimation purposes. Data can also be saved in this mode and compared to other storm events.



Assumptions (Estimate)		
Estimate Number	454545	Storm estimate number
Private Contractor	☑	If using a Private Contractor check the box
[Subarea 1 Write-In]	6	District identification number
[Subarea 2 Write-In]	797	Crew identification number
Urban/Rural	Urban	Primary maintenance area type
Date of Storm	2/17/2013	Date the storm began (mm/dd/yyyy)
Area Lane Miles	1500	Number of lane miles crew maintains
Serviced Lane Miles	3000	Lane miles receiving precipitation
Pass Lane Miles LOS A	1750	LOS A: Bare/wet pavement maintained at all times
Pass Lane Miles LOS B	1500	LOS B: Bare/wet pavement is prevailing condition
Pass Lane Miles LOS C	500	LOS C: Accumulations < 2 in, no packed or bonded snow
Pass Lane Miles LOS D	500	LOS D: Packed and bonded snow, wheel tracks upto 1.5 in
Pass Lane Miles LOS E	0	LOS E: Completely covered w/packed snow, been treated
Total Pass Lane Miles	4250	Number of lane miles driven by equipment

Storm Characteristics (Estimate)		Not Used in Calculations
Storm Duration (hours)	14	Hours of precipitation
Precipitation (inches)	5.0	Number of inches of precipitation (liquid equivalents)
Storm Type	Dry Snow	Type of precipitation (most prevelant storm type)

Screenshot 4

Materials (Estimate)	Use	Unit	Quantity Needed	Unit Cost Range ☑	Unit Cost Write-in	Cost by Category
Sand	☑	CY	74	$14-$16		$ 1,110.00
Salt	☑	Ton	96	$70-$80		$ 7,200.00
Salt Brine	☐	Gallon				
Chemical/Brine	☐	Gallon				
Chemical	☐	Gallon				
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					

Material Cost	**$ 8,310.00**

Screenshot 5

Equipment (Estimate)	Use	No. of Units	Days per Unit	Daily Rate ☑	Daily Costs	Total Hours	Hourly Rate ☑	Hourly Cost	Miles Covered	Rate per Mile ☑	Distance Cost	Cost by Category
22-35000 GVW Patrol Truck	☑	4	2.0	$ 100.00	$ 800.00	30.0	$ 24.28	$ 728.40	6,000.0	$ 10.00	$ 60,000.00	$ 61,528.40
1/2 Ton Pickup	☑	5	3.0	$ 31.50	$ 472.50	48.0	$ 0.38	$ 18.24			$ -	$ 490.74
4x4 Backhoe	☑	3	2.0	$ 57.30	$ 343.80	25.0	$ 22.66	$ 566.50			$ -	$ 910.30
54000 GVW TAT W/800	☑	4	3.0	$ 74.39	$ 892.68	15.0	$ 27.07	$ 406.05			$ -	$ 1,298.73
10/11GVW & Dump Rack	☐	1	2.0	$ 33.19		15.0	$ 0.49					
Grader	☑	2	3.0	$ 59.99	$ 359.94	15.0	$ 38.60	$ 579.00			$ -	$ 938.94
2 YD 4x4 Loader	☐	2	2.0	$ 57.30		3.0	$ 22.66		600.0	$ 12.00		
3 Yd Loader - Skid-Steer	☐			$ 32.68			$ 17.14					
Heavy Duty Truck - >54k GVW	☐			$ 89.97			$ 23.92					
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐					22.0	$ 25.00					
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
Equipment Cost												**$ 65,167.11**

