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Synthesis Study on Employing Snowplow Driving Simulators in Training

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16. Abstract

Departments of Transportation (DOTs) need to mobilize workers under harsh weather conditions for winter operations. Traditional snowplow driver training at INDOT is usually conducted annually before the snow season; therefore, it does not replicate the conditions which drivers will be exposed to during winter operations. To this point, some state DOTs have incorporated simulators in their snowplow driver training. Despite this raised interest, few studies have (1) surveyed other state DOTs about the use of this equipment in winter operations driver training, or (2) provided a systematic consideration of all factors involved in the decision to use driving simulators in snowplow driver training. To fill these gaps, the present study synthesizes information from previous literature, revises current information from INDOT, and surveys other state DOTs to identify the benefits and challenges of driving simulators for snowplow driver training. A mixed methods approach was utilized including a review of current INDOT practices, interviews with stakeholders, a survey of other state DOTs, and results from a pilot training. Based on the findings, the researchers recommend that INDOT continues to explore the use of driving simulators for training purposes in addition to the yearly snowplow driver training, due the ability to reinforce learning in a safe environment. Moreover, the research team suggests the following areas for further research: evaluating optimal simulator "seat time," peer learning in simulator training, and the impact of experience level and work assignment in the perception of driving simulator training effectiveness.

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EXECUTIVE SUMMARY

Introduction

Winter operations are an essential part of the Indiana Department of Transportation's (INDOT's) activities. To keep Indiana roads open to the public, snowplow drivers work under stressful and dangerous conditions. Operating a snowplow involves several concurrent cognitive activities, such as driving the truck, operating the salt spreader controls, operating the plow, and monitoring surrounding traffic and weather conditions. To improve public and employee safety, INDOT drivers receive yearly training prior to the snow season, but this training cannot replicate the weather conditions that drivers will actually face when plowing snow.

To mitigate the lack of training under winter weather conditions, some state Departments of Transportation (DOTs) have been using driving simulators in their training. Despite raised interest, few studies have explored the factors involved in the decision to use driving simulators in snowplow driver training at state DOTs. Furthermore, there is a lack of recent research about simulator technology and current practices in using driving simulators in snowplow driver training for state DOTs. To address these gaps, this study provides a literature review of the topic and current market options, surveys of state DOT stakeholders involved in winter operations training, a summary of interviews with INDOT snowplow drivers and supervisors, an assessment of a pilot study of the training, and recommendations to INDOT about the use of driving simulators for their snowplow driver training program.

Findings

Our literature review findings indicate considerations for hardware, software, and training. Hardware considerations are mainly related to improving realism and reducing cybersickness, which is a discomfort faced by some people while using virtual reality simulators. Software considerations are mainly related to improving driver training, such as scenario variability and tracking of trainees' data. Moreover, reports commissioned by state DOTs indicate that drivers have positive perceptions toward training with a simulator and suggest simulated training results in improved fuel efficiency and reduced accidents. However, the reports do not provide statistically significant results, mainly due to the low number of accidents and specificity of each accident.

Results from our review of current INDOT snowplow driver training and interviews with 10 snowplow drivers and 8 supervisors indicate that drivers rely frequently on each other for advice to improve driving techniques, but they are open to using driving simulators in training. Furthermore, the current yearly training is well regarded by INDOT drivers. In terms of risky situations, drivers mentioned traffic and public driving in low visibility and slippery road conditions as a main concern. This seems to be aligned with information from INDOT accidents, which indicate that vehicle sliding, loss of control, and speeding are frequently associated with snowplow-related accidents.

Furthermore, four driving simulator manufacturers answered our survey. Generally, their technology includes some haptic feedback and high-quality graphics. Main differences appear to be related to the quality of the haptic feedback, the customizability of scenarios, the ability to replicate truck equipment (such as replicating full truck cabin) and the ability to gather trainees' performance data. Cost for one simulator ranges from a low of \$110,000 to a high of \$300,000 per simulator. Two of the four manufacturers also provide training services to drivers directly.

A survey of state DOTs was conducted. Findings from the survey show that 10 out of 16 state DOTs who provided information about the status of driving simulator training for snowplow drivers were either using them or considering using them. Also, perceived long-term effects on public safety, cost of simulator-based training, ease of simulator training, and the ability to replicate vehicle dynamics and characteristics were found to be the top four decision-making factors when purchasing the snowplow driving simulator. Using the results from the previous phases, the research team drafted recommendations that were validated by interviews with two state DOTs that have been using driving simulators in their snowplow driver training for more than 5 years. Based on their comments, adjustments were made to the final set of recommendations.

