

# Defensive Driving for Snowplow Operators

Final Report



research for winter highway maintenance

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# Defensive Driving for Snowplow Operators

## Final Report

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<b>16. Abstract</b> An often-overlooked aspect of winter maintenance operations is snowplow operators' risk of a crash. The goal of this project was to examine key causes of collisions involving snowplows, identify defensive driving strategies snowplow operators can use to prevent crashes, and develop two comprehensive and engaging snowplow operator training modules on safe and defensive driving. Questionnaires, interviews, and crash data were used to develop the two modules to provide snowplow-specific information that operators can use to prevent crashes. The first module includes strategies the snowplow operator can use to prevent crashes caused by another vehicle. The second module focuses on general safe driving practices that the operator can use to prevent crashes often caused by the snowplow operator. Winter maintenance agencies can use the modules to help snowplow operators become better defensive drivers and avoid collisions with other vehicles and objects.			
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## **LIST OF ABBREVIATIONS AND SYMBOLS**

DOT	Department of Transportation
FMCSA	Federal Motor Carrier Safety Administration
G.O.A.L.	Get out and look
LTCCS	Large Truck Crash Causation Study
SIPDE	search, identify, predict, decide, and execute
SPOT	Snow Plow Operator Training
VTTI	Virginia Tech Transportation Institute



## Executive Summary

An often-overlooked aspect of winter maintenance operations is snowplow operators' risk of a crash. Not only can a snowplow crash result in significant damage and serious injuries or fatalities, the loss of even one snowplow due to a crash can significantly affect how quickly roads are cleared of snow. This, in turn, affects the safety of the traveling public. Thus, the safety of snowplow operators has significant financial and health consequences for winter maintenance agencies and all road users.

The goal of this project was to address this gap in snowplow safety. Specifically, this project had the following three objectives.

1. Examine the key causes of collisions involving snowplows and other vehicles.
2. Identify defensive driving strategies that snowplow operators can use to reduce the likelihood of being struck by other drivers.
3. Develop two comprehensive and engaging snowplow operator training modules on (a) defensive driving and (b) safe driving.

### Methods

Three separate data collection efforts were used to accomplish the project's objectives: (1) the collection of snowplow crash data, (2) a questionnaire sent to winter maintenance agencies to collect data on their experiences, and (3) expert interviews to collect data on common snowplow crash factors and safe/defensive driving strategies.

### Crash Data Collection

At least one year of snowplow crash data were collected from five states. These data included crash date and time, crash location, crash type, a written description, and weather conditions. These data were used to validate the most common snowplow crash types identified in the questionnaire.

### Questionnaire Data Collection

A questionnaire was developed to collect winter maintenance agencies' experiences regarding snowplow crashes. Specifically, the questionnaire collected data on the number of snowplow crashes, common crash types, contributing factors to snowplow crashes, and opinions on strategies that may be used by snowplow operators to prevent crashes. Clear Roads research consortium state representatives distributed the online questionnaire to their managers to complete. Additionally, the online questionnaire was posted on the American Association of State Highway and Transportation Officials' Snow and Ice Listserv.

### Interview Data Collection

In-depth interviews were conducted with three to five managers and/or operators in California, Colorado, Idaho, Ohio, Montana, and Virginia. These interviews were designed to further investigate the (1) common factors associated with snowplow crashes involving other vehicles

and (2) safe and defensive driving strategies that operators have used to successfully avoid crashes.

## Content Analysis

A content analysis was performed using the data collected from the questionnaire and interviews. The content analysis identified common themes and subthemes. Results from the content analysis were used to develop the defensive driving and safe driving training modules.

## Results

Eighty-six snowplow managers from 20 Clear Roads states responded to the questionnaire. Two snowplow operators, four safety managers, three winter maintenance trainers, five superintendents, and five road maintenance managers participated in interviews. Results from all three data collection efforts showed that the top five most common preventable snowplow crash types were as follows:

1. Fixed-object strikes
2. Run-off-road crashes
3. Backing crashes
4. Wing-plow strikes
5. Crashes where another vehicle rear-ended the snowplow

Based on the questionnaire results, five main topics were recommended for inclusion in the snowplow operator training.

- **Crash avoidance techniques:** performing hazard identification, general defensive driving best practices, winter driving best practices, steps necessary for safe backing, and turning safely.
- **Vehicle and equipment:** becoming familiar with the snowplow equipment, inspecting the equipment pre and post trip, and how and when to properly use equipment.
- **Operator alertness:** snowplow operator fatigue management, maintaining snowplow operator vigilance, and limiting distractions inside the cab.
- **Safe operation of the snowplow:** route timing based on conditions and traffic, proper wing plow use, snowplow operator communication, reducing the snow cloud, and the use of a shadow vehicle.
- **Snowplow route:** marking known hazards and becoming familiar with routes.

## Defensive Driving Training Module

This training focused on strategies the snowplow operator can use to prevent crashes caused by another vehicle. This training was grouped into three main sections.

1. General defensive driving practices
  - Proper visual scanning techniques related to rear-end crashes
  - Anticipating other vehicles' mistakes
  - Strategies to determine if a hazard requires a response

- Recommendations for executing evasive maneuvers
- Preventing and reducing the snow cloud
- Driving at a safe speed
- Avoiding road rage and other aggressive driving behavior
- Safe following distances
- 2. Improving conspicuity
  - The importance of cleaning equipment
  - Proper pre-trip and mid-trip inspections regarding lighting, mirrors, and windows
  - Using turn signals
- 3. Safe operating characteristics
  - Proper use of wings
  - Work with the wind to minimize the snow cloud
  - Selecting safe turn around points
  - Safe left turning procedures
  - Allowing public to pass

## Safe Driving Training Module

This training focused on general safe driving practices that the operator can use to prevent crashes often caused by the snowplow operator. This training was grouped into four main sections.

1. Hazard identification
  - Proper visual scanning related to fixed objects
  - Tips on how to predict and identify hidden hazards
  - Responding to hidden and unexpected hazards
  - Safe operating speeds
  - Pre-marking known hazards
2. Proper backing
  - Use of spotters
  - G.O.A.L. (get out and look)
3. Limiting distractions
  - Risk of distractions
  - Minimizing distractions
4. Fatigue management
  - Signs of fatigue
  - Self-assessment of fatigue
  - Importance of breaks
  - Other fatigue countermeasures

## Conclusion

Although there are numerous commercially-available defensive driving courses, these do not cover the unique challenges faced by snowplow operators. Thus, winter maintenance agencies have a need for safety training and education content specifically targeting snowplow operations. This project fills that gap. As a result of data collected from questionnaires, interviews, and with objective crash data, two education modules were developed to provide snowplow-specific information to prevent crashes. Winter maintenance agencies can use the modules to help

snowplow operators become better defensive drivers and avoid collisions with other vehicles and objects.

## Introduction

During winter maintenance activities, the risk of vehicle crashes involving snowplows remains an ongoing safety concern. These crashes result in substantive economic losses to the winter maintenance agency and the general traveling public, as they may result in property-damage, vehicle repair, out of service vehicles, reduced level of service, infrastructure damage, etc. Education and outreach activities directed at the traveling public often focus on improved driving on ice- or snow-covered roads and not traveling too closely behind snowplows (Iowa Department of Transportation [DOT], 2017a, b; Michigan DOT, 2017; Nixon, 2009). Despite these efforts, the number of snowplow-involved crashes remains an issue as well as an area of opportunity for improved safety for all drivers who share the roads with snowplows (Zockaie et al., 2018).

Not only can snowplow-involved crashes result in serious injuries and fatalities, they may result in significant costs due to equipment repairs and replacements. Additionally, most winter maintenance agencies are minimizing their equipment due to budget constraints. The loss of even one snowplow due to a crash can significantly affect how quickly roads are cleared of snow. Roads that are not cleared of snow quickly may, in turn, make the roadway less safe for the traveling public. These factors highlight the importance of informing snowplow operators about effective safe and defensive driving strategies.

Previous research indicates that light-vehicle drivers initiate the vast majority of light vehicle/heavy vehicle conflicts (Blower, 1998; Federal Motor Carrier Safety Administration, 2006; Hanowski et al., 2007). Although the majority of these studies specifically discuss tractor-trailer/light vehicle crashes, the statistics on snowplow/light vehicle crashes are likely similar. In fact, light vehicle drivers may initiate a higher percentage of snowplow crashes due to degraded roadway conditions, poor visibility from winter weather conditions, and reduced visibility related to clearing the roads of snow (i.e., snow clouds created by the plow). Additionally, light vehicle drivers may drive more aggressively due to the snowplow's slower speeds.

Zockaie et al. (2018) reviewed UD-10 Crash Report Forms in Michigan in calendar years 2012 to 2017 and found 1,354 crashes involving snowplows. The top contributing factors (%) in these crashes were reported as follows: 38.4% inattention/misjudgment by snowplow driver, 23.2% loss of control, 22.8% inattention/misjudgment by other driver, 7.1% unknown/other, 3.7% poor visibility, 2.6% blind spot, 2.2% operating near intersection. Hans et al. (2014) identified environmental issues that affected crash risk during winter emergencies. Using crash data from 11 selected sites in Iowa, the authors reported that blowing snow was the primary environmental issue associated with vehicle crashes during winter emergencies. Other environmental issues included:

- Glazing of wheel tracks (typically between 8:00 a.m. and 10:00 a.m.)
- Refreeze (typically between 4:00 p.m. and 6:00 p.m.)
- Slushy road conditions between 25 and 32 degrees Fahrenheit (i.e., moving in out and out of a frozen state)

To date, these were the only two readily available published studies that examined common crash types involving snowplows or the common contributing factors to crashes involving snowplows. This highlights a critical gap in knowledge regarding snowplow operator safety. To effectively prevent snowplow-involved crashes, it is important to understand the variables that commonly contribute to these crashes. Thus, this research will attempt to fill that gap in knowledge.

## Project Objective

This project (1) examined the key causes of collisions involving snowplows and other vehicles, (2) identified defensive driving strategies that snowplow operators can use to reduce the likelihood of being struck by other drivers, and (3) developed two comprehensive and engaging snowplow operator training modules on defensive driving and safe driving. Following are brief descriptions of these two modules.

1. ***Defensive driving training module.*** Based on data from crashes involving snowplows, this training focused on defensive driving practices that snowplow operators can employ to prevent crashes. Specifically, the training includes strategies for visual scanning, maintaining a safe following distance, creating a space buffer around the plow, approaching intersections, and safe evasive maneuvers. This training also included route-planning strategies that require supervisor involvement (e.g., minimizing left turns). The training also includes ways that snowplow operators can use existing mirrors, lights, and other existing components. However, equipment-related strategies, such as increasing vehicle conspicuity by adding lighting or reflective taps, were outside the scope of this module.
2. ***Safe driving training module.*** Based on a review of industry-recommended practices for safely operating a snowplow during winter maintenance activities, this training discussed general safe driving strategies for operating a snowplow. The safe driving training module included topics that are important to safety but are unrelated to defensive driving. Topics included strategies to prevent driver distraction, preventing driver fatigue, safely backing up, and the importance of buckling the seat belt. Similar to the defensive driving training, equipment-related strategies to improve safety were outside the scope of this module.

## Literature Review

This chapter reviews the existing literature on snowplow operator training to prevent collisions. The major information sources for the literature review included: (i) the Transportation Research International Documentation; (ii) U.S. Government technical reports, such as those from the United States Department of Transportation, (iii) industry groups, such as Clear Roads research consortium; and (iv) academic journals (e.g., *Accident Analysis and Prevention* and the *Journal of Safety Research*).

All research in the literature review was assessed to determine whether it contained: (i) a description of the snowplow operator training investigated and (ii) the effectiveness of that training. The research team eliminated literature that did not contain these two pieces of information. Some of the studies produced multiple reports, journal articles, and conference presentations (i.e., the same study published in different journals, conference proceedings, etc.). Where possible, the research team gave priority to a final report over journal articles and conference proceedings (which tend to provide less information).

### Assessing Crash Causation

One of the most commonly used crash investigation techniques to determine crash causation is a root cause, or fault tree, analysis (Kalestsky, 2016; Rooney & Heuvel, 2004; Verma, Khan, Maiti, & Krishna, 2014). This type of analysis takes a systems approach to identifying contributing factors to a crash. For example, the personal, behavioral, vehicle, management, and environmental factors that contributed to the crash occurrence and/or severity are assessed. In other words, the purpose of the root cause analysis is to identify the underlying factors that contributed to the crash occurrence. It is critical that someone with direct access to crash information conduct the analysis. Often this is a supervisor or manager.

There are four high-level steps involved in a root cause analysis (Rooney & Heuvel, 2004). An overview of these four steps is given below. For a more in-depth description of best practices related to crash investigations, please see the Network of Employers for Traffic Safety's Comprehensive Guide to Roadway Safety ([NETS's Guide to Roadway Safety](#)).

1. **Collect data on the crash.** Gather data on the facts surrounding the crash. Collect data on all factors that may have contributed to the crash. This includes information about the driver, the vehicle, any other vehicles involved, environmental conditions at the time of the crash, roadway conditions and design, scheduling, and management factors. These data may be collected via the driver, witnesses, police crash reports, electronic records, and/or an analysis of policies.
2. **Chart the sequence of events that led to the crash.** Organize the sequence of factors preceding the crash. The sequence of events should include all causal factors that led to the crash. Charting the sequence of events highlights the gaps in knowledge, skills, and countermeasures that may have prevented the crash.
3. **Identify the root causes of the factors that contributed to the crash.** Using the causal factor chart, investigators can identify the major causes that led to the crash. Eliminating these root causes likely would have prevented the crash from occurring.



**4. Develop recommendations to prevent the crash from occurring again.**

Recommendations should be developed to reduce the probability that the root causes will occur again.

Once a root cause analysis has been completed, additional analyses can be conducted to identify common trends and patterns across many crashes. These analyses focus on identifying relationships between frequent root causes or contributing factors and specific crash types and will be used in this study to identify common trends of snowplow crashes across several winter maintenance agencies.

### **Prior Efforts to Train Snowplow Operators**

We found few published studies on training and education programs geared toward snowplow operators, and even fewer studies demonstrating the efficacy of these types of programs. Following are summaries of the research investigating the efficacy of these types of programs.

Strayer et al. (2005) used a high-fidelity simulator-training program with 80 snowplow operators. The PowerPoint training and education program was informed by a task analysis of snowplow operators. The task analysis identified four key areas: space management, speed management (including “blade catching”), crew communication, and fuel management. The simulator training consisted of 18 scenarios in urban interstate and rural mountain settings. The authors compared the 40 drivers who received the training to 40 control drivers (i.e., no training) after 6 months. Although the program was viewed as favorable and important via self-reports, there was no significant difference in crash rates between the two groups (there was a significant 6.2% improvement in fuel efficiency in the group of operators that received the training).

Kihl et al. (2006) assessed the effectiveness of a blended curriculum to provide snowplow operator education and training on safety. The blended curriculum included a classroom component and a fixed-based driving simulator. The primary safety-related focus of these trainings was to encourage the use of the SIPDE module (Search, Identify, Predict, Decide, and Execute) in an effort to help snowplow operators anticipate hazards. Kihl et al. (2006) attempted to assess the effectiveness of the blended curriculum via qualitative surveys and focus groups and with a quantitative analysis of claims costs. Snowplow operators self-reported positive experiences using the blended curriculum. Operators reported an increase in ability to anticipate unexpected hazards. The quantitative data showed a reduction in operational costs per mile of snowplow operation, per hour of snowplow operation, and per inch of snowfall from the previous year. However, the quantitative assessment was inconclusive with respect to safety due to few crashes occurring in each year.

O’Rourke (2011) used a blended training curriculum with snowplow operators that consisted of instructor-led, computer-based, and simulator-based training. Core competencies consisted of “best practices” within the context of existing driver policies and procedures, plowing speeds, handling emergencies, radio communications, and fatigue. For example, following a brief lecture/discussion on space management (where operators were taught the SIPDE model), drivers worked in the simulator to practice using the five step SIPDE process. O’Rourke’s results were similar to those reported by Strayer et al. (2005), showing positive initial evaluations, but no conclusive findings on driver performance when comparing operators who received training to those who did not.



Johnson and Grothaus (2017) developed in-class education and training materials for snowplow operators on 22 topics related to snowplow operations. Of these 22 modules, one specifically focused on topics related to snowplow operator safety. This education and training module covered five high-level safety topics: tips for backing up safely, loading and installing snowplow equipment, personal safety, defensive driving, and plowing. There was some overlap between content included in Johnson and Grothaus (2017) and the current project. This included information on route familiarity, speed and space management, visibility, fatigue, and distraction. The authors did not evaluate the effectiveness of this education in improving snowplow operators' safety.

Although not documented in scientific literature, many State agencies responsible for winter road maintenance operations provide training to snowplow operators on safe driving practices. For example, Minnesota's DOT created the Snow Plow Operator Training (SPOT) program (see [MDOT's SPOT Program](#)). SPOT includes both classroom and behind the wheel training. Topics in SPOT include conducting pre- and post-trip vehicle inspections, operating equipment controls, safe backing, operating plows and spreaders, general safe driving practices, the application of materials, and equipment maintenance.

## Defensive Driving Training

The concept of defensive driving has been popular since 1965 when the National Safety Council developed the first well-known course teaching specific strategies to prevent crashes (National Safety Council, 2018). Defensive driving principles included driving at a safe speed, anticipating other vehicles' mistakes, staying alert, checking blind spots, maintaining a safe following distance, avoiding road rage, being courteous to other vehicles, obtaining adequate sleep, and maintaining good health. Defensive driving programs are useful in increasing driver safety, as they teach drivers to be patient and courteous to others, anticipate others' mistakes, and to be on constant lookout for potentially hazardous situations and conditions. Several reviews of the transportation safety literature show that incorporating defensive driving tips in fleet training programs reduces safety-related incidents (Cleaves, 1997) and results in safety improvements (Kiell, 1989).

## Current Defensive Driving Training Sources

There are a number of sources available for occupational driver defensive driving training, including those offered by public, private, and Federal agencies. One of the most popular defensive driving programs available to occupational drivers is the *Smith System* ([Smith System](#)). Although commercial motor vehicle drivers typically use the Smith System, the defensive driving strategies are relevant to snowplow operators as well. The primary goal of the Smith System is to help drivers anticipate driving hazards and to quickly react to hazards in order to prevent collisions. To accomplish this, the Smith System focuses on TheSmith5Keys® of Space Cushion Driving principles, which include the following:

1. *Aim high in steering*®: Drivers need to look further down the road, at least 15 seconds ahead, to anticipate and evaluate potential hazards. By looking at least 15 seconds ahead, drivers have time to recognize hazards and react to prevent a collision.
2. *Get the big picture*®: It is important for drivers to see the entire roadway. This includes the side and rear of their vehicles. Drivers should check mirrors every 5–8 seconds.

Additionally, drivers need to increase following distance to eliminate obstructions created by following vehicles too closely.

3. *Keep your eyes moving*<sup>®</sup>: Drivers should constantly scan the driving environment. To improve visual scanning, drivers should avoid fixating on objects, scan new objects every 2 seconds, and limit distractions.
4. *Leave yourself an out*<sup>®</sup>: Drivers should manage the space around their vehicle in case there is a need to avoid an emerging hazard or collision-imminent situation.
5. *Make sure they see you*<sup>®</sup>: Drivers should use warning signals (including eye contact) with other vehicles and road users. These warning signals help others anticipate future maneuvers.