Screenshot 6

Labor (Estimate)	Use	Hourly Rate Range ☐	Hourly Rate Write-in	Positions in Subarea	Number of Days on Job	Hours Worked per Day	Total Hours	Cost by Category
Standard Time								
Operations Manager (burdened)	☐		$ 49.50					
Crew Supervisor (burdened)	☑		$ 44.09	1	2.0	8.00	16.00	$ 705.44
Crew Leader (burdened)	☑		$ 35.65	2	4.0	4.00	32.00	$ 1,140.80
Worker III (burdened)	☑		$ 31.70	2	2.0	8.00	32.00	$ 1,014.40
Worker II (burdened)	☑		$ 29.78	5	4.0	8.00	160.00	$ 4,764.80
Worker I (burdened)	☐		$ 27.46					
[Write-in]	☐							
[Write-in]	☐							
[Write-in]	☐							
Standard Total							240.00	$ 7,625.44
Overtime		☐						
Operations Manager (burdened)	☐		$ 32.34					
Crew Supervisor (burdened)	☐		$ 28.80					
Crew Leader (burdened)	☐		$ 23.28					
Worker III (burdened)	☐		$ 20.71					
Worker II (burdened)	☑		$ 19.46	2	2.0	4.00	16.00	$ 311.36
Worker I (burdened)	☐		$ 17.94					
[Write-in]	☐							
[Write-in]	☐							
[Write-in]	☐							
Overtime Total							16.00	$ 311.36
Labor Cost							**256.00**	**$ 7,936.80**

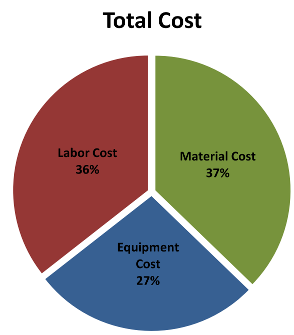
***Burdened rate: Includes all overhead associated with labor. [Write in definition or notes here]**

Screenshot 7

True Cost of Winter Maintenance Estimation Tool

Printed 23 Oct 2013

Total Cost Summary (Estimate)		
Estimate Number		23691
[Subarea 1 Write-In]		4
[Subarea 2 Write-In]		11307
Date of Storm		2/3/2011
Storm Duration (hours)		26
Precipitation (inches)		6
Storm Type		Dry Snow
Crew Maintenance Area Lane Miles		2,000
Cost per Maintenance Area Lane Mile	$	11.16
Lane Miles Serviced		1,000
Cost per Lane Mile Serviced	$	22.32
Pass Lane Miles		2,000
Pass Lane Miles LOS A		900
Pass Lane Miles LOS B		400
Pass Lane Miles LOS C		600
Pass Lane Miles LOS D		-
Pass Lane Miles LOS E		100
Cost per Pass Lane Mile	$	11.16
Material Cost	$	8,310.00
Equipment Cost	$	6,071.72
Labor Cost	$	7,936.80
Total Cost	**$**	**22,318.52**

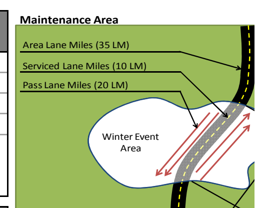


Notes (*450 character maximum*):

Many trees in the road

Screenshot 8

Instructions	
	Yellow cells are input cells
[Write-In]	White cells with "[Write-In]" can be modified
	Grey cells are not active with specified set of constraints
Grey Text	Grey text is not being used for calculations
Record Data Mode (Record)	This mode should only be used to save data into the storm database. Therefore, the storm and all of its costs should have already been realized.



Assumptions (Data Entry)		
Storm ID Number	84652	Unique storm identification number
Private Contractor	☑	If using a Private Contractor check the box
[Subarea 1 Write-In]	6	District identification number
[Subarea 2 Write-In]	2245	Crew identification number
Urban/Rural	Rural	Primary maintenance area type
Date of Storm	11/12/2012	Date the storm began (mm/dd/yyyy)
Area Lane Miles	3000	Number of lane miles crew maintains
Serviced Lane Miles	2000	Lane miles receiving precipitation
Pass Lane Miles LOS A	1750	LOS A: Bare/wet pavement maintained at all times
Pass Lane Miles LOS B	750	LOS B: Bare/wet pavement is prevailing condition
Pass Lane Miles LOS C	250	LOS C: Accumulations < 2 in, no packed or bonded snow
Pass Lane Miles LOS D	0	LOS D: Packed and bonded snow, wheel tracks upto 1.5 in
Pass Lane Miles LOS E	0	LOS E: Completely covered w/packed snow, been treated
Total Lane Miles Accomplished	2750	Number of lane miles driven by equipment