Implementation

Assessment findings from a pilot training with 64 participating drivers indicated increases in the average comfort levels of drivers for all the situations described in the survey, as well as in the average confidence level of drivers to plow snow for INDOT. Also, the majority of drivers were interested in training with this type of equipment and would recommend this type of training to all drivers. Future modifications in the survey questions could also allow for more statistical tests, such as a sign test. Furthermore, measuring the long-term impact on operations (such as accident reduction) will be helpful for long-term decision making.

Based on the current results, the research team recommends that INDOT continue to explore the use of a simulated snowplow driver in their training program, especially as an add-on to the regular annual training for novice drivers and as additional preparation for risky situations—such as objects on the road or vehicle sliding—in a safe environment. The additional training would allow novice drivers to increase their skill and confidence to drive under adverse conditions.

Implementation should start with a pilot focused on the best adoption practices for INDOT. After the pilot period, the research team recommends that INDOT re-evaluates the acquisition of driving simulators for snowplow driver training by considering its impact and the ability to use the equipment for other training purposes. Furthermore, the research team recommends INDOT review snowplow-related accident reporting to track risky situations and trouble location, which will inform training recommendations. Finally, the research team suggests that further research is needed to explore the effect of experience, work assignment (full-time or transfer snowplow drivers), simulator "seat time," and peer learning has on the effectiveness of simulator training for snowplow driving.

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1. INTRODUCTION

The Indiana Department of Transportation (INDOT) currently has 1,105 snowplows for winter operations (see Figure 1.1 for snowplow truck example). These operations involve several drivers, in addition to mechanics and managers. For drivers, this means driving and operating the plow and salt controls (see Figure 1.2) while under harsh winter conditions to ensure roads are open to the public. These operations may occur at any hour of the day, and workers alternate 12-hour shifts in cleaning highway routes and roads in Indiana (INDOT, 2021). Given that snowplow drivers are the front-line workers to remove snow, they often work in dangerous and stressful conditions (O'Rourke, 2011). At INDOT, yearly training is provided to any driver that may plow snow during winter season, however, this training is usually conducted before the first snow in that season. Therefore, it does not replicate some of the significant challenges faced by the drivers, such as low visibility and icy roads. This makes training for novices especially difficult (O'Rourke, 2011).

One strategy that can mitigate these issues is the use of simulators in the training of snowplow drivers (see examples in Figure 1.3). A simulator is a virtual reality environment with controls and visuals that mimic actual conditions. Previous research mentions that the use of simulation for training of uncommon, but critical driving scenarios is particularly helpful. Furthermore, its use can increase safety in training, given that simulators can replicate real-world situations without exposing drivers and the general public to risk (de Winter et al., 2012; Underwood et al., 2011). In fact, flight simulators are routinely used for commercial pilot training, with several airlines owning several simulators for yearly training (Arnold, 2021; United Airlines, 2022). And, although the Federal Aviation Administration only allows for a few hours of in-flight training to be substituted by simulator training, flight schools encourage simulator use as a way to reduce the number of hours needed for certification and to train for emergencies that would not be safe or feasible in an aircraft (Bernard, 2012; FAA, 2016; Myers et al., 2018).

Moreover, several benefits and challenges that come with the use of simulators need to be understood and addressed before a decision to use them is made. For example, de Winter et al. (2012) explored literature about the use of driving simulators in a variety of settings. Their findings indicate the following four major advantages of using them: (1) ability to customize the simulation to specific needs; (2) ease in collecting data; (3) training drivers in safety; (4) ability to review and comment on the simulation; and the following three main disadvantages for their use: (1) low fidelity scenarios may affect performance; (2) not enough information on training validity; and (3) some people experience simulator discomfort.