Another popular provider of occupational defensive driving programs is J.J. Keller and Associates. They offer a wide range of defensive driving programs aimed at drivers of CMVs, motorcoaches, straight trucks, and light and medium duty vehicles. Although each of these education and training courses targets different audiences, the majority of the topics are consistent. These topics include preparing for a safe trip, recognizing and reacting to driving hazards, and defensive driving strategies. Critical components of the defensive driving topics are the anticipation of unexpected hazards, speed and space management, perception of other drivers' behaviors, stopping distance, and the importance of remaining calm.

The Virginia Tech Transportation Institute (VTTI) developed a training program targeting CMV drivers. Many of the concepts in that program also apply to snowplow operations, as they focus on heavy trucks over 10,000 lbs. Sponsored by the Federal Motor Carrier Safety Administration (FMCSA), VTTI developed driving tips ([FMCSA's Driving Tips](#)) based on those driver errors identified by the Large Truck Crash Causation Study (LTCCS; FMCSA, 2006). In addition to collecting descriptive data, the LTCCS assessed contributing factors for fatal crashes involving large trucks and coded each crash for critical events, critical reason, and other crash-associated factors (FMCSA, 2006). Using these data from the LTCCS along with data collected in a heavy vehicle naturalistic driving study (Hickman et al., 2005), VTTI created defensive driving tips to address the most frequently coded driver errors. The final list of tips is shown below. Some of these topics may not be applicable to snowplow operations; however, they may still be important to briefly discuss in the training modules.

#### **Driver Error 1. Failure to buckle up**

- Tip #1. Always wear your safety belt
- Tip #2. Safety belts prevent ejection from a vehicle in a crash
- Tip #3. Even the best drivers need to wear safety belts at all times

#### **Driver Error 2. Traveling too fast for conditions**

- Tip #1. Reduce your driving speed in adverse road and/or weather conditions
- Tip #2. Enter a curve slowly
- Tip #3. Reduce your speed before entering an exit/entrance ramp
- Tip #4. Drive slowly with a loaded trailer
- Tip #5. Slow down in work zones

#### **Driver Error 3. Unfamiliarity with roadway**

- Tip #1. Review maps and plan your route before driving
- Tip #2. Do not suddenly change your direction of travel

Tip #3. Signal your intentions

**Driver Error 4. Inadequate surveillance**

Tip #1. Be aware of your “no zone”

Tip #2. Always drive defensively

Tip #3. Look far enough ahead

Tip #4. Check your mirrors often

Tip #5. Approach and enter intersections with caution

**Driver Error 5. Driver fatigue**

Tip #1. Get enough sleep before getting behind the wheel

Tip #2. Maintain a healthy diet

Tip #3. Take a nap

Tip #4. Avoid medication that may induce drowsiness

Tip #5. Recognize the signals and dangers of drowsiness

Tip #6. Do not rely on “alertness tricks” to keep you awake

**Driver Error 6. Driver inattention**

Tip #1. Do not let objects outside of your truck distract you

Tip #2. Do not text while driving

Tip #3. Do not use a dispatching device while driving

Tip #4. Do not dial a handheld phone while driving

Tip #5. Do not read, write, or use paper maps while driving

Tip #6. Avoid eating and drinking when driving

**Driver Error 7. Following too closely**

Tip #1. Maintain a safe following distance

Tip #2. Double your following distance in adverse conditions

**Driver Error 8. Inadequate evasive action**

Tip #1. Watch for brake lights

Tip #2. Practice good scanning habits

Each tip includes a written description of specific behavioral strategies for driving safely. Additionally, most tips include interesting facts, example crash scenarios, and/or training exercises to reinforce the importance of the safe driving practice. Furthermore, the website uses video examples of driver errors to demonstrate how to avoid a particular scenario/behavior. The next section discusses the benefits of such an observational learning approach.

## **Purpose and Effectiveness of Video Examples in Education and Training**

In a widely accepted theory of human learning and motivation, Bandura (1977) states that observing the consequences of others' behavior is a strong motivator for human behavior. For example, if one driver watches another driver suffer negative consequences (e.g., a crash) due to a particular behavior, then the observer may be motivated to avoid the same mistake. Conversely, if one driver observes another driver experience a positive outcome (e.g., a friendly wave from another motorist who was allowed room to merge in front of the driver's vehicle), the observer will be motivated to engage in similar behavior to obtain the same reward.

As part of his Social Learning Theory, Bandura (1977) states that observational learning requires four components: attention, retention, motor reproduction, and incentive and motivation. Regarding attention, Bandura states that observational learning will only occur if the learner is paying attention to the learning environment. Thus, it is critical to ensure education and training materials are appealing and interactive, with periodic quizzes included. Regarding retention, Bandura believes humans store the behavioral information they observe in the form of mental images or verbal descriptions and are later able to recall the image or description to reproduce the observed behavior. Based on this theory, video-examples may assist drivers in retaining the necessary mental images of those specific driver-related behaviors or errors to avoid. Thus, all in-class education and training should include video examples showing how operators drive safely.

## Conclusions

Although there is not much published literature on the efficacy of classroom-based education and training with snowplow operators, this is a generally accepted practice to prevent snowplow crashes. The most effective education and training programs incorporate engaging content and video examples. Additionally, there is consistency across published defensive driving programs. The core components of the proposed defensive driving education and training will include the following topics (in no particular order).

1. Proper visual scanning techniques
2. Tips on how to predict and identify hidden hazards
3. Anticipating other vehicles' mistakes
4. Strategies to determine if a hazard requires a response
5. Recommendations for executing evasive maneuvers
6. Driving at a safe speed
7. Staying alert, including limiting distractions
8. Avoiding road rage and other aggressive behaviors
9. Scenarios related to common crash types
10. Tips for backing up
11. Preparing the vehicle

## Methods

Three types of data were collected in this project: questionnaire data, interview data, and snowplow crash data. Methods for each data collection effort are described below.

### Questionnaire Data Collection

Following the successful questionnaire development in Camden et al. (2014) and Camden et al. (2017), VTTI developed a questionnaire to obtain detailed information about snowplow crashes and best practices to prevent those crashes (see Appendix A). The purpose of this questionnaire was to collect the following information from state DOTs:

1. Current experiences with snowplow crashes (crashes involving another vehicle and any other crashes that require the snowplow to be removed from service for repairs)
2. Total number of snowplow crashes
3. Common crash types (e.g., rear-end and sideswipe crashes)
4. The snowplow configurations involved in crashes
5. Perceived contributing factors and critical reasons for snowplow crashes
6. Environmental, roadway, level of service, and other conditions related to frequent snowplow crashes
7. Safe and defensive driving techniques used by snowplow operators and the perceived effectiveness of those techniques in preventing crashes
8. Ability to participate in a follow-up interview with managers and operators
9. Existing training materials on safe and defensive driving for snowplow operators that may be shared
10. The availability of snowplow crash datasets, potentially including the availability of snowplow insurance claims—the datasets will only include snowplows

The questionnaire was administered via the internet using Qualtrics.com. As in Camden et al. (2014) and Camden et al. (2017), the VTTI team worked with Clear Roads member states to distribute the questionnaire. Links to the questionnaire were provided to each Clear Roads member state (highlighted states in Figure 1), and each state representative then distributed the link to managers. Completed questionnaire responses were automatically entered into a secure online database. Additionally, VTTI distributed the questionnaire to snowplow personnel in local governments through the American Association of State Highway and Transportation Officials' Snow and Ice Listserv. Paper-based versions of the questionnaire were also made available for individuals without reliable access to the internet. All paper-based questionnaires were returned to VTTI, where a researcher entered the responses into the secure database.



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## Content Analysis

Snowplow operator and manager responses to the questionnaire and interview were analyzed using a content analysis. This method includes the following steps:

1. Review the data set once to identifying key themes in responses to each question
2. Review the data set a second time to become familiar with all responses
3. Review the data set a third time to develop a list of key subthemes for each theme
4. Organize all themes and subthemes in a logical order to create an index of responses
5. Systemically apply the index to all responses
6. Chart all responses in the themes and subthemes
7. Analyze the themes and subthemes to develop an understanding of participant perspectives

## Questionnaire and Interview Results

This section of the report provides a high-level overview of the analysis results. The full results are located in Appendix C.

### Questionnaire Results

Eighty-six snowplow managers from 20 Clear Roads states responded to the questionnaire. The following sections provide an overview of their responses.

#### Snowplow Crashes

Overall, the five most common crash types were:

1. Fixed-object strikes
2. Crashes where another vehicle rear-ended the snowplow
3. Sideswipes
4. Run-off-road crashes
5. Wing-plow strikes

The five most common preventable snowplow crashes were:

1. Fixed-object strikes
2. Run-off-road crashes
3. Backing crashes
4. Wing-plow strikes
5. Crashes where another vehicle rear-ended the snowplow

#### Snowplow Crash Contributing Factors

Common contributing factors in snowplow crashes varied based on crash type. The first type of crash investigated was a crash where the snowplow struck another object, vehicle, or pedestrian. Respondents indicated the most common contributing factors to these types of crashes involved:

1. Increased fatigue
2. Lack of situational awareness
3. Snowplow operator inattention
4. Snowplow operator complacency
5. Operating the snowplow at a speed greater than the conditions dictated
6. Adverse road and weather conditions

The second type of crash investigated was a crash where the snowplow was struck by another vehicle. The most common contributing factors to these types of crashes were:

1. Driving too fast for conditions
2. General risky driving by the driving public
3. Other driver inattention
4. Reduced visibility



The last type of crash investigated was a single snowplow vehicle crash. Contributing factors to these types of crashes included:

1. Poor situational awareness of the snowplow operator
2. Operator fatigue
3. Operator inexperience
4. Driving too fast for conditions
5. Adverse driving conditions

Additionally, respondents were asked to provide other common contributing factors to snowplow crashes. These were largely consistent with regard to the contributing factors for specific crash types. However, some commonly mentioned contributing factors that were not previously mentioned included:

1. Plowing during peak travel times
2. Snowplow operator inattention
3. Inadequate preventative maintenance of the snowplow
4. Heavy snow and ice
5. Blowing and drifting snow/snow cloud

### Current Safety Training for Snowplow Operators

Current snowplow operator training related to safe driving focused mainly on crash avoidance techniques and general safe practices for operating the snowplow. Specifically, common training topics included:

1. Information on general defensive driving strategies
2. Hazard identification
3. Importance of slow operating speeds
4. Strategies to improve situational awareness of the plows
5. Operator alertness
6. Vehicle and equipment
7. Snowplow route

### Recommended Snowplow Operator Safety Training Topics

Respondents provided 117 recommended topics that should be included in defensive driving and safe driving training for snowplow operators. The most recommended topics can be divided into five general categories.

1. **Crash avoidance techniques:** performing hazard identification, defensive driving, winter driving, safe backing, and turning safely.
2. **Vehicle and equipment:** becoming familiar with the equipment, inspecting the equipment, pre-trip inspections, a differential GPS, and proper tire chain use.
3. **Operator alertness:** fatigue management, operator vigilance, and limiting distractions.
4. **Safe operation of the snowplow:** route timing, wing plow use, snowplow operator communication, not rushing, reducing the snow cloud, and the use of a shadow vehicle.

5. ***Snowplow route***: marking known hazards, becoming familiar with routes, and avalanche safety.

## Interview Results

These interviews were designed to gather more detailed information on the causes of common snowplow crashes and recommended mitigation strategies. The following sections, broken down by crash type, provide an overview of the interview results.

### Fixed Object Strikes

The recommended training topics to address fixed object strikes are provided below.

1. ***Become familiar with route***: marking known hazards, pre-driving the route, proactively adjusting the plow, and creating a database of known hazards.
2. ***Increase situational awareness***: using techniques to maintain vigilance, stowing equipment, proper visual scanning, limiting distractions, and safe backing.
3. ***Fatigue management***: limiting the number of hours operating the snowplow, taking breaks, and ensuring good nutrition.
4. ***Become familiar with equipment***: practicing with the equipment.
5. ***Safe snowplow operation***: maintaining slow speeds while plowing, reducing speeds prior to turns, and plowing only on paved surfaces.

### Run-off-Road Crashes

The recommended training topics to address run-off-road crashes are provided below.

1. ***Improve situational awareness***: proactive hazard assessment, techniques to remain vigilant, do not push the edge line on the roadway, and fatigue management.
2. ***Safe operation of the snowplow***: slow speeds, limiting downward pressure, maximizing the reach of the plow, keeping a low center of gravity, and increasing experience.

### Backing Crashes

The recommended training topics to reduce the number of backing crashes are provided below.

1. ***Increase situational awareness***: walk around inspections, spotters, and delineators.
2. ***Limit exposure***: avoid backing when possible and clear turnaround locations.
3. ***The use of technology***: using backup cameras and garage door indicators.

### Rear-ended by Another Vehicle

The recommended training topics to prevent vehicles from striking the rear of the snowplow are provided below.

1. ***Snowplow equipment***: cleaning lights, limiting warning lights during turn signal use, turn signal timing, additional rear warning lights, conspicuity tape, a rear spoiler, and warning light color.

2. ***Reducing the snow cloud:*** slow speeds, plow in the direction of the wind, allow public to pass before entering the snow cloud, and reduce speed prior to changes in direction.
3. ***Safe snowplow operation:*** let the public pass often, plow during non-peak hours, winter driving techniques, convoys, and turnaround locations with good sightlines.
4. ***Strategies to increase situational awareness:*** hazard assessments and maintaining good communication between snowplow operators.
5. ***Educate the driving public:*** public educational and media campaigns.
6. ***Snowplow operator:*** self-report dangerous conditions and remain calm.

## Wing Plow Strikes

The recommended training topics to prevent wing plow strikes are provided below.

1. ***Use of additional equipment:*** rear facing lights on wing plows, reflective tape, a rear spoiler, and snow deflectors.
2. ***The driving public:*** public education about safely sharing the road with snowplows.
3. ***Proper use of wings:*** only use wing plows to clear the shoulders of the roadway.

# Defensive Driver Training for Snowplow Operators

Based on the literature review and the results from the questionnaire and interviews, the following topics were included in the snowplow operator training.

## Defensive Driving Training

This training focused on strategies the snowplow operator can use to prevent crashes caused by another vehicle. The full module with videos can be accessed through the Clear Roads website, along with an instructional guide and pre- and post-module quiz.

This training discussed four major topics:

1. General defensive driving practices
2. The importance of cleaning equipment
3. How to properly use vehicle lighting
4. Safe operating characteristics

This module was separated into three sections: basic defensive driving strategies, improving conspicuity (combined topic 2 and 3 from above), and safe operating characteristics. Included in the notes section of each slide was a suggested narration. The suggested narration can be used by the training facilitator word-for-word or can be modified.

There are brief check-on-learning breaks throughout the module. These questions break the content into small sections and help operators remember important information.

Finally, facilitators can add agency-specific guidance or policies where appropriate throughout the module.

## Slide Summary

This module contains 59 slides. Table 1 provides an overview of the slides.

**Table 1. Defensive Driving Training Slide Descriptions**

Slide	Content Topic	Content Description
1–6	Introduction to the module	The first six slides provide a summary of the training, the training objectives, and an overview of snowplow crashes where another vehicle struck the snowplow.
7–24	Basic defensive driving strategies	This section of the module provides information and strategies to prevent crashes using general defensive driving behaviors.
8–9	Rear-end crash simulation	A simulation showing another vehicle rear-ending the snowplow. This video should be shown twice. The first time, the operators should just view the simulation. During the second viewing of the simulation, the trainer should discuss appropriate

Slide	Content Topic	Content Description
		scanning strategies and the importance of using the warning lights.
10–11	Appropriate visual scanning	These two slides discuss the process of scanning the environment for hazards and provides recommendations for improved scanning.
12–13	Hidden hazards	These two slides review how to identify and predict hidden hazards. They also describe the snowplow's blind spots.
14–15 21–22 29–30 35–36 41–42 47–48 54–55	Check-on-learning	These slides present example quiz questions. This information can be used as a brief review or can actually be used as an evaluation.
16–17	Responding to hazards	These slides present information on how snowplow operators can safely respond to other vehicles using evasive maneuvers. Specific strategies are provided.
18–19	Snow clouds	Hazards associated with a snow cloud are presented. A short crash video from the Wisconsin DOT is included. It demonstrates the dangers of a large snow cloud.
20	Speed	Recommendation for plow speeds. Trainers can adjust the recommended speeds if their agency has a lower recommended plowing speed.
23	Road rage	Tips to avoid road rage and aggressive driving are discussed.
24	Following distance	Recommendations related to safe following distance are presented.
25–36	Improving conspicuity	This section includes information about the importance of keeping the windows, mirrors, and lights clear of snow and ice buildup.
26–27	Example of poor visibility	These slides provide information on why it is important to remove snow and ice buildup. The photo in slide 26 is an example of reduced visibility due to snow and ice buildup on a windshield. The driver of the vehicle continued down the road even though the visibility out the front windshield was partially obstructed. The trainer should discuss the dangers of not cleaning the windshield.
28–32	Vehicle inspections	Recommendations on equipment to check during pre-, mid-, and post-trip inspections.
33–34	Turn signals	Information about the importance of using turn signals is shown. Suggestions are provided on the proper use of turn signals.
37–55	Snowplow operating characteristics	This section covers other operating strategies that snowplow operators can use to prevent crashes where another vehicle strikes the snowplow. These include using a wing plow, selecting safe turnarounds, and making left turns.
38–40	Using wing plows	These slides describe wing plows, how they can be used to clear snow, and why they can create a hazard if not used carefully. Slide 39 shows a short video from the Idaho DOT

Slide	Content Topic	Content Description
		about the benefits of wing plows. The trainer should facilitate a discussion about the benefits discussed in the video. The video also demonstrates how the wing needs to be raised prior to approaching roadside obstacles.
43	The wind	This slide discusses some of the dangers associated with plowing during high winds and how the wind may be used to carry snow spray away from other vehicles.
44–46	Safe turnaround locations	These slides present information related to safe turnaround locations. Slide 44 shows an example photo of an unsafe turnaround location. This turnaround is small, and the snowplow is not able to turn around without doing a 3-point turn. Secondly, the turnaround is already occupied. The other plow makes it difficult for the snowplow to safely enter and exit the turnaround location. Third, there is a curve in the road a short distance away. The snowplow operator would not be able to identify approaching cars until it was too late. The example on slide 45 is a safe alternative. This turnaround location provides clear sight lines in both directions and the snowplow operator can clearly see any approaching vehicles.
49–51	Left turns	These slides present information on performing safe left turns. The simulation on slide 49 shows an example of an unsafe left turn. The simulation on slide 50 provides an example of a safe left turn. The trainer should compare and contrast what made one safe and the other unsafe.
52–53	Allowing the public to pass	These slides provide information on why long lines of following vehicles may become a hazard. Strategies to allow the public to pass are presented.
56	Additional resources	Information on additional resources are presented.
57–59	Acknowledgements	Acknowledgements of thanks to all participating agencies.

## Safe Driving Training

This training focused on general safe driving practices that the operator can use to prevent crashes often caused by the snowplow operator. The full module with videos can be accessed through the Clear Roads website, along with an instructional guide and pre- and post-module quiz.

This training focused on four major topics.

1. Hazard identification
2. Safe backing
3. Limiting driver distractions
4. Driver fatigue management

This module was separated into four sections: hazard identification, safe backing, distracted driving, and fatigue management. Included in the notes section of each slide was a suggested narration. The suggested narration can be used by the training facilitator word-for-word or can be modified.

There are brief check-on-learning breaks throughout the module. These questions break the content into small sections and help the operators remember important information.

Finally, facilitators can add agency-specific guidance or policies where appropriate throughout the module.

## Slide Summary

This module contains 70 slides. Table 2 provides an overview of the slides.