Storm Characteristics (Data Entry)		Not Used in Calculations
Storm Duration (hours)	12	Hours of precipitation
Precipitation (inches)	4.0	Number of inches of precipitation (liquid equivalents)
Storm Type	Wet Snow	Type of precipitation (most prevelant storm type)

Screenshot 9

Materials (Data Entry)	Use	Unit	Quantity Needed	Unit Cost Range ☐	Unit Cost Write-in	Cost by Category
Sand	☐	CY				
Salt	☑		105		$ 68.00	$ 7,140.00
Salt Brine	☑	Gallon	80		$ 0.36	$ 28.80
Chemical/Brine	☑	Gallon	2,795		$ 0.65	$ 1,816.75
Chemical	☐	Gallon				
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
[Write-in]	☐					
Material Cost						**$ 8,985.55**

Screenshot 10

Equipment (Data Entry)	Use	No. of Units	Days per Unit	Daily Rate ☑	Daily Costs	Total Hours	Hourly Rate ☑	Hourly Cost	Miles Covered	Rate per Mile ☑	Hourly Cost	Cost by Category
22-35000 GVW Patrol Truck	☑	50	2.0	$ 57.01	$ 5,701.00	100.0	$ 24.28	$ 2,428.00	1,000	$ 24.28	$ 24,280.00	$ 32,409.00
1/2 Ton Pickup	☑	8	2.0	$ 31.50	$ 504.00	12.0	$ 0.38	$ 4.56	8	$ 0.38	$ 3.04	$ 511.60
4x4 Backhoe	☑	2	2.0	$ 57.30	$ 229.20	12.0	$ 22.66	$ 271.92	6	$ 22.66	$ 135.96	$ 637.08
54000 GVW TAT W/800	☑	2	2.0	$ 74.39	$ 297.56	15.0	$ 27.07	$ 406.05		$ 27.07	$ -	$ 703.61
10/11GVW & Dump Rack	☑	2	2.0	$ 33.19	$ 132.76	15.0	$ 0.49	$ 7.35	6	$ 0.49	$ 2.94	$ 143.05
Grader	☐			$ 59.99			$ 38.60			$ 38.60		
2 YD 4x4 Loader	☐			$ 57.30			$ 22.66			$ 22.66		
3 Yd Loader - Skid-Steer	☐			$ 32.68			$ 17.14			$ 17.14		
Heavy Duty Truck - >54k GVW	☐			$ 89.97			$ 23.92			$ 23.92		
[Write-in]	☐			$ 100.00			$ 12.00			$ 12.00		
[Write-in]	☐			$ 50.00		36.0	$ 20.00			$ 20.00		
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
[Write-in]	☐											
Equipment Cost												**$ 34,404.34**

Screenshot 11

Labor (Data Entry)	Use	Hourly Rate Range ☐	Hourly Rate Write-in	Positions in Subarea	Number of Days on Job	Hours Worked per Day	Total Hours	Cost by Category
Standard Time								
Operations Manager (burdened)	☐		$ 49.50					
Crew Supervisor (burdened)	☑		$ 44.09	2	2.0	6.00	24.00	$ 1,058.16
Crew Leader (burdened)	☑		$ 35.65	1	2.0	8.00	16.00	$ 570.40
Worker III (burdened)	☐		$ 31.70					
Worker II (burdened)	☑		$ 29.78	3	8.0	8.00	192.00	$ 5,717.76
Worker I (burdened)	☑		$ 27.46	2	4.0	8.00	64.00	$ 1,757.44
[Write-in]	☐							
[Write-in]	☐							
[Write-in]	☐							
Standard Total							296.00	$ 9,103.76
Overtime		☐						
Operations Manager (burdened)	☐		$ 32.34					
Crew Supervisor (burdened)	☑		$ 28.80				-	$ -
Crew Leader (burdened)	☐		$ 23.28					
Worker III (burdened)	☐		$ 20.71					
Worker II (burdened)	☐		$ 19.46					
Worker I (burdened)	☐		$ 17.94					
[Write-in]	☐							
[Write-in]	☐							
[Write-in]	☐							
Overtime Total							-	$ -
Labor Cost							**296.00**	**$ 9,103.76**
***Burdened rate includes all overhead associated with labor. [Write in definition or notes here]**								