The option to train snowplow drivers using driving simulators is currently being used or has been explored in several states, including Arizona (Kihl et al., 2006, 2007), Delaware (Delaware T^2/LTAP, 2012/2013), Iowa (Iowa DOT, 2019; Masciocchi et al., 2006; 2007), Illinois (O'Rourke, 2011), Minnesota (Harlow, 2016), Ohio (Ash et al., 2022; Smith, 2019), and Utah (Strayer et al., 2004). Some of these experiences were part of funded DOT projects, so public reports are available on these efforts. The focus of most reports was on evaluating initial use of simulators, including training perceptions (Kihl et al., 2006; Masciocchi et al., 2007; O'Rourke, 2011; Strayer et al., 2004), cost of training (O'Rourke, 2011), and implications for long term safety and maintenance of operations (Kihl et al., 2007; Strayer et al., 2004). Unfortunately, reports analyzing implications for long-term simulator use had inconclusive results due to large variability in data sets. Furthermore, a recent report by Camden et al. (2020) suggested that more research is required on the use of driving simulators for snowplow driver training. Indeed, the issue of validity in simulation use is a complex one, involving numerous variables, and previous research acknowledged the difficulty of designing experimental studies for evaluating the effectiveness of

Figure 1.1 INDOT snowplow truck.

Figure 1.2 INDOT snowplow truck controls.

Figure 1.3 Snowplow driving simulators examples from Virage (left) and L3 Harris (right).

driving simulators (Martín-DelosReyes et al., 2019). Recently, researchers have proposed a framework to help guide validation studies (Schneider & Bengler, 2020), indicating that this is an ongoing issue that must be considered while evaluating the use of simulations in current curriculum.

Despite difficulties with performance assessment, recent literature indicates that simulators are being used for training snowplow drivers in different states (Delaware T^2/LDAP, 2012/2013; Harlow, 2016; Iowa DOT, 2019). This informs us that more states are using driving simulators in their snowplow driver training programs. Still, there is a lack of holistic and unified information about factors affecting decision making about the use of driving simulators for snowplow driver training. Furthermore, there is a need for an updated review of technology and current practices of this type of training in the United States, specifically within state Departments of Transportation (DOTs). To this point, the present report answers the following questions.

- How are driving simulators being used in snowplow training programs of state Departments of Transportation (DOTs)?
  - What has been published about the use of snowplow training simulators for training use in DOTs?
  - How are DOTs that use driving simulators incorporating them into their training efforts?
  - Which options of driving simulators for snowplow training are currently available in the United States?
- Which recommendations can be made to INDOT related to the use of simulators for snowplow driver training?

Our results help support INDOT in defining to use or not simulators in their snowplow driver training events by identifying relevant factors from previous and current state DOT experiences and academic literature. Furthermore, our findings provide information about the current state of the practice in the use of driving simulators for snowplow driver training for all American state DOTs.

2. METHODOLOGY

This project used a mixed-methods approach and was initially carried out in eight main tasks. After the conclusion of these eight tasks, a pilot implementation was added to the project, as outlined in Figure 2.1. Some of these tasks were in sequence and others in parallel. To start, Tasks 1 and 2 were carried out concurrently. In Task 1, a review of literature was performed to collect information on updated publications related to the use of driving simulators and their training and evaluation; this task also included the review of published DOT reports about the use of snowplow driving simulators. Task 1 resulted in an initial table of factors that should be considered when deciding whether to use or not use driving simulators for snowplow driver training.

Task 2 included a review of current INDOT training and data related to winter operations indicating leading causes for accidents. Several subtasks were included in Task 2 to provide an up-to-date scenario on current INDOT training and snowplow operations. This included a review of training PowerPoint presentations for each INDOT district, summary information about training format, number of employees trained, and training cost per employee, and information on incidents related to winter operations.

Task 2 also included interviews with the following two groups of INDOT workers: (a) snowplow drivers and (b) winter safety managers and crew leaders, to capture in-depth impressions about potential scenarios for driving simulations, current training format, and perceptions related to driving simulators. Appendix A includes the interview questions for each of those groups. A recruitment email was forwarded to potential participants by INDOT so that they could provide their contact information and basic information regarding their assignments during winter operations. The screening of potential interview applicants was done to ensure a stratified sample for snowplow drivers of novice (less than 3 years of snowplow driving experience), experienced (more than 3 years of snowplow driving experience in routine snowplow driving assignments), and transfer (more than 3 years of snowplow driving experience in non-routine snowplow driving assignments) drivers; and a stratified sample of safety managers and crew leaders, to assure that all six INDOT districts were represented in the interviews.

The goal of Task 2 was to identify potential risk scenarios for INDOT snowplow drivers, as well as understand the current format for the snowplow driver annual training, and other expenses incurred by INDOT in winter operations that could be influenced by the use of driving simulators in training of snowplow drivers.