**Table 2. Safe Driving Training Slide Descriptions**

Slide	Content Topic	Content Description
1–6	Introduction to the module	The first six slides provide a summary of the training, the training objectives, and an overview of snowplow crashes where the snowplow struck another vehicle or object.
7–22	Hazard identification	This section of the module provides information and strategies to identify and respond to fixed object hazards
8–10	Strategies to identify hazardous fixed objects	These two slides discuss the process of scanning the environment for hazards and provide recommendations for improved scanning.
11	Simulation related to fixed object hazard	A simulation showing a crash related to a fixed object. Although the simulation does not show an actual crash with a fixed object, the sideswipe crash is caused by poor visual scanning and late identification of the fixed object. This video can be shown twice. During the first viewing, simply review the simulation. During the second viewing, ask operators to identify strategies to prevent this crash from occurring.
12–13 17–18 26–27 33–34 43–44 51–52 58–59 65–66	Check-on-learning	These slides present example quiz questions. This information can be used a brief review or can actually be used as an evaluation.
14–16	Documenting hazards	These slides include information on documenting areas with known and hidden hazards.
19–21	Preventing fixed object strikes	Specific strategies are presented to help operators avoid fixed object strikes.
22–36	Safe backing	This section discusses how operators can safely back their snowplow.

Slide	Content Topic	Content Description
23–25	Causes of backing crashes	These slides present information on the common causes of backing crashes. Slide 25 includes a simulation of a typical backing crash. In this simulation, the snowplow operator enters a gas station and needs to back up to turnaround. While backing up, the snowplow strikes a light pole. The pole could have been seen in the side mirrors; however, as is common in backing crashes, the operator failed to properly scan their mirrors or G.O.A.L. – get out and look.
28–29	Circle of Safety	These slides discuss G.O.A.L. – get out and look.
30–31	Spotters	Spotters should be used while backing if available. These slides discuss why spotters should be used and common signals spotters can use to communicate with the operator. If your agency has additional or alternative signals frequently used, you can replace or add to this slide.
32	Additional backing suggestions	This slide presents additional safety suggestions related to backing.
35–36	Alternatives to backing	Alternatives to backing should be used when available and appropriate. These slides discuss these alternatives.
37–52	Limiting distractions	This section discusses the dangers of distracted driving and provides tips for avoiding distractions while driving.
38	Description of distraction	This slide defines distracted driving.
39	Distracted driving video	The driver in this video is clearly distracted. The video demonstrates what can happen when the driver's eyes are off the road for an extended period of time.
40–42	Inattention	These slides discuss the risks of driving while distracted, including cognitive distraction, and present specific tips drivers can use to reduce or eliminate general inattention.
45–47	External distraction	These slides present information on external distractions and present specific tips drivers can use to reduce or eliminate external distractions. Slide 47 includes a video example of the risks of external distractions. This video has four views: 1) the top left quadrant is the driver, 2) the top right quadrant is looking out the forward windshield, 3) the bottom left is the view from the right side mirror, and 4) the bottom right is the view from the left side mirror.
48–50	Internal distractions	These slides present information on internal distractions and present specific tips drivers can use to reduce or eliminate internal distractions.
53–67	Fatigue management	This section discusses driver fatigue management.
54–60	Understanding driver fatigue	These slides describe what driver fatigue is, provide a video example, and discuss the common causes of driver fatigue. Slide 57 includes a video example of what driver fatigue often looks like. This video has four views: 1) the top left quadrant is the driver, 2) the top right quadrant is looking out the forward windshield, 3) the bottom left is the view from the right side mirror, and 4) the bottom right is the view from the left side mirror.



Slide	Content Topic	Content Description
61–64	Reducing fatigue	These slides discuss proven strategies drivers can use to reduce or prevent driver fatigue.
67	Additional resources	Information on additional resources are presented.
68–70	Acknowledgements	Acknowledgements of thanks to all participating agencies.

## Conclusions

This project developed two comprehensive and engaging snowplow operator training modules on defensive driving and safe driving. To accomplish this goal, questionnaires, interviews, and crash data were collected to examine the key causes of collisions involving snowplows and to identify strategies that snowplow operators can use to prevent crashes. Data from this project showed that snowplows are involved in many crashes every year. Although a large portion of these crashes are relatively minor, many are considered preventable by winter maintenance agencies. These preventable crashes include fixed-object strikes, run-off-road crashes, backing crashes, wing-plow strikes, and crashes where another vehicle rear-ended the snowplow.

The two snowplow operator training modules developed in this project were designed to specifically target ways operators may prevent these common snowplow crash types. The defensive driving training modules include information, video examples, and strategies for snowplow operators to prevent wing-plow strikes and strike-from-behind crashes. The safe driving training modules include information, video examples, and strategies for snowplow operators to prevent fixed-object strikes, run-off-road, and backing crashes.

Although this project provides an excellent starting point for preventing and mitigating snowplow crashes, additional research, public outreach, and training programs are needed to identify additional countermeasures to prevent crashes involving a snowplow. Some examples are listed below.

- Additional research is needed to assess knowledge retention and transfer of knowledge from operators taking these training modules.
- Although some objective crash data was collected in this study, additional crash data from a larger sample of states is needed to further investigate contributing factors to snowplow crashes.
- There is a need for an assessment of the effectiveness of different configurations of rear-facing warning lighting, including different variations of brake lights.
- An analysis is needed to assess the effectiveness and return-on-investment of advanced safety systems for snowplows, including vehicle-to-infrastructure, forward radar, rear-facing radar, differential GPS, and active lane steering.
- Although some state DOTs have programs that include sharing the road with snowplows, additional hands-on programs are needed to further promote safe practices. Previous research by VTTI showed that students prefer kinematic learning (i.e., hands-on and video learning) compared to traditional text-based learning (Baker et al., 2014). Additionally, research on the effectiveness of VTTI's *Sharing the Road with Trucks* program ([Sharing the Road with Trucks](#)) showed that students significantly increased their knowledge about safely sharing the road with heavy vehicles with an in-person, hands-on educational event (Camden et al., in press).

- An assessment of the effectiveness of state DOTs' public outreach related to sharing the road with snowplows is needed.
- There is a need to create and assess the effectiveness of simulator and hands-on training to prevent snowplow-related crashes.

## Appendix A: Questionnaire

### DEFENSIVE DRIVING TRAINING FOR SNOWPLOW OPERATORS

Dear Winter Maintenance Manager,

Under sponsorship of the Clear Roads Pooled Fund, the Virginia Tech Transportation Institute (VTTI) is collecting information about crashes in snowplows and best practices to prevent those crashes. Clear Roads is a national research consortium of 36 States focused on rigorous testing of snowplow materials, equipment, and methods used by highway maintenance crews.

The purpose of this project is to identify common crash types involving snowplows, analyze common causes of these crashes, and develop operator training to mitigate these common causes.

Your experiences and opinions as winter maintenance manager will assist in identifying causes of crashes involving snowplows and suggestions on operator training to prevent those crashes. The current questionnaire, which will take about 15 minutes to completed, asks about your experience with crashes involving snowplows, common crash types, the reasons behind these crashes, and defensive driving techniques used by snowplow operators and their perceived effectiveness in preventing crashes.

The outcome of this project will be the creation of two comprehensive and engaging snowplow operator training modules on defensive driving and safe driving.

After submitting your questionnaire responses, you will have the option to provide contact information in a separate questionnaire. Your contact information will be confidential and will only be used by VTTI research to gain additional insight in snowplow crashes and safe driving best practices.

If you have any questions, please feel free to contact Matt Camden, [mcamden@vtti.vt.edu](mailto:mcamden@vtti.vt.edu), or 540-231-1503.

If you are not the appropriate person to answer these questions, please forward to someone in your agency that could.

If you agree to participate in this research project, please click “next” below. Once you click “next” you will automatically be taken to the questionnaire. You may simply close this window if you do not wish to complete the questionnaire.

1. Please select the choice that best represents who you work for during winter operations.
  - a. State DOT
  - b. Contractor
  - c. City/County
  - d. Other (Please specify): \_\_\_\_\_
  
2. If you work for a State DOT, please select where most of your work is performed.
  - a. In the central office
  - b. Within a specific region/district
  
3. In what state are you responsible for snowplow operations?  
\_\_\_\_\_
  
4. What city or county is your jurisdiction?  
\_\_\_\_\_
  
5. What is your current job title? \_\_\_\_\_
  
6. On average, how much snow does your county/winter maintenance jurisdiction receive each year (in inches)? \_\_\_\_\_
  
7. How many snowplow trucks operate in your maintenance jurisdiction?  
\_\_\_\_\_
  
8. On average, how many miles do your snowplows travel each year **during snowplow operations**? \_\_\_\_\_
  
9. Last winter season, how many crashes were your snowplows involved in **during snowplow operations**? If you do not have this information available, please ask the appropriate person in your agency or forward this survey to someone in your agency that has this information. \_\_\_\_\_
  - a. How many of these crashes only involved the snowplow (e.g., run-off-road, hit fixed object, etc.)? \_\_\_\_\_
  - b. How many of these crashes involved one other vehicle? \_\_\_\_\_
  - c. How many of these crashes involved two or more other vehicles? \_\_\_\_\_

10. Last winter season, how many of the following crash types were your snowplows involved each year **during snowplow operations**? A preventable crash is defined as a crash where, if your operator did something differently, the incident could have been mitigated or avoided. If you do not have this information available, please ask the appropriate person in your agency or forward this survey to someone in your agency that has this information.

Crash Type	Total Number of Crashes	Number of Preventable Crashes
Run-off-road		
Head-on		
Rear-end (i.e., snowplow rear-ends another vehicle)		
Rear-ended (i.e. another vehicle rear-ends the snowplow)		
Sideswipe		
Wing plow strike (i.e., another vehicle struck the wing plow)_		
Backing		
Hit road debris		
Hit fixed object (e.g., mailbox, guardrail, bridge, etc.)		
Animal strike		
Rollover		
Broadside		
Other (please describe)		

11. On average, how many of these crashes involved the following snowplow configurations?
- Plow truck: \_\_\_\_\_
  - Tractor: \_\_\_\_\_
  - Pick-up truck: \_\_\_\_\_
  - Motor Patrol: \_\_\_\_\_
  - Front-end loader: \_\_\_\_\_
  - Other: \_\_\_\_\_

12. Think about your crashes last winter season where **the snowplow struck another vehicle, person, or object**. What were the top five factors that contributed to these crashes?

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

13. Think about your crashes last winter season where **another vehicle struck the snowplow**. What were the top five factors that contributed to these crashes?

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

14. Think about your crashes last winter season where **the snowplow ran off road the road/rolled over by itself (no other vehicles involved)**. What were the top five factors that contributed to these crashes?

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

15. Please describe any other factors that contribute to snowplow crashes?

a. Environmental factors:

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b. Roadway factors:

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c. Level of service factors:

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d. Other conditions/factors:

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16. Please describe in detail the training and education programs you use to help operators prevent crashes.

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17. What topics should the research team include in the safe and defensive driving training for snowplow operators?

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18. Do you have any other comments or suggestions for the research team to consider when developing the safe and defensive driving training for snowplow operators?

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Please Click "Submit" to submit your responses (if submitting online).

In addition to the questionnaire you just submitted, we would like to follow-up with individuals in 3 to 5 states. The purpose of these follow-up conversations is 1) to gather additional data on specific snowplow crashes and 2) collect examples of effective strategies to prevent these crashes.

1. May a researcher from the Virginia Tech Transportation Institute contact you for a follow-up phone conversation?
  - a. Yes
  - b. No
  
2. If yes, please provide the following contact information (please note that this information is not tied to your recently submitted survey in any way)
  - a. Email: \_\_\_\_\_
  - b. Telephone: \_\_\_\_\_
  
3. In which state do you manager snowplow operations?  
\_\_\_\_\_
  
4. If yes, can you share existing training material on safe and defensive driving for snowplow operators with the research team?
  - a. Yes
  - b. No
  
5. Does your state have a crash or insurance claim data set with all snowplow crashes?
  - a. Yes
  - b. No
  
6. If yes, can you share an anonymized portion of this data set with the research team? You will not need to share identifiable information with the research team.
  - a. Yes
  - b. No

Thank you for completing the questionnaire.

Please mail/email/fax completed paper surveys to the following address. Also, please mail/email/fax your contact information back separately to the same address.

Matt Camden  
Virginia Tech Transportation Institute  
3500 Transportation Research Plaza  
Blacksburg, VA 24061  
Email: [mcamden@vtti.vt.edu](mailto:mcamden@vtti.vt.edu) or Fax: 540-231-1555

## Appendix B: Interview Questions

As you know, the Virginia Tech Transportation Institute is conducting a Clear Roads study to develop snowplow operator training related to safe and defensive driving. The goals of the proposed project are to (1) examine the key causes of collisions involving snowplows and other vehicles, (2) identify defensive driving strategies that snowplow operators can use to reduce the likelihood of being struck by other drivers, and (3) develop two comprehensive and engaging winter maintenance operator training modules on defensive driving and safe driving.

1. What is your title?
2. What are your responsibilities related to snowplow operations?
3. How long have you worked in snowplow operations?

### Crashes

1. Based on our survey, the most common types of crashes involving snowplow vehicles are: hitting a fixed object, run-off-road crashes, backing incidents, crashes where another vehicle strikes the rear of the snowplow, and wing plow strikes. In your experience, are these five crash types some of the most common types of crashes involving snowplow operators?
2. In your state, what are the most common causes of:
  - a. Incidents where the snowplow struck a fixed object? Can you provide any examples?
  - b. Run-off-road crashes? Can you provide any examples?
  - c. Backing crashes? Can you provide any examples?
  - d. Crashes where the snowplow is struck from behind? Can you provide any examples?
  - e. Wing plow strikes? Can you provide any examples?

### Training

1. What techniques and strategies can we teach snowplow operators to prevent or mitigate:
  - a. Incidents where the snowplow struck a fixed object?
  - b. Run-off-road crashes?
  - c. Backing crashes?
  - d. Crashes where the snowplow is struck from behind?
  - e. Wing plow strikes?
2. Are there any other ways snowplow operators can use existing mirrors, lights, and other existing componentry to prevent or mitigate:
  - a. Incidents where the snowplow struck a fixed object?
  - b. Run-off-road crashes?
  - c. Backing crashes?
  - d. Crashes where the snowplow is struck from behind?
  - e. Wing plow strikes?

3. Are there any route-planning strategies (such as minimizing left turns) that should be used to prevent or mitigate:
  - a. Incidents where the snowplow struck a fixed object?
  - b. Run-off-road crashes?
  - c. Backing crashes?
  - d. Crashes where the snowplow is struck from behind?
  - e. Wing plow strikes?
4. Can you share existing training material on safe and defensive driving for winter maintenance operators with the research team?

#### Review of Crash Data

1. Can you provide us with an anonymized data set of your state's snowplow crashes?
2. How many years of data are available?
3. After we review the data, can we have a follow call to discuss specific crashes if needed? This may provide us with more detailed information about the conditions and contributing factors to the crashes.

## Appendix C: Full Analysis Results

A total of 86 individuals from 20 different states responded to the online questionnaire from (Table 3). Most of these respondents performed winter maintenance for a state DOT (84 out of 86); the other two respondents performed winter maintenance as contractors for state DOTs. Further, 73 respondents were responsible for winter maintenance operations within a specific region/jurisdiction, and 13 respondents were responsible for winter maintenance operations for an entire state.

**Table 3. Number of Responses by State**

State	Number of Responses
Alaska	4
California	31
Colorado	1
Connecticut	1
Delaware	1
Idaho	6
Illinois	7
Indiana	6
Iowa	1
Kansas	1
Maryland	3
Missouri	2
Montana	9
North Dakota	2
Ohio	1
Oregon	1
Pennsylvania	1
South Dakota	1
Virginia	1
Wyoming	7
Total	87

### Snowplow Crashes

Questionnaire respondents reported a total of 1,007 snowplow crashes last season. These included 536 single vehicle crashes, 402 multivehicle crashes involving the snowplow and one other vehicle, and 69 multivehicle crashes involving the snowplow and two or more other vehicles.

Some respondents also provided the number of snowplow crashes by crash type (Table 4). The five most common crash types were fixed-object strikes (162), crashes where another vehicle rear-ended the snowplow (131), sideswipes (92), run-off-road crashes (78), and wing-plow strikes (77). The five most common preventable crashes were fixed-object strikes (142), run-off-road crashes (60), backing crashes (50), wing-plow strikes (45), and crashes where another vehicle rear-ended the snowplow (43).

**Table 4. Self-Reported Snowplow Crashes by Crash Type**

Crash Type	Total Number of Crashes	Number of Preventable Crashes
Run-off-road	78	60
Head-on	22	4
Rear-end (i.e., winter maintenance vehicle rear-ended another vehicle)	19	13
Rear-ended (i.e., another vehicle rear-ended the winter maintenance vehicle)	131	43
Sideswipe	92	29
Wing plow strike (i.e., another vehicle struck the wing plow)	77	45
Backing	58	50
Hit road debris	22	7
Hit fixed object (e.g., mailbox, guardrail, bridge, etc.)	162	142
Animal strike	0	0
Rollover	12	8
Broadside	9	4

Additionally, snowplow crash data were requested from six state DOTs to confirm the self-report questionnaire data. To date, three states have provided snowplow crash data spanning eight years. These data included 1,126 crashes. Table 5 shows the number of crashes by crash type. Excluding the crashes coded as unknown or non-contact, the most common crashes were: fixed object strikes, backing incidents, wing plow strikes, hit by another vehicle, sideswipes, and run-off-road crashes.

**Table 5. State DOT Snowplow Crashes by Crash Type.**

Crash Type	Total Number of Crashes
Backing – fixed object strike	58
Backing – other vehicle strike	27
Broadside another vehicle	2
Broad-sided by another vehicle	3
Head-on	3

Crash Type	Total Number of Crashes
Hit by other vehicle (location undetermined)	68
Fixed object strike – on road (not backing)	161
Fixed object strike – parking lot (not backing)	45
Hit road debris	17
Mechanical malfunction	21
Non-contact incident (e.g., employee slip, snow spray, etc.)	109
Opposite direction sideswipe	14
Parking Lot – hit other vehicle	18
Hit pedestrian	1
Rear-end other vehicle	18
Rear-ended by other vehicle	55
Run-off-road	33
Sideswipe	45
Truck hit other vehicle (location undetermined)	41
Wing plow strike – fixed object	53
Wing plow strike – hit by other vehicle	14
Wing plow strike – struck another vehicle	14
Unknown (no details provided)	306

### Crash Contributing Factors

In addition to collecting data on common crash types, questionnaire respondents were asked to provide insight into common contributing factors in snowplow crashes. These responses are provided in the sections below.