Screenshot 12

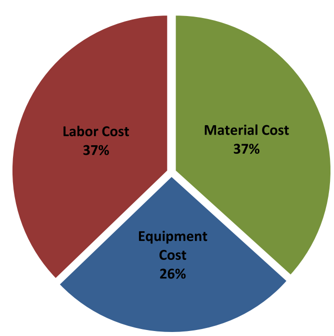
True Cost of Winter Maintenance Estimation Tool

CLEAR ROADS

Printed 23 Oct 2013

Total Cost Summary (Data Entry)	
Storm ID Number	24758
[Subarea 1 Write-In]	4
[Subarea 2 Write-In]	11401
Date of Storm	2/1/2011
Storm Duration (hours)	18
Precipitation (inches)	6
Storm Type	Wet Snow
Crew Maintenance Area Lane Miles	1,200
Cost per Maintenance Area Lane Mile	$ 20.41
Lane Miles Serviced	600
Cost per Lane Mile Serviced	$ 40.81
Pass Lane Miles	2,250
Pass Lane Miles LOS A	1,200
Pass Lane Miles LOS B	800
Pass Lane Miles LOS C	250
Pass Lane Miles LOS D	-
Pass Lane Miles LOS E	-
Cost per Pass Lane Mile	$ 10.88
Material Cost	$ 8,985.55
Equipment Cost	$ 6,397.17
Labor Cost	$ 9,103.76
Total Cost	**$ 24,486.48**

Total Cost



Notes (*450 character maximum*):

Large Urban Storm

Screenshot 13

True Cost of Winter Maintenance Estimation Tool

Printed 23 Oct 2013

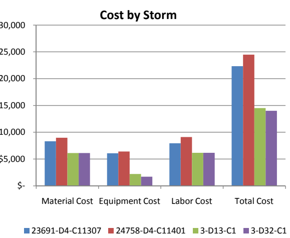
Storm Comparison	Estimate	Data Entry	Data Entry	Data Entry
Storm Name / Estimate Name	23691-D4-C11307	24758-D4-C11401	3-D13-C1	3-D32-C1
Storm ID Number / Estimate Number	23691	24758	3	3
Private Contractor	TRUE	TRUE	TRUE	TRUE
District Number	4	4	13	32
Crew Number	11307	11401	1	1
Date of Storm	2/3/2011	2/1/2011	2/6/2014	3/6/2013
Storm Duration (hours)	26	18	5	5
Precipitation (inches)	6	6	6	6
Storm Type	Dry Snow	Wet Snow	Wet Snow	Wet Snow
Crew Maintenance Area Lane Miles	2,000	1,200	1,000	1,000
Cost per Maintenance Area Lane Mile	**$ 11.16**	**$ 20.41**	**$ 14.51**	**$ 14.01**
Lane Miles Serviced	1,000	600	400	900
Cost per Lane Mile Serviced	**$ 22.32**	**$ 40.81**	**$ 36.28**	**$ 15.56**
Pass Lane Miles	2,000	2,250	1,300	1,200
Pass Lane Miles LOS A	900	1,200	1,000	700
Pass Lane Miles LOS B	400	800	200	400
Pass Lane Miles LOS C	600	250	100	100
Pass Lane Miles LOS D	-	-	-	-
Pass Lane Miles LOS E	100	-	-	-
Cost per Pass Lane Mile	**$ 11.16**	**$ 10.88**	**$ 11.16**	**$ 11.67**
Material Cost	$ 8,310.00	$ 8,985.55	$ 6,120.00	$ 6,120.00
Equipment Cost	$ 6,071.72	$ 6,397.17	$ 2,217.96	$ 1,713.36
Labor Cost	$ 7,936.80	$ 9,103.76	$ 6,173.52	$ 6,173.52
Total Cost	**$ 22,318.52**	**$ 24,486.48**	**$ 14,511.48**	**$ 14,006.88**