#### Snowplow Striking Crashes

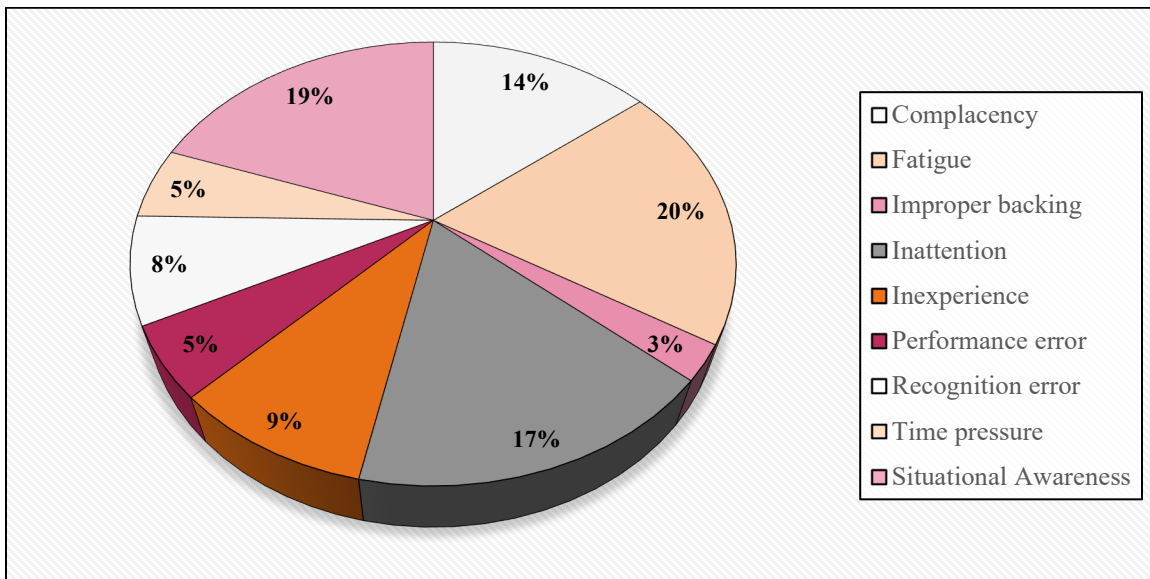
As shown above in Table 4 and Table 5, the most common crash type involved the snowplow striking another object, vehicle, or pedestrian. Questionnaire respondents were asked what factors often contributed to these crash types. Table 6 shows respondents most often attributed these crash types to the snowplow operator (77), weather (31), and vehicle maneuvers (22). Fewer comments involved the driving public (12) and snowplow equipment (10).

**Table 6. Contributing Factors to Snowplow Striking Crashes.**

Theme	Number of Responses
Plow Operator	77
Equipment	10
Driving public	12
Vehicle maneuvering	22
Weather	31

### ***Snowplow Operator Contributing Factors***

The 77 comments about the contributing factors associated with the snowplow operator focused on nine subthemes (Figure 2). The four most common subthemes were snowplow operator fatigue (e.g., “Sleep deprivation, working 18 hours overnight”), lack of situational awareness (e.g., “Not knowing surroundings”), snowplow operator inattention (e.g., “Lack of focus”), and snowplow operator complacency (e.g., “Operator becomes complacent over time”). A few comments included operator improper backing (e.g., “Operator not getting out to check distances”), operator inexperience (e.g., “Lack of training”), performance errors (e.g., “Wrong angle on plow causing snow damaging windshield of a private vehicle going in the opposite direction”), recognition errors (e.g., “Misjudgment on stopping distance”), and time pressures (e.g., “False sense of urgency”).

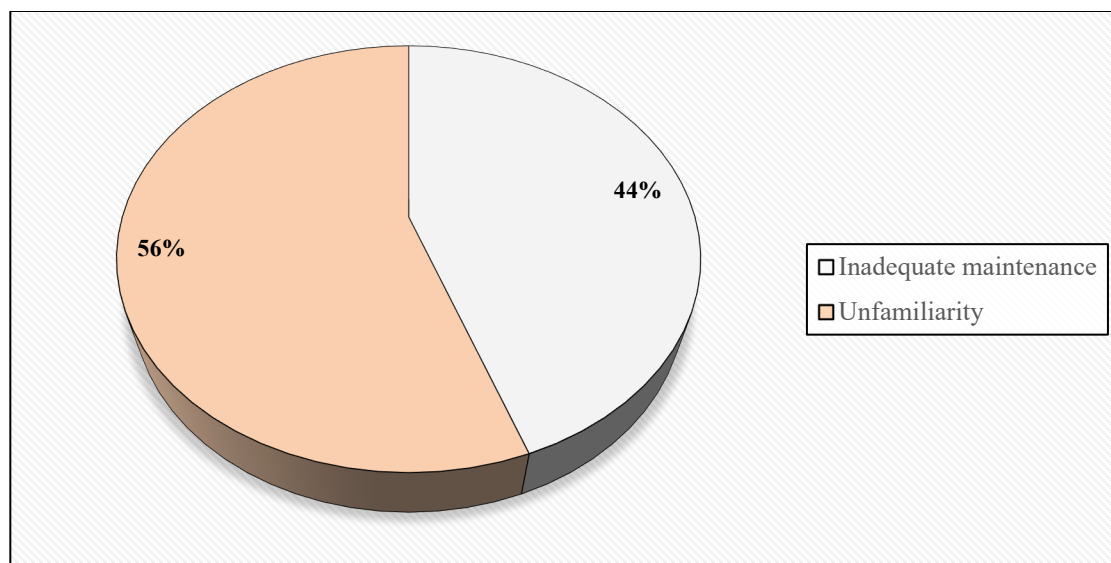


**Figure 2. Snowplow Striking Crashes – Plow Operator Contributing Factors**

### ***Equipment Related Contributing Factors***

There were 10 comments about the contributing factors associated with snowplow equipment (Figure 3). These included inadequate equipment maintenance (e.g., “Bad tires”), and unfamiliarity with equipment (e.g., “New plow design different geometry of the plow”).

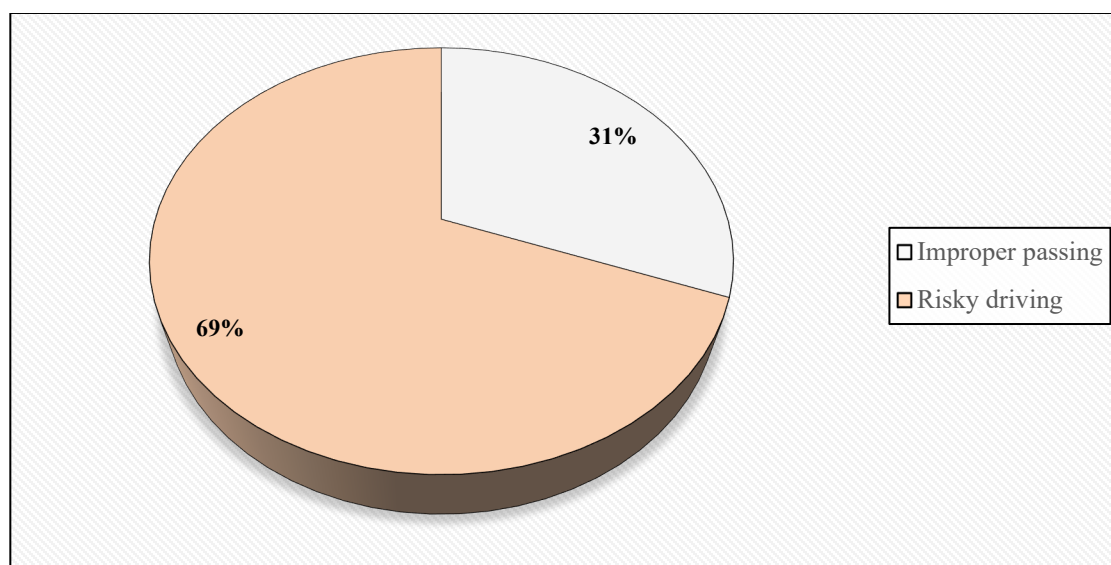




**Figure 3. Snowplow Striking Crashes – Equipment Related Contributing Factors**

### ***Driving Public Related Contributing Factors***

There were 12 comments about the contributing factors associated with the general driving public. These involved two subthemes (Figure 4): general risky driving (e.g., “Other vehicle out of control”), and improper passing the snowplow (e.g., “Passing on right side”).

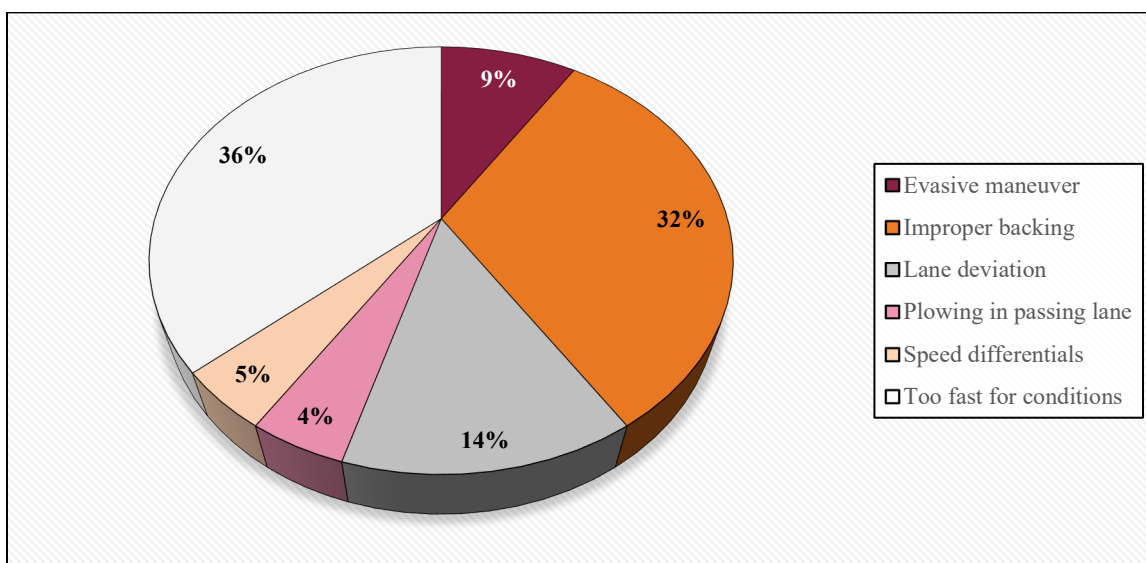


**Figure 4. Snowplow Striking Crashes – General Driving Public Contributing Factors**

### ***Vehicle Maneuvering Contributing Factors***

The 22 comments about contributing factors associated with vehicle maneuvering focused on six subthemes (Figure 5). The most common contributing factors were driving too fast for conditions (e.g., “Traveling too fast for conditions”), and improper backing (e.g., “Improper procedures during backing”). Other comments involved performing evasive maneuvers (e.g., “Avoiding object or auto”), deviating outside the lane of travel (e.g., “Crossing over center line”), plowing

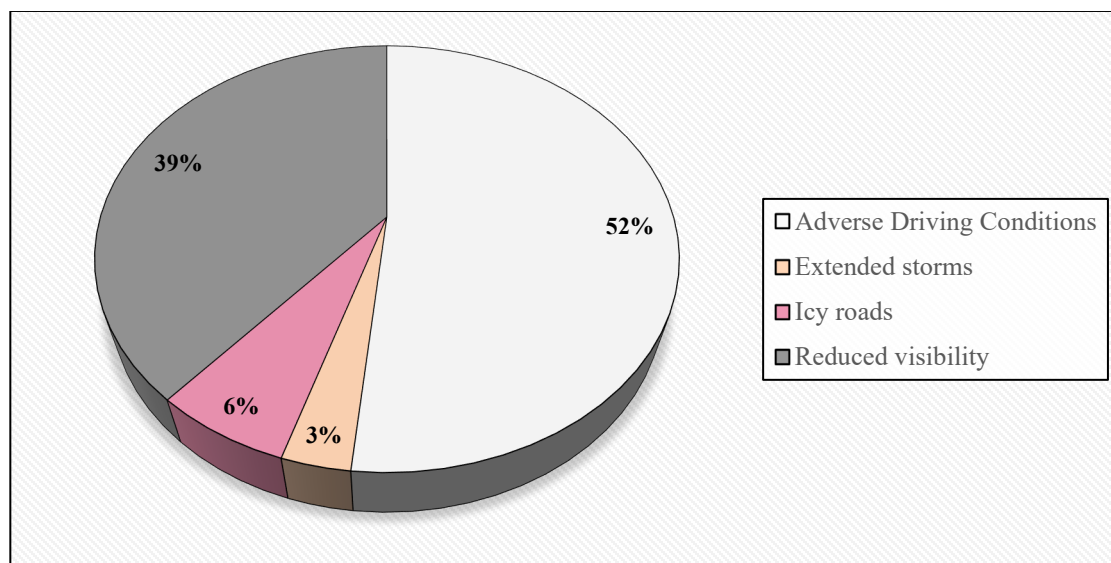
in the passing lane (e.g., When plowing in the passing lane or left shoulder on rural interstates), and speed differentials between the driving public and the snowplow (e.g., Difference in speed between public and snow plow truck”).



**Figure 5. Snowplow Striking Crashes – Vehicle Maneuvering Contributing Factors**

### *Weather-related Contributing Factors*

The 31 comments about contributing factors associated with the weather focused on four subthemes (Figure 6). The most common weather-related contributing factors were driving in adverse conditions (e.g., “Out of control on slick pavement”), and reduced visibility (e.g., “Poor visibility due to blowing snow”). There were a few comments associated with long duration winter storms (e.g., “Extended duration of storms”) and driving on icy roads (e.g., “Icy road”).



**Figure 6. Snowplow Striking Crashes – Weather-Related Contributing Factors**

## Crashes Where the Snowplow is Hit by Another Vehicle

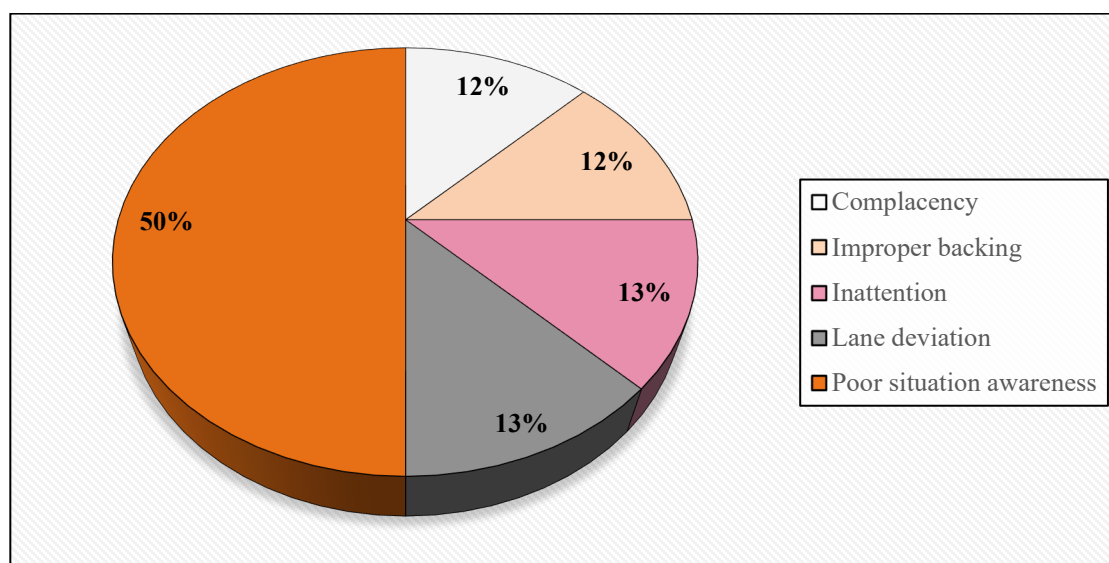
Questionnaire respondents were asked to provide contributing factors to crashes where another vehicle strikes the snowplow (Table 7). Most of the comments indicated that the general driving public (90) and weather (33) caused most of these crashes. Other contributing factors included factors associated with the snowplow operator (7) and vehicle maneuvering (5).

**Table 7. Contributing Factors to Crashes where Another Vehicle Strikes the Snowplow**

Theme	Number of Responses
Plow operator	7
Driving public	90
Vehicle maneuvering	5
Weather	33

### *Snowplow Operator Related Contributing Factors*

There were seven comments about contributing factors associated with the snowplow operator (Figure 7). Four of the comments focused on poor situational awareness of the snowplow operator (e.g., “Plow driver not letting traffic clear before making turn across center line to turn around”). There was one comment related to each of the following topics: improper backing into traffic (e.g., “Our driver was backing into live traffic”), operator inattention (e.g., “Driver inattention”), and deviating outside the lane (e.g., “Crossing line on narrow roads”).

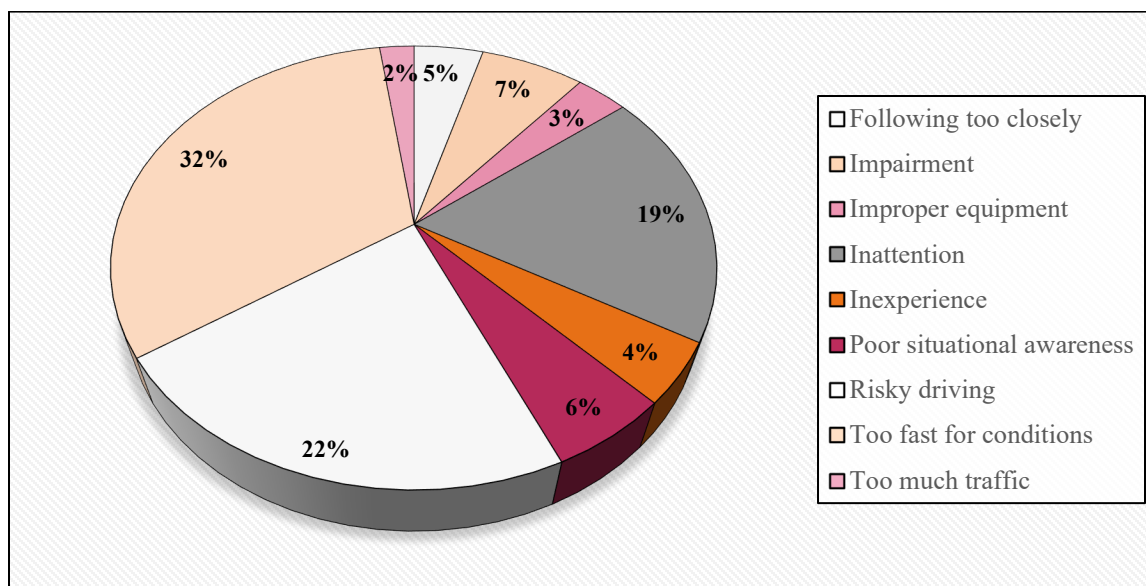


**Figure 7. Struck by Other Vehicle – Snowplow Operator Related Contributing Factors**

### *Driving Public Related Contributing Factors*

The respondents provided 90 comments related to contributing factors associated with the general driving public (Figure 8). These comments focused on nine subthemes. The most common comments focused on the general driving public driving too fast for conditions as a primary contributing factor in crashes where another vehicle hit the snowplow (e.g., “Traffic from the rear could not slow down on slick pavement”). Other common contributing factors

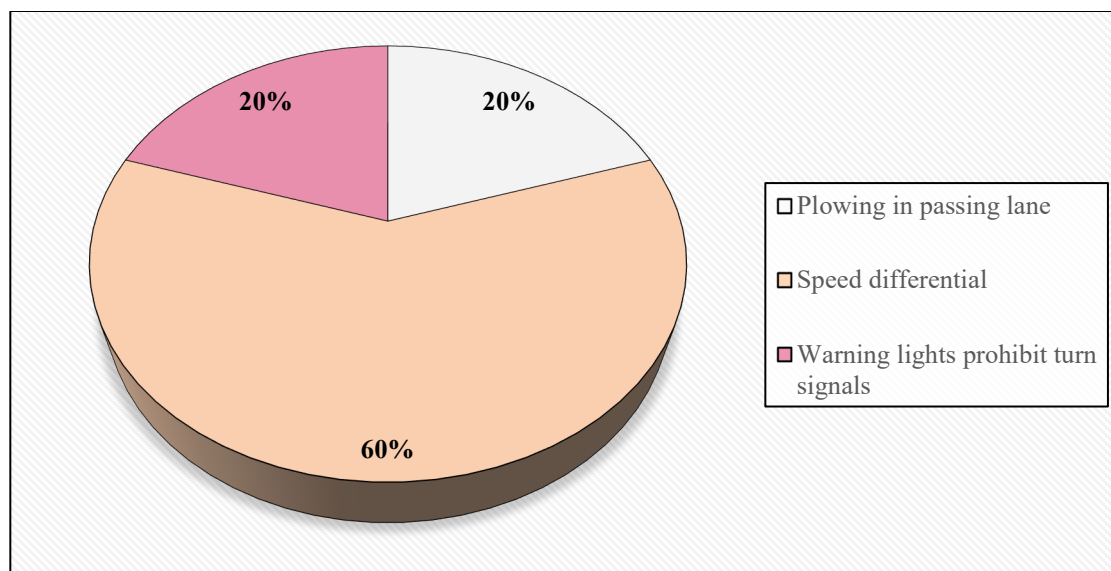
included general risky driving by other vehicles (e.g., “Passing in a snow cloud”) and other driver inattention (e.g., “Other vehicle not paying attention). A few comments discussed another vehicle following the snowplow too closely (e.g., “Following too close to the snowplow”), driver impairment (e.g., “Head on crash - drunk driver driving on the wrong side of the road”), improper equipment (e.g., “Bald tires”), inexperience driving in winter conditions (e.g., “Lack experience”), poor situational awareness (e.g., “Unaware of surroundings), and too much traffic on the roadway (e.g., “Traffic”).