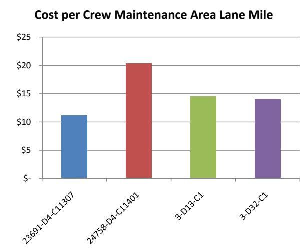
23691-D4-C11307 Notes
Many trees in the road

24758-D4-C11401 Notes
Large Urban Storm

3-D13-C1 Notes
Rained during clean up

3-D32-C1 Notes
Many frozen areas



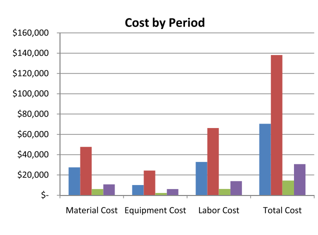


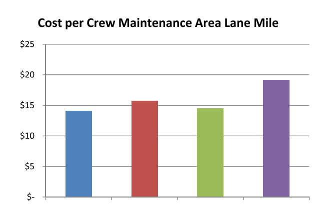
Screenshot 14

True Cost of Winter Maintenance Estimation Tool

Printed 23 Oct 2013

Period Comparison (Data Entry Only)				
Year	2014	2013	2014	2013
Month	All	All	February	February
Private Contractors	☑	☑	☑	☑
State Crews	☐	☑	☐	☑
Number of Storms	5	13	1	3
Storm Duration (hours)	25	65	5	15
Precipitation (inches)	30	78	6	18
Crew Maintenance Area Lane Miles	5,000	8,800	1,000	1,600
Cost per Maintenance Area Lane Mile	**$ 14.09**	**$ 15.70**	**$ 14.51**	**$ 19.18**
Lane Miles Serviced	2,000	6,400	400	1,700
Cost per Lane Mile Serviced	**$ 35.21**	**$ 21.59**	**$ 36.28**	**$ 18.06**
Pass Lane Miles	4,800	6,208	1,300	1,204
Pass Lane Miles LOS A	3,300	1,708	1,000	204
Pass Lane Miles LOS B	1,000	2,800	200	600
Pass Lane Miles LOS C	500	1,300	100	300
Pass Lane Miles LOS D	-	400	-	100
Pass Lane Miles LOS E	-	-	-	-
Cost per Pass Lane Mile	**$ 14.67**	**$ 22.25**	**$ 11.16**	**$ 25.49**
Material Cost	$ 27,535.00	$ 47,595.00	$ 6,120.00	$ 10,710.00
Equipment Cost	$ 10,080.60	$ 24,271.72	$ 2,217.96	$ 6,073.62
Labor Cost	$ 32,813.04	$ 66,281.76	$ 6,173.52	$ 13,911.12
Total Cost	**$ 70,428.64**	**$ 138,148.48**	**$ 14,511.48**	**$ 30,694.74**





Appendix C Glossary of True Cost Tool Terms

Assumptions Tab:

Estimate Number:
The number agencies use to distinguish storm events. This field may be alphanumeric if necessary.

Private Contractor:
A private contractor is a crew or equipment supplier/operator whom is not owned or operated by the state or local government. Typically a private contractor will still have access to the state's infrastructure of maintenance yards and staging areas, but not always.

[Subarea - Write In]:
Many agencies divide their maintenance area into sections and subsections. This field can be used to identify one of these sections or subsections. The field's title is able to be modified to "District," "Region," "Crew ID," or any other descriptor.

Urban/Rural:
This field is used to distinguish whether the pass lane miles accomplished were urban or rural. Urban is typically defined as having curb and gutter, higher traffic, and presents more challenges in clearing snow. Rural is typically defined as having open sections, wider shoulders or clear zones for snow accumulation, and lower traffic.