**Figure 8. Struck by Other Vehicle – Driving Public Related Contributing Factors**

### ***Vehicle Maneuvering Related Contributing Factors***

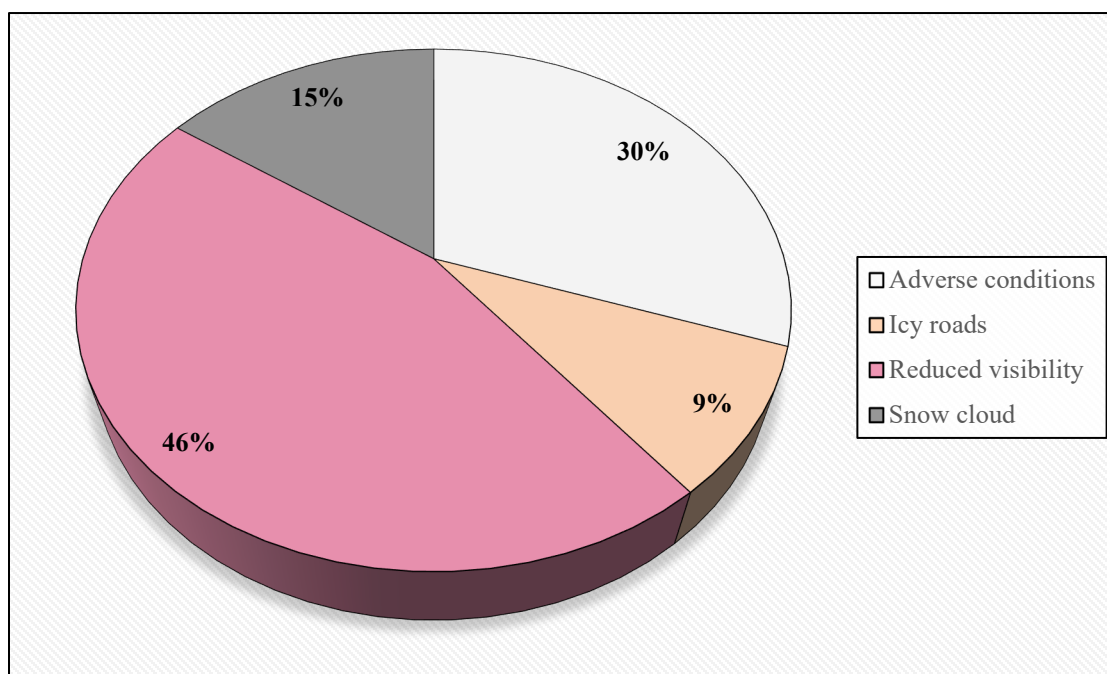
There were four comments related to how the snowplow was maneuvering on the roadway (Figure 9). Three of these comments related to the speed differential between the snowplow and the general driving public (e.g., “Difference in public vs. snowplow truck speed”). One other comment indicated other vehicles are more likely to strike the snowplow when it is plowing in the passing lane (e.g., “Operating on 4-lane in passing lane). The last comment indicated the snowplow’s warning lights made it difficult for vehicles following to identify if a turn signal was activated (e.g., “Warning lights limiting signal visibility on plow trucks”).



**Figure 9. Struck by Other Vehicle – Vehicle Maneuvering Related Contributing Factors**

### *Weather Related Contributing Factors*

Participants provided 33 comments associated with weather-related contributing factors in crashes where another vehicle struck a snowplow (Figure 10). The two most common types of comments were related to reduced visibility (e.g., “Wing plows could not be seen at night”) and general adverse road conditions (e.g., “Poor driving conditions”). Other comments mentioned the dangers of icy roads (e.g., “Icy roads”) and a snow cloud (e.g., “Snowplow white out, where the plow creates a white out for travelers”).



**Figure 10. Struck by Other Vehicle – Weather Related Contributing Factors**

## Single Vehicle Crashes

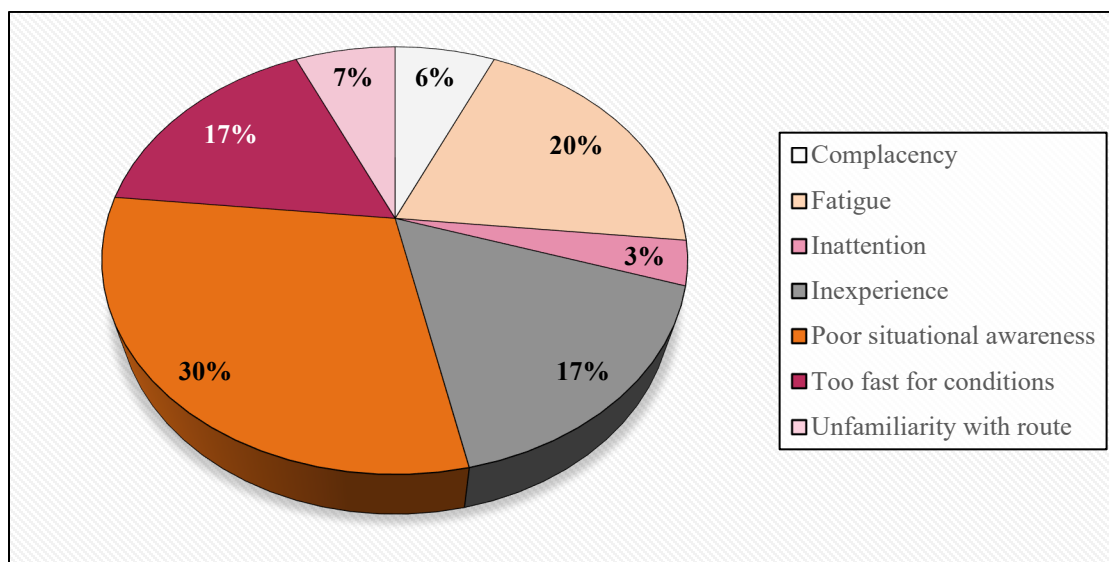
Respondents were asked to indicate the contributing factors associated with single vehicle snowplow crashes. Table 8 shows the 49 comments surrounding three main themes: the snowplow operator (30 comments), weather (16 comments), and various equipment and infrastructure.

**Table 8. Contributing Factors to Single Vehicle Snowplow Crashes.**

Theme	Number of Responses
Snowplow operator	30
Equipment and Infrastructure	3
Weather	16

### *Snowplow Operator Related Contributing Factors*

The 30 comments related to contributing factors associated with the snowplow operator were grouped into four main subthemes (Figure 11), including poor situational awareness (e.g., “Misjudged where edge of road was”), operator fatigue (e.g., “Sleep deprivation, overnight shift 18 or more hours long”), operator inexperience (e.g., “Not enough experience”), and driving too fast for condition (e.g., “Plowing too fast for conditions”). A few comments included operator complacency (e.g., “Complacency”), operator inattention (e.g., “Distracted driving”), and being unfamiliar with the route (e.g., “Driver not familiar with the road”).



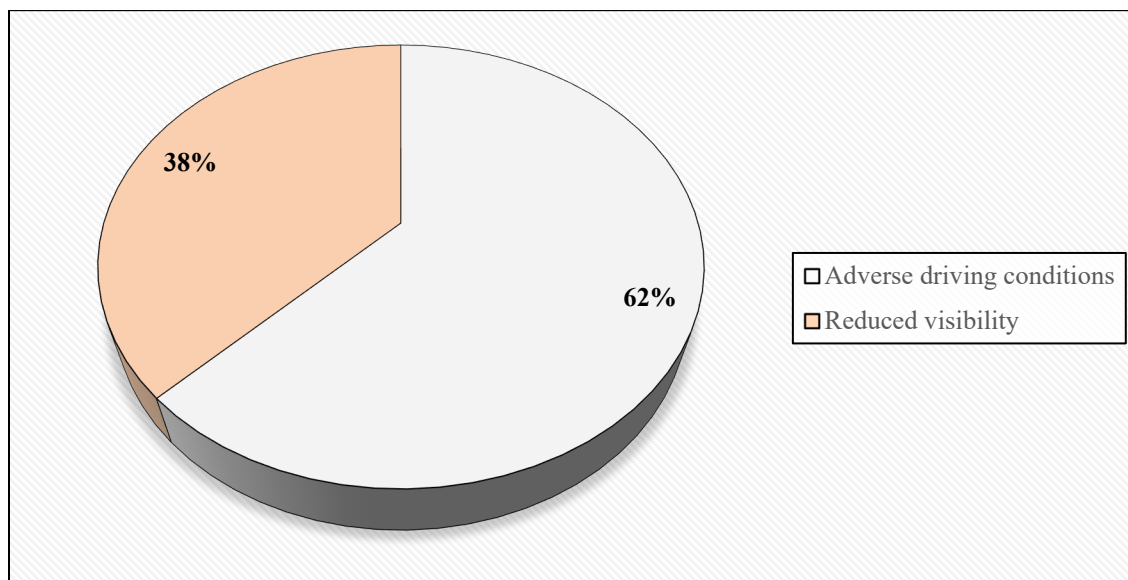
**Figure 11. Single Vehicle Snowplow Crashes – Snowplow Operator Related Contributing Factors**

### *Equipment and Infrastructure Contributing Factors*

Respondents provided two comments related to equipment or infrastructure. One of these responses indicated that a lack of roadway shoulder contributed to run off road crashes. The other comment mentioned the misuse or lack of tire chains.

### ***Weather Related Contributing Factors***

There were 16 comments about weather-related contributing factors in single vehicle snowplow crashes (Figure 12). These comments were related to general adverse road conditions (e.g., “Slick pavement...lost control”) and reduced visibility (e.g., “Zero visibility”).



**Figure 12. Single Vehicle Snowplow Crashes – Weather Related Contributing Factors**

### ***Other Crash Contributing Factors***

Respondents were asked to provide comments on other potential contributing factors in snowplow crashes related to the environment, roadway, and/or level-of-service (Table 9). Respondents provided an additional 260 comments on snowplow crash contributing factors; however, many of these contributing factors were already discussed above. These 260 comments focused on six main themes, including weather (103 comments), snowplow operator (41 comments), general driving public (40 comments), snowplow operation (36 comments), road design (32 comments), and vehicle and other equipment (8 comments).

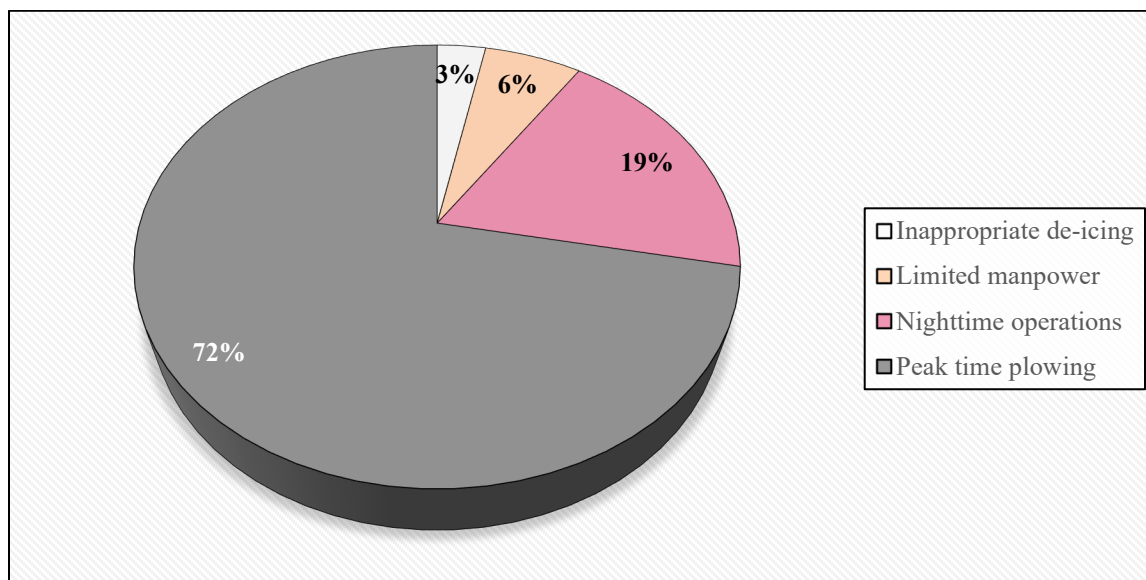
**Table 9. Other Snowplow Crash Contributing Factors**

Theme	Number of Responses
Snowplow operations	32
Snowplow operator	41
General driving public	41
Road design	32
Vehicle and equipment	5
Weather	104

### ***Snowplow Operation Contributing Factors***

There were 32 comments about other snowplow contributing factors related to the operation of the snowplow (Figure 13). Most of these comments referenced the risk of plowing during peak travel times (e.g., “Heavy traffic coming into town to work”). Other comments discussed the

risks associated with nighttime plowing operations (e.g., “Night ops/low visibility due to darkness at night”), the limited number of operators available to plow (e.g., “They do the best they can at providing a high level of service but we are low in staff and can’t work our primary and secondary routes 24-7”), and inappropriate de-icing techniques (e.g., “DOTs who do NOT understand the concept anti icing....which continue to use a de-icing practice. We no longer can leave a ½” of snow on high volume roads which can quickly turn to ice”).

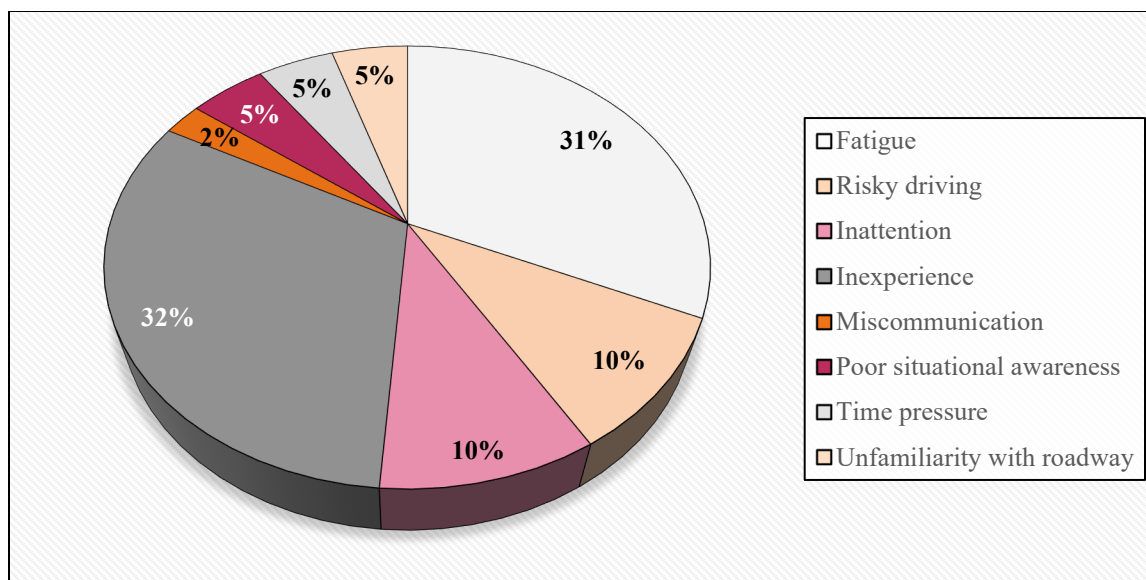


**Figure 13. Other Crash Contributing Factor – Snowplow Operations**

### ***Snowplow Operator Contributing Factors***

Respondents provided 41 comments regarding contributing factors associated with the snowplow operator (Figure 14). The majority of these comments focused on snowplow operator inexperience (e.g., “Inexperienced operators, need more hands on training courses and showing of seasoned operators”) and snowplow operator fatigue (e.g., “Driver fatigue after multiple shifts for a large event”). Other comments related to snowplow operator inattention (e.g., “Distractions”), general risky driving (e.g., “Speeding”), poor situational awareness (e.g., “Difficult to identify obstacles when buried in snow”), time pressure (e.g., “Pressure from management to hurry”), unfamiliarity with roadways (e.g., “Unfamiliar with area and different obstructions, lack of local knowledge and unforeseen events”), and operator miscommunication (e.g., “Miscommunication between drivers”).