Date of Storm:
The date the storm event began.

Area Lane Miles:
The Area Lane Miles is the total number of lane miles in the subarea described above.

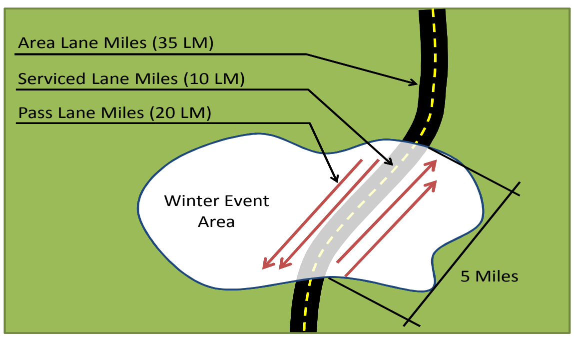
Serviced Lane Miles:
The Serviced Lane Miles are the total number of lane miles that were affected by the storm event. As an example, if the Crew Area Lane Miles total 100, but only 10 lane miles received snow, the Crew Serviced Lane Miles is 10.

Level of Service: The level of service (LOS) used on the assumptions tab should conform with the standard definitions established in NCHRP 526. This is necessary to ensure costs and LOS can ultimately be compared across state lines. The definitions are as follows:	
LOS A	All snow and ice are prevented from bonding and accumulating on the road surface. Bare/wet pavement surface is maintained at all times. Traffic does not experience weather-related delays other than those associated with wet pavement surfaces, reduced visibility, incidents, and "normal" congestion.
LOS B	Bare/wet pavement surface is the general condition. There are occasional areas having snow or ice accumulations resulting from drifting, sheltering, cold spots, frozen melt-water, etc. Prudent speed reduction and general minor delays are associated with traversing those areas.
LOS C	Accumulations of loose snow or slush ranging up to (2 in.) are found on the pavement surface. Packed and bonded snow and ice are not present. There are some moderate delays due to a general speed reduction. However, the roads are passable at all times.
LOS D	The pavement surface has continuous stretches of packed snow with or without loose snow on top of the packed snow or ice. Wheel tracks may range from bare/wet to having up to (1.5 in.) of slush or unpacked snow. On multilane highways, only one lane will exhibit these pavement surface conditions. The use of snow tires is recommended to the public. There is a reduction in traveling speed and moderate delays due to reduced capacity. However, the roads are passable.
LOS E	The pavement surface is completely covered with packed snow and ice that has been treated with abrasives or abrasive/chemical mixtures. There may be loose snow of up to (2 in.) on top of the packed surface. The use of snow tires is required. Chains and/or four-wheel drive may also be required. Traveling speed is significantly reduced and there are general moderate delays with some incidental severe delays.
LOS F	The pavement surface is covered with a significant buildup of packed snow and ice that has not been treated with abrasives or abrasives/chemical mixtures. There may be (2 in.) of loose or wind-transported snow on top of the packed surface due to high snowfall rate and/or wind. There may be deep ruts in the packed snow and ice that may have been treated with chemicals, abrasives, or abrasives/chemical mixtures. The use of snow tires is the minimum requirement.

Pass Lane Miles Accomplished:

The Pass Lane Miles Accomplished is the number of lane miles of work performed. Furthering the example above, if 10 lane miles received snow, and the crew plowed those 10 lane miles 2 times, the Total Lane Miles Accomplished would be 20 (10x2=20). Lane Miles Accomplished should be recorded by LOS category when possible. If 8 of the 10 Serviced Lane Miles were LOS A and 2 were LOS B, the Lane Miles Accomplished LOS A would be 18 and Lane Miles Accomplished LOS B would be 4.

Maintenance Area:



Storm Duration:

This is the number of hours of precipitation during a storm event. If it snowed for 2 hours and rained for 30 minutes, the Storm Duration would be 2.5 hours. This is NOT the length of time required to achieve bare and wet pavement.