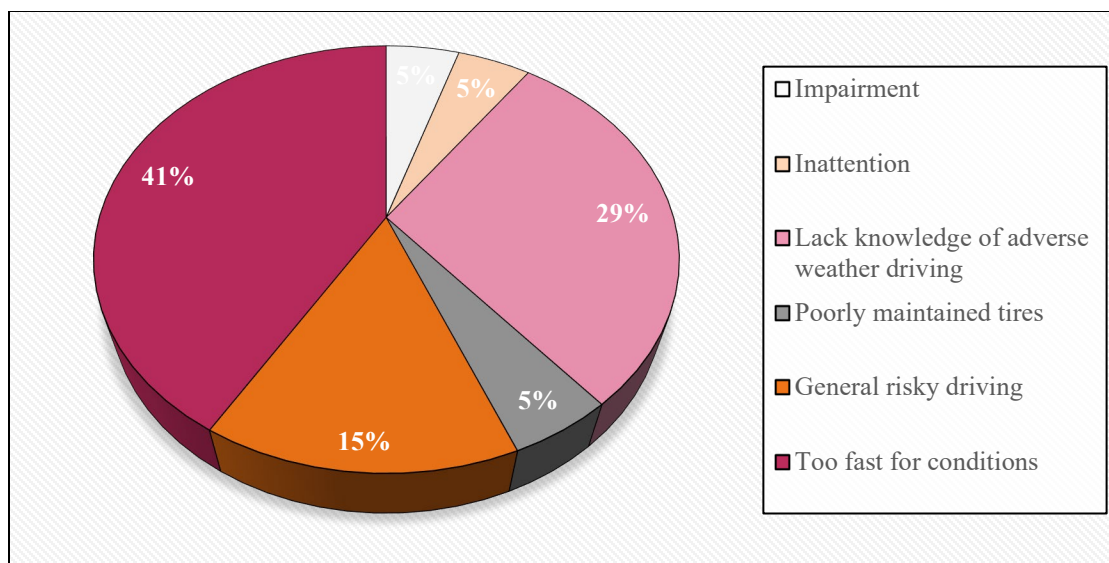




**Figure 14. Other Crash Contributing Factors – Snowplow Operator**

### *General Driving Public Contributing Factors*

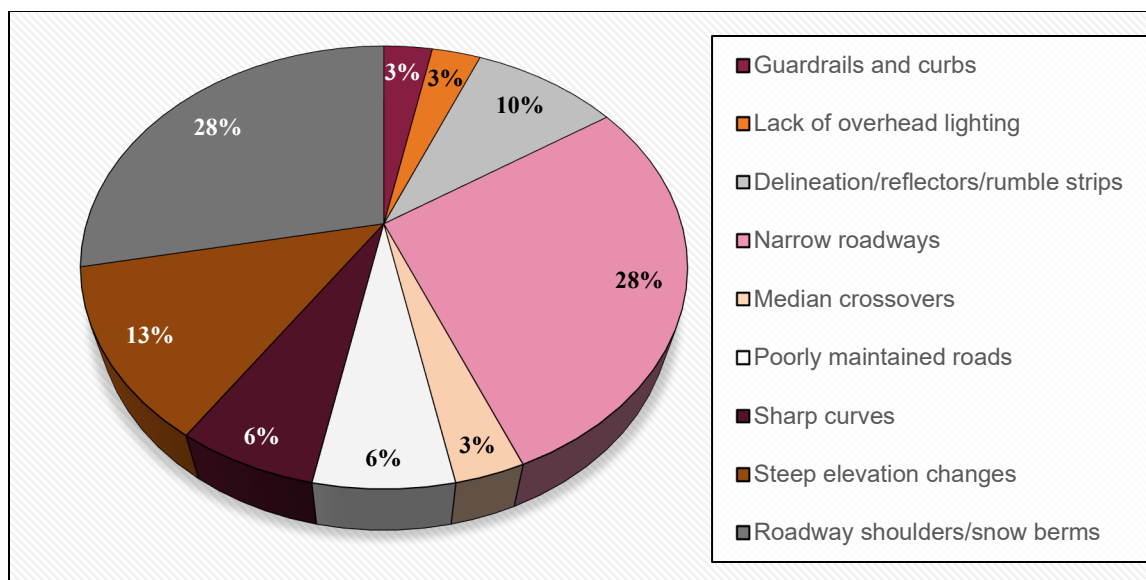
There were 41 comments discussing contributing factors associated with the general driving public (Figure 15). The most frequent comments focused on the risks associated with the general driving public driving too fast for conditions (e.g., “Traveling public not giving way to the plow trucks or respecting the road and/or environmental conditions. The public seems to expect that they can travel winter roads without giving themselves any additional time to get to their destination safely. Many are traveling beyond the safe speed for the road existing conditions or their winter driving skills.”). Other common comments focused on the public’s lack of knowledge about driving in adverse weather conditions (e.g., “Travelers who don’t get snow at home. Those that don’t realize there is a difference between snow at 2000 foot elevation 32 degrees [wet heavy] and 5000 foot 28 degree [small dry icy] snow.”), and the public’s general risky driving behaviors (e.g., “Impatient drivers, passing when they can’t see or don’t have enough room, passing on the right of the plow when discharging that way”). A few comments described driver impairment (e.g., “DUI drivers”), driver inattention (e.g., “Distracted drivers”), and poorly maintained tires (e.g., “Other vehicles that lost control and hit our snowplow trucks had inadequate tires for winter conditions”).



**Figure 15. Other Crash Contributing Factors – General Driving Public**

### ***Road Design Contributing Factors***

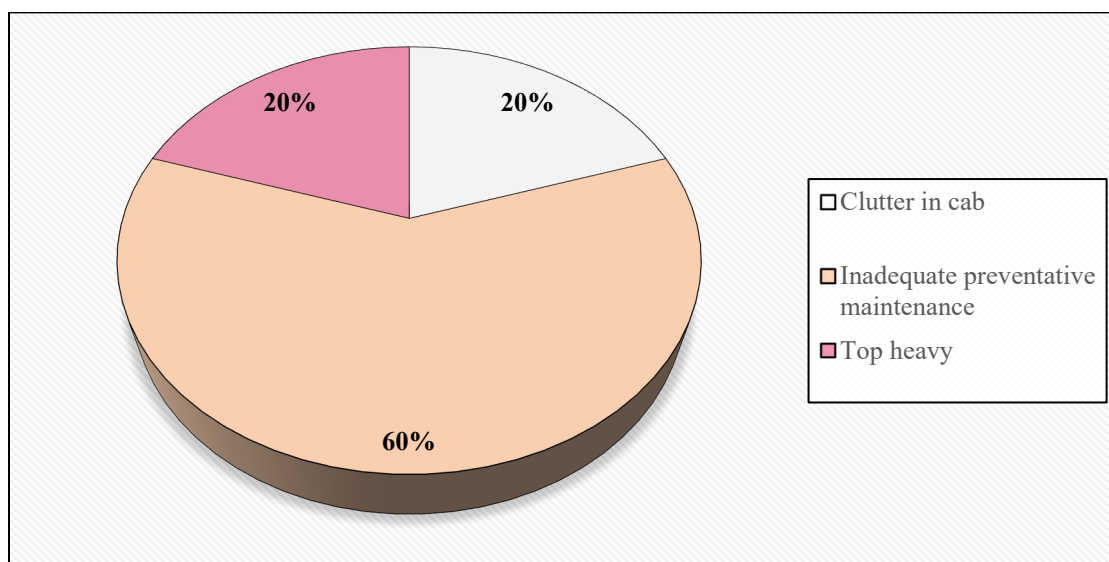
There were 32 comments about contributing factors associated with road design and/or maintenance (Figure 16). Over half of the comments were related to factors associated with narrow roadways (e.g., “Some of the roadways are narrow and as snow berms build up the roads get even narrower”), and how the roadway shoulders (or lack thereof) or snow berms contribute to snowplow crashes (e.g., “No shoulder”). A few comments focused on guardrails or curbs (e.g., “Guardrails and curbs not designed for snow removal operations”), overhead lighting (e.g., “Night time, low lighted areas”), steep elevation changes (e.g., “Many of our roads have very challenging vertical and horizontal alignments”), lane or roadway delineation, reflectors, and/or rumble strips (e.g., “Lack of delineation of shoulder, reflectors”), the risk of using median crossovers (e.g., “No acceleration/deceleration into our out of median cross-overs”), poorly maintained roads (e.g., “Rutted roads, poor drainage, potholes”), and sharp curves (e.g., “Road design [tight curves]”).



**Figure 16. Other Crash Contributing Factors – Road Design**

### *Vehicle and Equipment Contributing Factors*

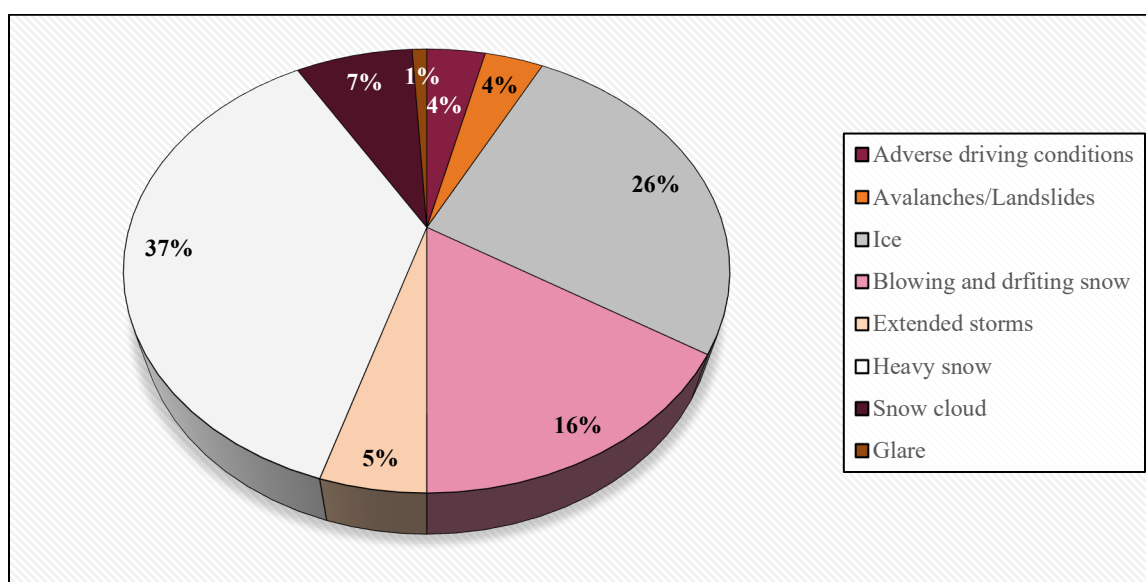
There were five comments associated with vehicle and equipment contributing factors in snowplow crashes (Figure 17). The most common comment mentioned inadequate preventative maintenance on the vehicle and other snowplow equipment (e.g., “Equipment issues: improper walk-a-round inspections antequiate preventative maintenance”). Other comments included clutter inside the cab environment (e.g., “Clutter in cab”), and the truck being top heavy (e.g., “Our V-bottom spreaders can be top heavy due to their configuration when fully loaded”).



**Figure 17. Other Crash Contributing Factors – Vehicle and Equipment**

### Weather Related Contributing Factors

Participants provided 106 comments about contributing factors associated with weather (Figure 18). Most of these comments involved heavy snow (e.g., “Heavy snow white out conditions”), ice (e.g., “Ice accumulation on the roadway”), and blowing and drifting snow (e.g., “Wind driven snow, creates poor visibility, which makes it difficult to maintain the center of the road. That leads to wandering the highway (e.g., “Potential vehicle collisions, delineation damage, mailbox, etc.”). Other comments discussed general adverse driving conditions (e.g., “Poor road conditions”), avalanches and landslides (e.g., “Area has a lot of landslides heavy wind and falling trees come across highway in heavy snow and wind events”), extended duration storms (e.g., “48’ of snow in 20 days”), snow clouds (e.g., “The snow cloud that is naturally kicked up by the snowplow truck limits visibility”), and glare (e.g., “Glare from sun”).



**Figure 18. Other Crash Contributing Factors – Weather**

### Current Training for Snowplow Operators Related to Safe Driving

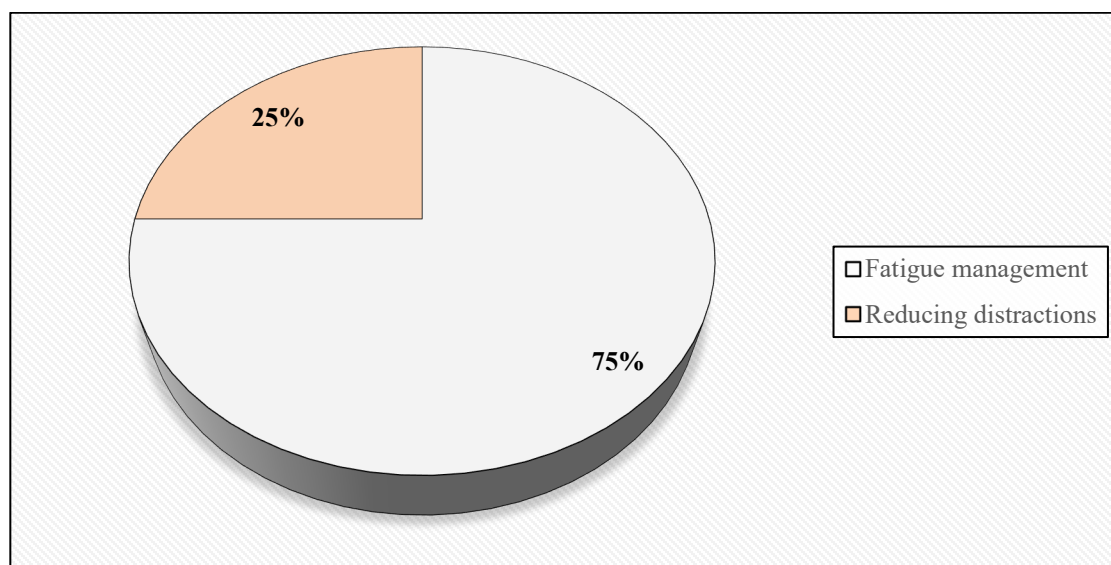
As the objective of this project is to develop snowplow operator training related to defensive driving and strategies to prevent crashes, respondents were asked to provide topics that were included in their fleet’s training program. Table 10 shows that there were 70 separate comments related to five main themes. The most common training focused on crash avoidance techniques (27 comments) and snowplow operation (26 comments). Other training content focused on vehicles and equipment (7 comments), the snowplow route (6 comments), and operator alertness (4 comments).

**Table 10. Current Training Topics Related to Safe Driving**

Theme	Number of Responses
Operator alertness	4
Crash avoidance techniques	27
Snowplow operation	26
Route-related	6
Vehicle and equipment	7

## Snowplow Operator Alertness

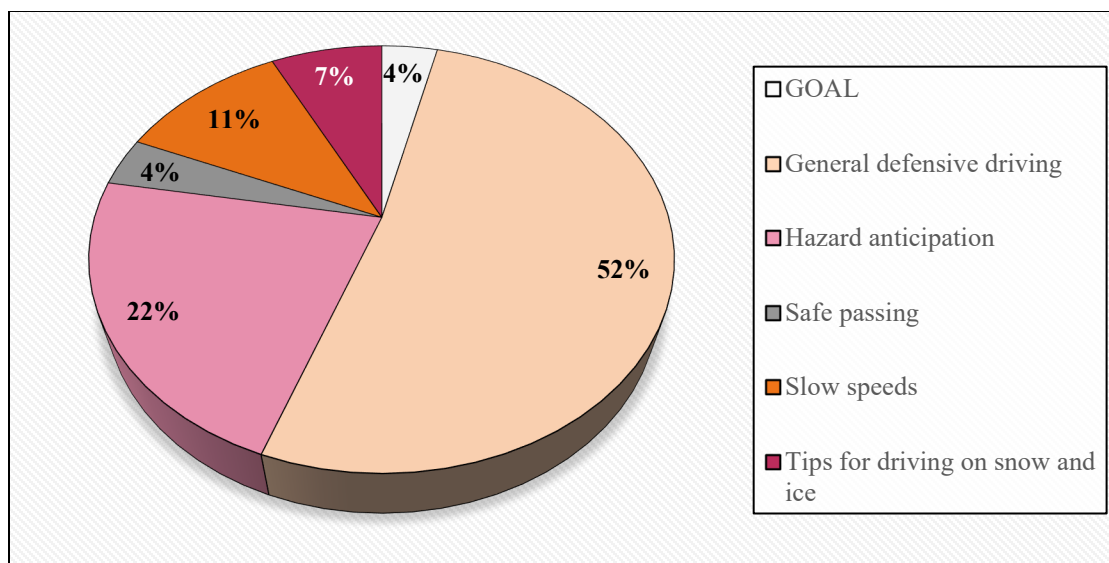
There were only four comments related to current training content focusing on snowplow operator alertness (Figure 19). Three of these comments mentioned fatigue management (e.g., “Take a break if you’re tired”), and the other comment mentioned reducing distractions in the cab (e.g., “Distraction”).



**Figure 19. Current Training – Operator Alertness**

## Crash Avoidance Strategies

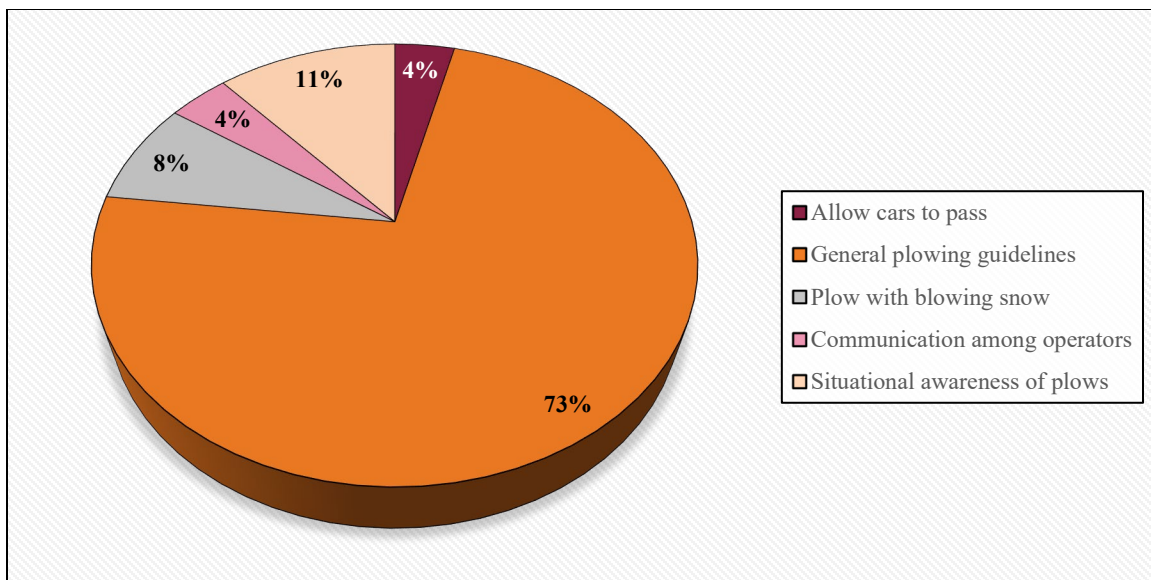
There were 27 comments related to training content focusing on various crash avoidance strategies (Figure 20). The most common training content focused on general defensive driving concepts (e.g., “Defensive driving tailored to the maintenance truck driver”). Another common training topic included hazard identification (e.g., “Being aware of roadway conditions and severity of the storm”). A few comments mentioned training related to getting out and looking (G.O.A.L) before backing (e.g., “Walk around before backing up”), safe passing (e.g., “Safe passing of roadside obstacles and other vehicles”), slow speeds (e.g., “Safe speeds for plowing snow”), and tips for driving on snow and ice (e.g., “Preseason winter driving”).



**Figure 20. Current Training – Crash Avoidance Strategies**

### Snowplow Operation

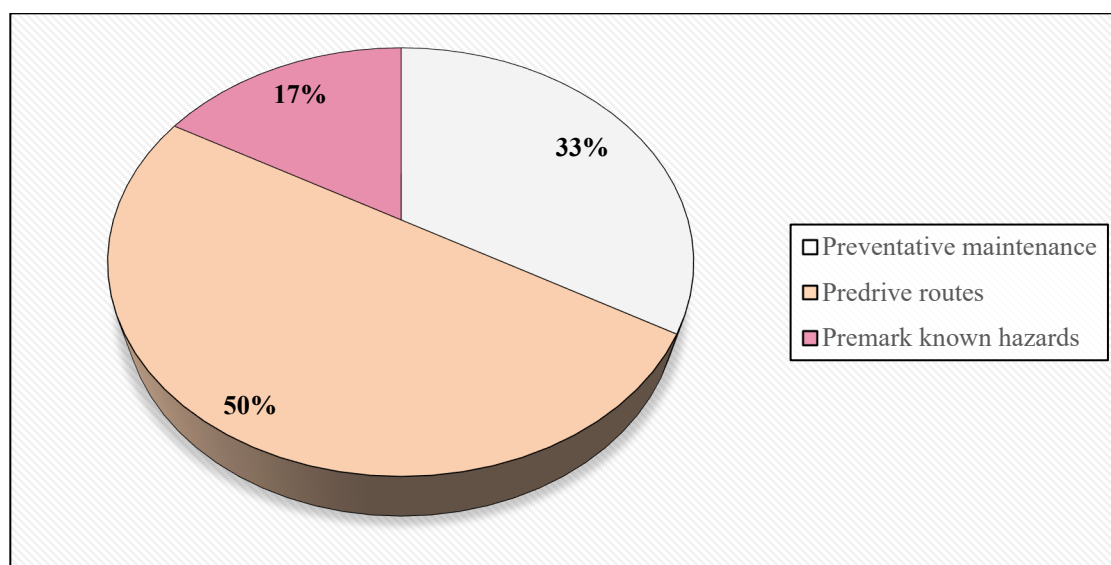
There were 26 comments regarding training on safe snowplow operation (Figure 21). Over 70% of the comments discussed training content on general safe plowing guidelines (e.g., “We have safety meetings every week about work in heavy snow storms, icing conditions”). Other comments discussed allowing cars to pass the snowplow (e.g., “The plow operators pull over whenever they can to allow traffic to pass from behind. The snowplow drivers are also trained to pay close attention and watch their mirrors before making any left hand turns to avoid a collision with vehicles that attempt to pass the truck when it is trying to make a left hand turn.”), plowing with blowing snow (e.g., “Consider the blowing snow and how best to plow that section or if it is completely necessary”), communication strategies among operators (e.g., “Communicate clearly with other employees”), and situational awareness of the snowplows (e.g., “Awareness of drivers turning in front of them and not allowing enough time to make the turning movement”).



**Figure 21. Current Training – Safe Snowplow Operation**

### Snowplow Route

There were six comments about training content related to the snowplow route (Figure 22). Three of the six comments mentioned the importance of pre-driving the route (e.g., “Knowing the road and the timing of traffic”). Other comments mentioned preventative maintenance of the routes (e.g., “Roadway structure maintenance”) and the importance of pre-marking known hazards (e.g., “Mark locations of curbs, drains, signs, drop offs, overpasses, bridges, etc.”).

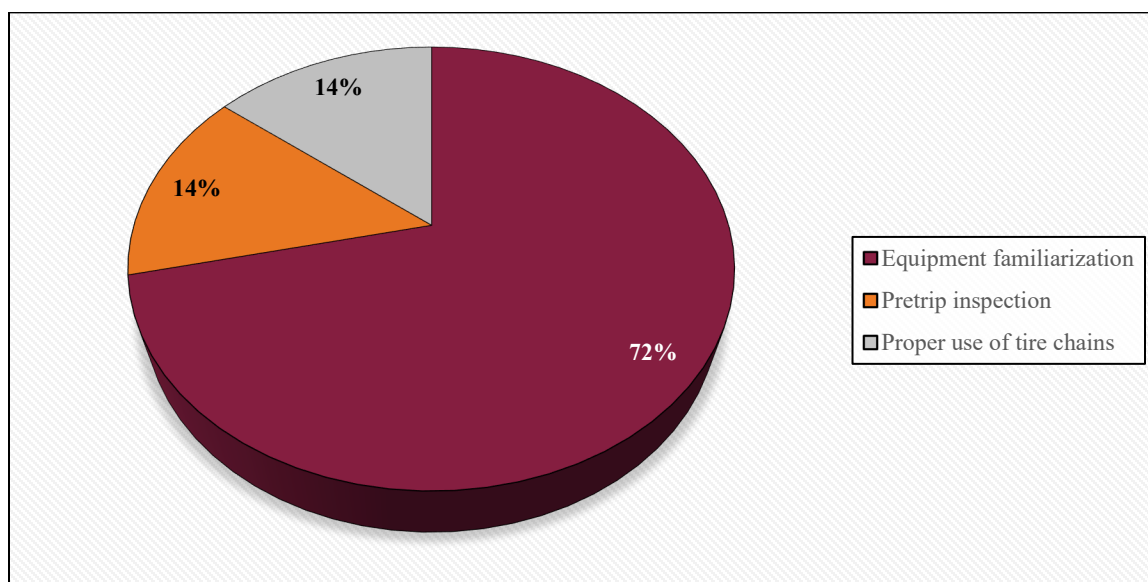


**Figure 22. Current Training – Snowplow Route**

### Vehicle and Equipment

There were seven comments related to training about the vehicle and other snowplow equipment (Figure 23). Most of these comments focused on equipment familiarization (e.g., “Equipment

familiarization”). Other comments mentioned pre-trip inspections (e.g., “Attention to detail doing walk around/pre trip inspections”) and the proposed use of tire chains (e.g., “Importance of traction control devices [chains]”).



**Figure 23. Current Training – Vehicle and Equipment**

### Recommended Topics to be Included in Operator Training

Lastly, participants were asked for their recommendations on topics that should be included in defensive driving and safe driving training (i.e., to be developed in the current project). The 117 recommended topics were grouped around six main themes (Table 11), including operator alertness (17 comments), crash avoidance techniques (48 comments), education for the driving public (10 comments), strategies related to snowplow operation (12 comments), route-related techniques (8 comments), and the vehicle and equipment (22 comments).

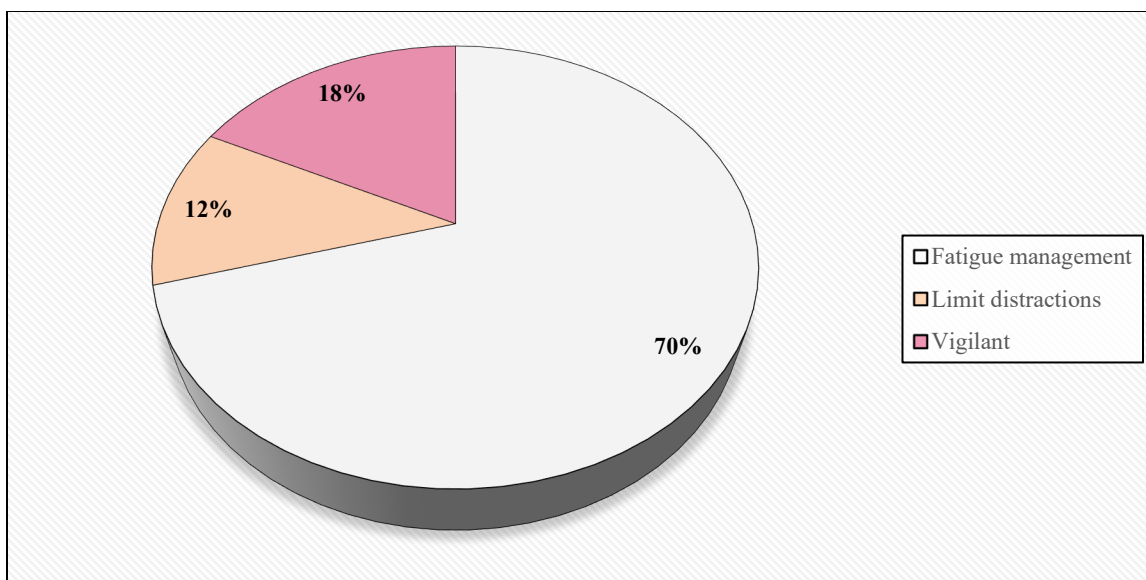
**Table 11. Themes for Recommended Training Topics**

Theme	Number of Responses
Operator alertness	17
Crash avoidance techniques	48
Driving public	10
Snowplow operation	12
Route-related	8
Vehicle and equipment	22

### Operator Alertness

There were 17 recommendations for the Clear Roads training to include information about operator alertness (Figure 24). Most of these comments recommended training on fatigue management (e.g., “Stay alert and take breaks”). The other comments discussed the importance of limiting distractions (e.g., “Plow operator distractions with in-cab equipment”) and operator vigilance (e.g., “Constantly being aware of your surroundings”).

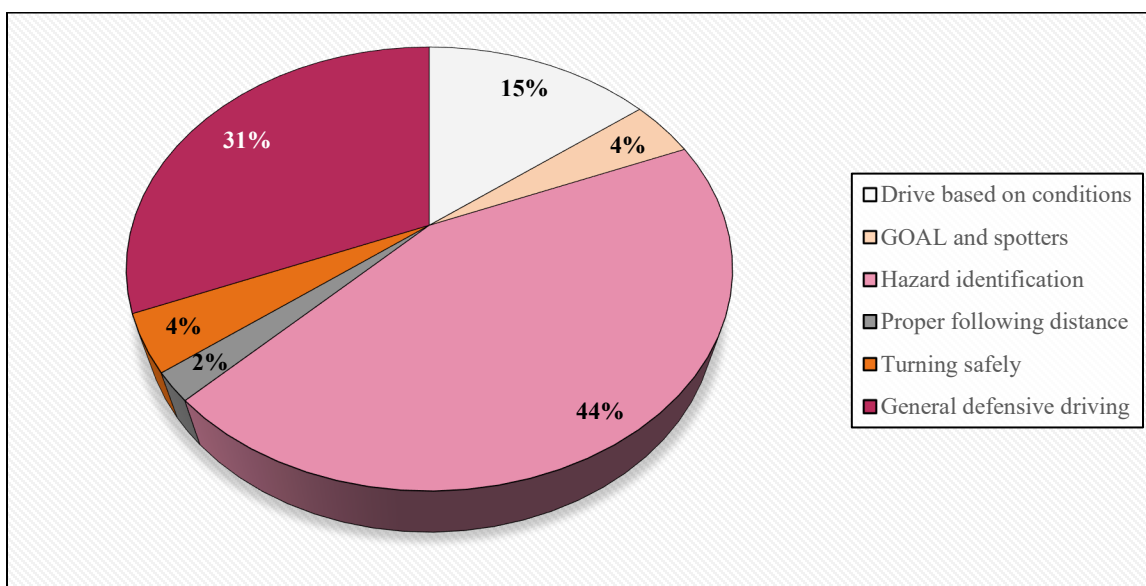




**Figure 24. Recommended Training Topics – Operator Alertness**

### Crash Avoidance Techniques

There were 48 recommendations for the Clear Roads training to include crash avoidance techniques (Figure 25). Most of the comments recommended training on hazard identification (e.g., “Main thing is to be aware of traffic sliding out of control in front of so you have time to take action, traffic trying to pass plow trucks and hitting you”) and general defensive driving (e.g., “Safe driving and defensive driving while plowing and sanding”). Other recommendations included driving based on the road conditions (e.g., “Speed awareness vs. public stopping distance”), G.O.A.L. and spotters (e.g., “Safe backing principles”), proper following distance (e.g., “Distance from other vehicles”), and turning safely (e.g., “Slow down early to allow enough time to make the turning movement”).



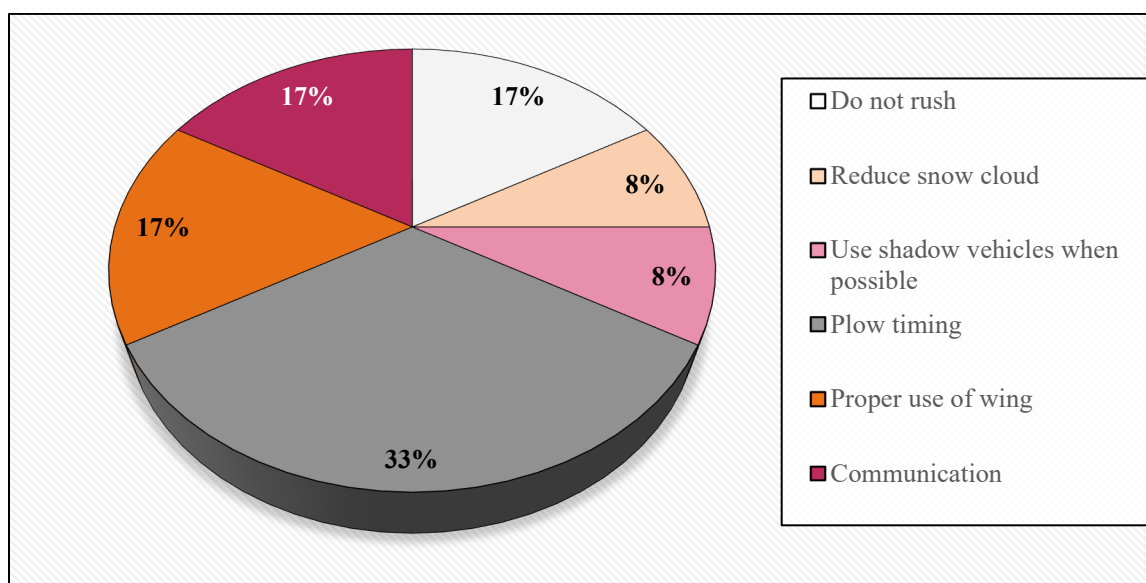
**Figure 25. Recommended Training Topics – Crash Avoidance Techniques**

## General Driving Public

There were 10 recommendations about the general driving public. All 10 of these comments mentioned the importance of educating the driving public on how to share the road with snowplow trucks (“Educate traveling public, media awareness – don’t crowd plow”).

## Snowplow Operation

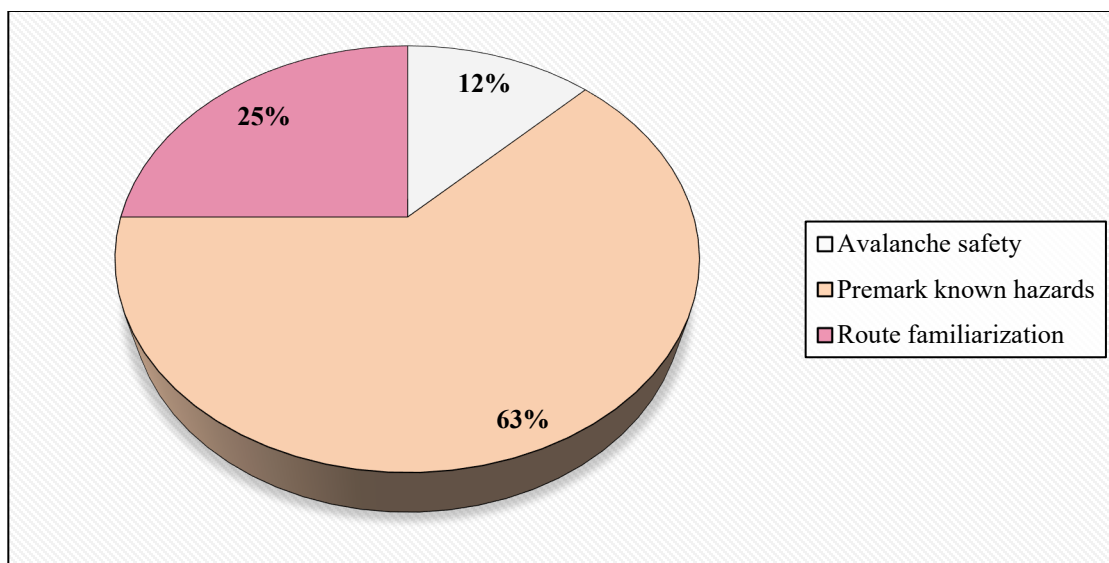
Participants provided 12 recommendations related to the snowplow operation (Figure 26). These recommendations included timing the route to avoid peak traffic or low visibility (e.g., “Know timing of traffic”), operators not rushing to complete each pass (e.g., “Don’t hurry”), strategies to reduce the snow cloud (e.g., “Techniques to minimize the amount of snow fog kicked up by a plow truck”), using shadow vehicles (e.g., “Use of shadow vehicles”), proper use of the wing (e.g., “Learn that when you see an accident or a stuck vehicle to suck in their wing plow the very first thing”), and communication (e.g., “There is a tendency for snow plow operators to not ask for assistance”).



**Figure 26. Recommended Training Topics – Snowplow Operation**

## Snowplow Route

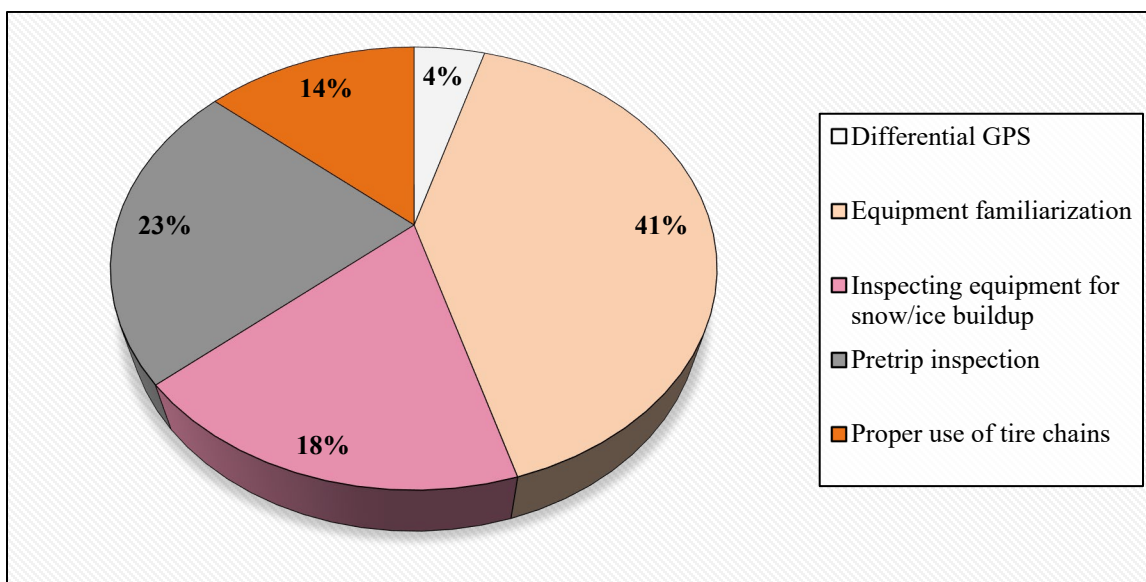
There were 8 recommendations about topics related to the snowplow route (Figure 27). Most of these recommendations suggested pre-marking known hazard locations (e.g., “Plow hazard identification and marking”). Other recommendations included route familiarization (e.g., “Plan your route; know what objects are on your route”) and avalanche safety (e.g., “Avalanche safety in this area”).



**Figure 27. Recommended Training Topics – Routes**

### Vehicle and Equipment

There were 22 suggestions related to the snowplow truck and equipment (Figure 28). Most of the comments suggested equipment familiarization (e.g., “Proper equipment operation”), the importance of a pre-trip inspection (e.g., “The importance of checklist adherence pre & post maintenance”), and inspecting equipment for snow/ice buildup (e.g., “The importance of keeping lights clear of snow buildup”). A few comments were related to the proper use of tire chains (e.g., “Proper tire chain installation”) and differential global positioning system (e.g., “High accuracy differential global positioning system”).



**Figure 28. Recommended Training Topics – Vehicle and Equipment**

## Interview Results

Based on the questionnaire results and recommendations from the project subcommittee, follow-up interviews were conducted with individuals from six states (California, Colorado, Idaho, Ohio, Montana, and Virginia). A total of 19 interviews were completed across the six states, including two in California, three in Colorado, three in Idaho, seven in Montana, one in Ohio, and three in Virginia. Across the six states, the interviews included two snowplow operators, four individuals responsible for safety across all state DOT employees, three winter maintenance trainers, five superintendents, and five road maintenance managers.

The interviews were designed to identify (1) common factors associated with five common winter maintenance vehicle crashes and (2) safe and defensive driving strategies operators have used to avoid crashes. The five common crash types included fixed object strikes, run-off-road crashes, backing crashes, crashes where another vehicle struck the rear of the snowplow, and wing plow strikes. The common causes and mitigation strategies in each of these crashes is presented below.

### Fixed Object Strikes

Fixed object strikes were defined as any incident where the snowplow struck a fixed object not in the roadway. For the purpose of this project, cars parked on the shoulder of the road were considered fixed objects.

### Causes of Fixed Object Strikes

The interviewees provided 21 comments related to common causes of fixed object strikes (Table 12). These 21 comments pointed to three main causes of fixed object strikes: poor situational awareness (11 comments), reduced visibility (8 comments), and being unfamiliar with the route (2 comments). Table 12 shows the subthemes, the number of comments for each subtheme, and an example quote.