Precipitation:

Precipitation is the amount of precipitation received by the Serviced Lane Miles. This amount recorded should be in units to match Storm Type. If there was a mix of precipitation, the predominant state should be recorded.

Storm Type:

Storm Type can be selected from the dropdown list. The predominant storm type should be indicated.

Materials Tab:

Materials:

Materials are the products or raw substances used over the course of winter maintenance. These may include sand, salt, brine, chemicals, etc. Each agency should define their own material list and use it consistently across all areas and subareas. It is critical that while one subarea refers to a “Salt & Sand Mix 50/50”, that another not refer to it as “Salt/Sane #4”. Units should also be consistent.

Unit Cost Range:

The Unit Cost Range box can be checked if the user does not have an exact unit cost and wants to use a range instead. This will cause inconsistency in the data. Units should also be consistent.

Equipment Tab:

Equipment:

Equipment is the items used for winter maintenance that required a capital investment. This includes trucks, plows, blades, etc. Each agency should define their own equipment list and use it consistently across all areas and subareas. It is critical that while one subarea refers to a “1/2 Ton Pickup”, that another not refer to it as “0.5 Ton Pickup”. This will cause inconsistency in the data. Units should also be consistent.

Daily Rate:

Some agencies charge equipment back to storm events on an hourly or daily basis, while others do both. If the Daily Rate box is checked, the user can enter a daily rate which will be used in the calculation.

Hourly Rate:

Some agencies charge equipment back to storm events on an hourly or daily basis, while others do both. If the Hourly Rate box is checked, the user can enter an hourly rate which will be used in the calculation.

Milage Rate:

Some agencies charge equipment back to storm events by mileage. If the Mileage Rate box is checked, the user can enter miles used and the rate which will be used in the calculation.

Labor Tab:

Labor:

The Labor tab will capture the expenses due to person labor hours. The data entered on this tab should only include labor relevant/billed to the storm event described on the assumptions tab.

Hourly Rate [Labor]:

This is the hourly rate applied to a labor category. The Hourly Rate should be the fully burdened cost of that labor category and include all overhead, benefits, etc. Each agency may define this differently and should record what is included in the labor rate in row 29.

Positions in Subarea:

The Positions in Subarea are the number of people in that labor category within the subarea described on the assumptions tab.

Standard Time:

The Standard Time section is intended to capture the cost of labor under normal working conditions.

Overtime:

The Overtime section is intended to capture the cost of labor exceeding normal working conditions. In most agencies, overhead is lower in overtime categories, but base labor rates may be higher. This is because overtime often does not include the overhead expenses associated with regular hour rates.

Summary & Comparison Tabs:

Cost per Maintenance Area Lane Mile:

This is the total cost of the storm event divided by the number of Maintenance Area Lane Miles or cost per lane mile in the maintenance area.

Cost per Lane Mile Serviced:

This is the total cost of the storm event divided by the number of Lane Miles Serviced.

Cost per Lane Mile Accomplished:

This is the total cost of the storm event divided by the number of number lane miles accomplished, or the cost of per lane miles of work performed.

Material Cost:

Total cost of materials from the Materials sheet.

Equipment Cost:

Total cost of equipment from the Equipment sheet.

Labor Cost:

Total cost of labor from the Labor sheet.

Total Cost:

Total cost for the storm event described.

Storm Comparison:

This is a comparison of storms side-by-side. Storms can be selected from the data entry or estimated storms databases.

Period Comparison:

This is a comparison of storm cost summaries by time period. Storms saved within the data entry database are summarized according to the time period and within the parameters selected. Available parameters include year, month, private contractor, and state crews.

Number of Storms [Period Comparison]:

This is the number of storms recorded within the parameters selected.
Storm Duration [Period Comparison]:
This is the sum of storm duration for all storms within the parameters selected.

Precipitation [Period Comparison]:

This is the sum of precipitation for all storms within the parameters selected. This may be a sum of different precipitation types without conversion.