**Table 12. Causes of Fixed Object Strikes**

Theme	Subtheme	Number of Comments	Example Quote
Poor situational awareness	Decreased alertness	2	"Operators becoming complacent after hours of driving. Their mind is not on task."
Poor situational awareness	Inappropriate winter driving	1	"At the start of the winter season, operators sometimes drive as they have become accustomed to during the summer months."
Poor situational awareness	Fatigue	2	"Drivers get fatigued."
Poor situational awareness	Lack of hazard assessment	1	"Unexpected hazards because the operator wasn't watching carefully."
Poor situational awareness	Misjudge gap	5	"Strikes are usually guardrail treatment ends or bridge ends. Drivers either misjudge or are not aware. The strikes are usually with the wing plow or front plow. It comes down to a lack of awareness."

Theme	Subtheme	Number of Comments	Example Quote
Reduced visibility	Blowing and drifting snow	3	"One cause is limited visibility often from blowing and drifting snow. This is a problem especially for the wing plow."
Reduced visibility	Obstacles not marked	5	"Most wing strikes are fixed objects either buried in the snow or ones you can't see. Usually the ones hit are not marked."
Route familiarization	Unfamiliar route	2	"A problem that causes some of these are when the operator is not familiar with the surroundings."

### Strategies to Prevent Fixed Object Strikes

The interviewees provided 43 comments related to strategies to prevent fixed object strikes. These comments were related to five main themes: equipment familiarization (5 comments), snowplow operator fatigue (7 comments), operating the snowplow (4 comments), route familiarization (16 comments), and situational awareness (11 comments; Table 13). Most of the comments were related to familiarization with the route and increasing situational awareness.

**Table 13. Strategies to Prevent Fixed Object Strikes.**

Theme	Subtheme	Number of Comments	Example Quote
Equipment familiarization	Practice using equipment	5	"Preplanning...getting guys out to transition from summer mode to winter mode. Getting guys used to driving the trucks with the plow equipment on. It is much heavier and longer. This makes the truck drive different and respond differently in the winter compared to the summer."
Snowplow operator fatigue	Good nutrition	2	"Talk to the drivers about eating healthier and avoiding processed sugars. When I eat unhealthily or a lot of processed sugars, I get tired much faster."
Snowplow operator fatigue	Limiting hours	3	"We can't do much about blowing and drifting of snow. We can help by limiting the time where you're out there in the off hours. Need 12-hour maximum shifts. Three 8-hour shifts are better. Mandatory 8 hours off between shifts."
Snowplow operator fatigue	Take breaks	2	"Get out of the truck at each stop to walk around and get coffee. They are required every time they get to the end of each section of road to get out, stretch, check blade edges, brush off lights, etc."
Snowplow operation	Plow only on paved surfaces	1	"Cannot use a plow on anything that's not a paved surface and don't plow beyond the edge of the pavement."
Snowplow operation	Reduce speed prior to turn	1	"Before turning at a turnaround spot, the operator should slow down to a crawl or the plow will dip and dig into the dirt or soft asphalt."
Snowplow operation	Slow plowing speeds	2	"Slow down! Drivers often get in a hurry to clear the road."

Theme	Subtheme	Number of Comments	Example Quote
Route familiarization	Database of hazards	2	"We use a GIS geo-based system to document all obstacles and to be able to track them. Operators will review the database prior to going out to plow."
Route familiarization	Mark known hazards	6	"Do a pre-hazard analysis of each route or area. Go out prior to the winter season and identify potential hazards such as mailboxes too close to the road or curbs that may be buried under snow."
Route familiarization	Pre-drive the route	4	"Experience is crucial. Operators are taken out on their route prior to plow operations so that they can personally identify where the obstacles are."
Route familiarization	Proactively adjust plow	2	"Raise the plow high enough to avoid obstacles. Proactively raise or angle the plow for bridge joints, manholes, etc."
Situational awareness	Remain vigilant	3	"Strategies for keeping the mind on task to increase situational awareness."
Situational awareness	G.O.A.L.	1	"Make sure the garage door is full open before going through."
Situational awareness	Limit distractions	1	"Improve situational awareness related to limiting distractions and alertness."
Situational awareness	Stow equipment	3	"Make sure the front plow is centered before entering the garage."
Situational awareness	Visual scanning	2	"Look for obstacles by regularly scanning mirrors and windows to be sure of your surroundings."

## Run-off-Road Crashes

Run-off-road crashes were defined as any instance where the snowplow first traveled off the roadway before contact with any vehicle, object, or pedestrian.

### Causes of Run-Off-Road Crashes

There were 15 comments related to the causes of snowplow run-off-road crashes. These comments were grouped into four main themes: being unfamiliar with the equipment or route (3 comments), performing an evasive maneuver (1 comment), snowplow operator inattention (2 comments), and poor situational awareness (8 comments; Table 14).

**Table 14. Causes of Run-Off-Road Crashes**

Theme	Subtheme	Number of Comments	Example Quote
Unfamiliar with equipment or route	Too much down pressure	1	"Operators push plow so far down that the front tires no longer create traction on the road. This doesn't allow the tires to steer."
Unfamiliar with equipment or route	Unfamiliar route	2	"Not familiar with the roads."

Theme	Subtheme	Number of Comments	Example Quote
Evasive maneuver	Avoiding contact	1	"We have instances where the general public drifts towards the plow and the operator tries to give them room."
Inattention	Distraction	1	"Driver distraction"
Inattention	Fatigue	1	"Driver fatigue"
Poor situational awareness	Plow off road	5	"Usually a guy pushes the edge to move snow out a little further, which ends up being too far. For example, one guy makes a first pass with a wing to clear the road. Another guy made a second pass with a straight plow, and he just followed the line because he thought it had been plowed with a regular plow. Because he pushed the line, he ran off the road and turned over."
Poor situational awareness	Improper backing	1	"Backing into an area where they don't fit."
Poor situational awareness	Reduced visibility	1	"Lack of visibility due to heavy snow. The drivers lose orientation of where they are on the roadway."
Poor situational awareness	Not judging bad road conditions	1	"They are often not properly adjusting their speed for bad road conditions."

### Strategies to Prevent Run-Off-Road Crashes

Table 15 shows the 22 suggestions operators can use to prevent run-off-crashes. As shown in Table 15, the 22 suggestions were related to two main themes: the snowplow operation (10 comments) and improved situational awareness (12 comments).

**Table 15. Strategies to Prevent Run-Off-Road Crashes**

Theme	Subtheme	Number of Comments	Example Quote
Snowplow operation	Slow speeds	4	"Take time, slow down, and be methodical."
Snowplow operation	Limit downward pressure	3	"There is a fine line on the amount of down pressure. A float device is helpful to put upward pressure so that the weight is applied to the front axle."
Snowplow operation	Maximize reach of plow	1	"Try not to turn the plow to the right too much. Keep it straight out which gives the plow more reach so that the vehicle can stay further back on the roadway."
Snowplow operation	Low center of gravity	1	"Keep bed down because it lowers the center of gravity."

Theme	Subtheme	Number of Comments	Example Quote
Snowplow operation	Operator experience	1	"Experience is important. Sometimes new operators ride with more seasoned operators."
Improve situational awareness	Don't push edge line	3	"As long as your tires are right inside the fog line you should be okay. If you don't know the road, then don't go outside the fog line."
Improve situational awareness	Fatigue management	2	"Fatigue management is important. If a driver is at the end of the shift and really tired, they should call a replacement in if there are terrible whiteout conditions."
Improve situational awareness	Hazard Assessment	4	"Begin slowing down when you notice another vehicle encroaching into your lane. Also, just maintain your lane while slowing down...you don't need to try to move over to the shoulder. By slowing down you will give others room."
Improve situational awareness	Vigilance	3	"Staying alert, situational awareness"

## Backing Crashes

A backing crash was defined as any incident where the snowplow was in reverse and struck another vehicle, object, or pedestrian, regardless of where the backing crash occurred (i.e., parking lot, roadway, off road).

### Causes of Backing Crashes

Interviewees provided 13 comments about causes of backing crashes. All 13 comments were related to one theme: poor situational awareness (Table 16).

**Table 16. Causes of Backing Crashes.**

Theme	Subtheme	Number of Comments	Example Quote
Poor situational awareness	Complacency	7	"Just a lack of awareness and complacency. For example, the snowplow was backing up to the sand pile to clean up all the sand from the back of the truck. The mirrors were dirty and covered from plowing. The operator didn't clean off the mirrors and backed up carelessly. The operator backed up to the snow berm and hit the sander shoot."
Poor situational awareness	Failure to walk around	5	"It a lack of situational awareness. They don't look right before backing, even if it's only been 5 minutes because you don't know if something has moved into the path of the plow."
Poor situational awareness	Fatigue	1	"Fatigue at the end of a long shift during extended storms."



### Strategies to Prevent Backing Crashes

There were 27 comments regarding strategies to prevent backing crashes (Table 17). Most of these suggestions were improvements to the operator's situational awareness (18 of the comments). The other comments were related to limiting instances where the operator needs to back (6 comments) and the use of technology (3 comments).

**Table 17. Strategies to Prevent Backing Crashes**

Theme	Subtheme	Number of Comments	Example Quote
Limit exposure	Avoid backing when possible	4	"Don't back up unless it is completely necessary."
Limit exposure	Clear large enough turnaround	2	"Most of our backing crashes are at a tight turnaround. Operators should make sure to make the turnaround big enough by plowing snow in a large enough area."
Increase situational awareness	Use delineators	1	"Use delineators to mark where plows should stop. For example, don't get so close to the sand pile. You have to clean it up after unloading anyway. Just unload it and plow it up into the pile."
Increase situational awareness	Spotters	6	"Use spotters when possible."
Increase situational awareness	Walk arounds	11	"Walk around the truck. Look at the path where the vehicle is going to go when backing up, not just directly at the truck. For example, a driver did a walk around looking at the truck. But the garage door was closed. The driver finished the walkaround and then pressed the button to open the garage door. He backed up out the door and hit a pickup truck that was parked on the opposite side of the garage door. Had the driver opened the door first to see the full path where the plow was going to go, he would have noticed the truck."
Technology	Backup cameras	2	"Use technologies such as backup cameras or sensors."
Technology	Garage door indicators	1	"Have green/red indicator lights showing the operator if the garage door is open."

### Rear-End, Other Vehicle Striking

Crashes where another vehicle struck the rear of the snowplow or any equipment on the rear of the snowplow were considered rear-end, other vehicle striking crashes.

### Causes of Rear-End, Other Vehicle Striking Crashes

There were 27 comments regarding possible causes of crashes where the snowplow was struck from the rear. These comments surrounded four main themes: the driving public (14 comments), snowplow equipment (2 comments), the snowplow operator (2 comments), and the weather (9 comments; Table 18).

**Table 18. Causes of Rear-End, Other Vehicle Striking Crashes.**

Theme	Subtheme	Number of Comments	Example Quote
Driving public	Distraction	3	"Distracted public drivers."
Driving public	Impairment	1	"DUI"
Driving public	Impatience	2	"The public gets impatient when the plow is going slower than the traveling public and there is a long line following the plow."
Driving public	Lack of knowledge	2	"General public may not understand how to drive in the snow, such as vacationers and people coming from other states."
Driving public	Misjudge intent	1	"A lot of the crashes occur where the plow is going to turn off at an approach. Usually on a left-hand turn. Vehicles don't understand what the plow is going to do and try to go around the plow and hit it."
Driving public	Too fast for conditions/ Speed differential	5	"There are 80 mph speed limits on the interstates. The public does not adjust their speed to the conditions. Meanwhile the plows are going 35 to 40 mph maximum for plowing."
Equipment	Lighting	2	"When the operator makes a left turn, they should turn off the rear-facing warning lights and then turn on blinker and then slow down."
Snowplow operator	Road rage	1	"Drivers give in to road rage. For example, they don't give ample space because someone was tailgating them, or brake checking them because someone else is following them too close."
Snowplow operator	Letting public pass	1	"When the plow is making a left turn into the median, the plows were not letting other vehicle pass by before initiating the turn."
Weather	Ice	1	"Ice"
Weather	Snow cloud	8	"Lack of visibility due to a snow cloud or blowing and drifting snow. The public assumes nothing is in the cloud."

### Strategies to Prevent Rear-End, Other Vehicle Striking Crashes

There were 58 suggestions on how to prevent vehicles from striking the rear of the snowplow. These suggestions targeted six themes: the driving public (5 comments), snowplow equipment (20 comments), the snowplow operator (3 comments), snowplow operations (9 comments), improved situational awareness (7 comments), and reducing the snow cloud (14 comments; Table 19).

**Table 19. Strategies to Prevent Rear-End, Other Vehicle Striking**

Theme	Subtheme	Number of Comments	Example Quote
Driving public	Public education	5	"There needs to be public education and a media campaign on how to share the road with snowplows."
Equipment	Additional warning lights	3	"A new blinker on top facing the rear would provide better visibility because it would be more likely to be above the snow cloud."
Equipment	Conspicuity tape	1	"Use conspicuity tape on the back of the truck in a 'V' pattern."
Equipment	Flashing lights	1	"Plows are equipped with back up lights, and if they notice a vehicle is approaching too quickly, the operator could flip on the back up lights to catch the other driver's attention."
Equipment	Check and clean lights	5	"Check lights at the end of each section to make sure they are clean and to make sure all the lights are still there and working."
Equipment	Limit flashing lights when signal is engaged	4	"All the lights make it hard for the public to see the turn signals. There are too many blinking lights all at the same time. The public doesn't recognize that the plow is actually turning, when the turn signal is on because it just blends in with all the other flashing lights. The operator may not turn off all the lights, but most of the rear-facing ones."
Equipment	Rear spoiler	1	"Put a rear spoiler on the back of the plow. It scoops air and blasts it across the back of the truck to clear off the back lights."
Equipment	Use signals early	4	"Turn the turn signals on about 1,000 feet before a turn or lane change. You can't wait until the last minute to put the turn signals on."
Equipment	Light color	1	"Change the light pattern and color."
Snowplow operator	Stay calm and professional	1	"Remember driving etiquette. Stay professional, don't let others make you engage in road rage. You should provide strategies to avoid road rage."
Snowplow operator	Self-report	2	"Communicate with state communications on 511 about blowing and drifting snow and low visibility areas. Self-report bad conditions for dissemination to the public."
Snowplow operations	Alternative turnarounds	1	"Don't turn around in locations with poor sightlines or areas that require a 3-point turn."
Snowplow operations	Convoys	2	"We see more crashes when the plow is by itself versus when it is in a convoy."
Snowplow operations	Proper winter maintenance driving	2	"Be smooth in all maneuvers."

Theme	Subtheme	Number of Comments	Example Quote
Snowplow operations	Non-peak plowing	2	“Stay out of the light fluffy snow – this is what causes the largest snow cloud. Plow this at non-peak traffic times.”
Snowplow operations	Let public pass	2	“Before making a left turn, pull over to the shoulder of the road, come to a complete stop, let traffic go by, and when clear, go ahead and make the turn.”
Situational awareness	Constant hazard assessment	6	“The operator should expect that vehicles will pass on the left. Look in the mirrors to ensure no vehicles are trying to pass on the left prior to initiating a left turn. Triple check the mirrors each time.”
Situational awareness	Communication	1	“If working together tandem when there is blowing snow, communicate between the plows. Let the other drivers know other vehicles are approaching.”
Snow cloud	Plow with wind	2	“Plowing with the wind to get the snow cloud away from the vehicle. Angle the front plow to throw the snow with the wind as much as possible. You can’t do it all the time due to other vehicles, but when possible it is best.”
Snow cloud	Allow public to pass	2	“When you can’t see behind you because of windy and blustery days, pull into a safe spot and slow down to let traffic by and build up. If there is a lot of slush, it’s better to slow down instead of stopping because the public will pass you and spin out.”
Snow cloud	Reduce speed for maneuvering	1	“Before making a lane switch, slow down to get rid of the snow cloud and then move to the next lane.”
Snow cloud	Slow plowing speed	9	“Speed is the main factor in reducing the snow cloud. The plow operator needs to know where the snow cloud is. You can slow down and try to get the snow cloud under the back light.”

## Wing Plow Strikes

Wing plow strikes were defined as another vehicle striking an extended wing plow. However, some of the comments and suggestions mentioned fixed object strikes where the wing plow struck a fixed object. These types of comments and suggestions focused on fixed object strikes were not included in this section.

## Causes of Wing Plow Strikes

There were 11 comments on the causes of wing plow strikes. These comments focused on three main themes: the general driving public (5 comments), poor situational awareness (4 comments), and reduced visibility (2 comments; Table 20).

**Table 20. Causes of Wing Plow Strikes.**

Theme	Subtheme	Number of Comments	Example Quote
Driving public	Distraction	1	"Distracted drivers."
Driving public	Impatience	1	"Impatient other driver."
Driving public	Lack of awareness	3	"Lack of attention from the public. For example, a few cases happened when the operator was in the left lane with the right wing down and the public hit the wing."
Poor situational awareness	Forgetfulness	4	"Operator forgets the wing is out."
Reduced visibility	Snow cloud	2	"Snow cloud reduces visibility for following vehicles."

### Strategies to Prevent Wing Plow Strikes

There were 17 comments or suggestions on how to prevent wing plow strikes. These comments and suggestions focused on three main themes: the general driving public (4 comments), additional equipment (9 comments), and snowplow operation (4 comments; Table 21).

**Table 21. Strategies to Prevent Wing Plow Strikes**

Theme	Subtheme	Number of Comments	Example Quote
Driving public	Public education	2	"Public education on important safety information for driving around snow plows, such as no passing on the right, the use of wings, and maximum plow speeds."
Driving public	Weather reports	2	"Use variable message boards to inform public of dangerous conditions approaching."
Equipment	Rear facing lights on wings	5	"Have lights on the end of the wing."
Equipment	Rear spoiler	1	"A rear spoiler may help some."
Equipment	Reflective tape	2	"Reflective tape on back of wing."
Equipment	Snow deflectors	1	"Rubber flaps on the front plow to keep blowing snow down."
Snowplow operation	Wings only to clear shoulder	4	"If using a right side wing, only use it while driving in the right lane to clear the shoulder. If using a left wing, only use it while driving in the left lane to clear the left shoulder."

## Training Content Recommendations

Based on the results of the questionnaire and interviews, the following training content is recommended in the two training modules.

### Defensive Driving Training

The focus of the defensive driving training will focus on strategies the snowplow operator can use to prevent crashes caused by another vehicle. Two of the common snowplow crash types are relevant to this training: wing plow strikes and rear-end, other vehicle striking crashes.

Below are recommended training components that will be included in this training module.

#### Basic defensive driving strategies

- Proper visual scanning techniques related to rear-end crashes
- Anticipating other vehicles' mistakes
- Strategies to determine if a hazard requires a response
- Recommendations for executing evasive maneuvers
- Preventing and reducing the snow cloud
- Driving at a safe speed
- Avoiding road rage and other aggressive driving behavior
- Safe following distances

#### Conspicuity

- Proper pre-trip and mid-trip inspections regarding lighting mirrors and windows
- Using turn signals.

#### Snowplow operating characteristics

- Proper use of wings
- Work with the wind to minimize the snow cloud
- Selecting safe turn around points
- Safe left turning procedures
- Allowing public to pass

### Safe Driving Training

The focus of the safe driving training modules will be general safe driving practices the operator can use to prevent crashes often caused by the snowplow operator. Three of the common crash types are relevant to this training: fixed object strikes, run-off-road, and backing crashes.

Below are the recommended training components that will be included in this training module.

#### Hazard identification

- Proper visual scanning related to fixed objects
- Tips on how to predict and identify hidden hazards
- Responding to hidden and unexpected hazards
- Safe operating speeds
- Pre-marking known hazards

#### Proper backing

- Use of spotters

- G.O.A.L.

Limiting Distractions

- Risk of distractions
- Minimizing distractions

Fatigue Management

- Signs of fatigue
- Self-assessment of fatigue
- Importance of breaks
- Other fatigue countermeasures

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