Task 3 was initiated prior to the conclusion of Task 2 interviews, whose conclusion was delayed due to low participant enrollment. For Task 3, pilot interviews were carried out with researchers and DOT employees to validate the factors identified from the literature review (Task 1), as well as provide feedback on draft questions that will be used to assess decision factors for other DOTs related to the use or non-use of driving simulators in snowplow driver training. The interview questions included in Task 3 interviews are presented in Appendix B. The outcome of Task 3 was a set of

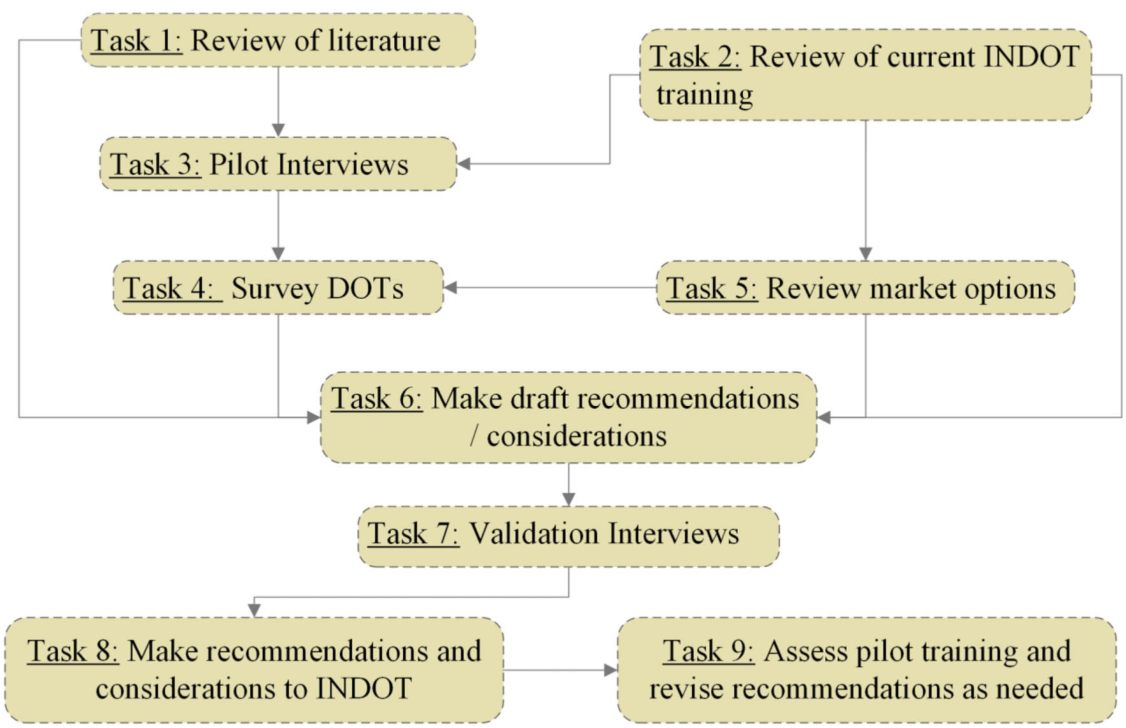


Figure 2.1 Tasks included in this project.

questions to be used in the survey of other DOTs, which will be covered in Task 4.

In Task 4, an online survey about decision factors related to the use (or not) of driving simulators was developed based on the feedback from the Pilot Interviews in Task 3 and on the information gathered during the preceding project tasks. Appendix C includes the questions used in the online survey. INDOT personnel were asked to forward this survey to their contacts in other DOTs with winter operations in the United States. Additional recruitment was performed by including flyers about the study in the Clear Roads September 2022 meeting and by the research team calling state DOTs.

Task 5 included a review of available market options for snowplow simulators in the United States. This task included collecting information available online, as well as drafting a survey that allowed manufacturers to include product information for INDOT review. This survey is attached to this report as Appendix D. This task aimed to provide INDOT with comparative information on available options of driving simulators that could be used for training snowplow drivers. Information collected in Task 5 was summarized in this report.

Following the conclusion of Tasks 4 and 5, the researchers developed draft considerations and recommendations for INDOT as part of Task 6. The recommendations included considerations organized according to the Technology-Organization-environment (T-O-E) framework. T-O-E is based on previous research and provides a framework to consider factors for the adoption of technology at the organizational level (Awa et al., 2017a and b; Baker, 2012; Oliveira & Martins, 2011). Following the T-O-E framework, the researchers provide recommendations taking into consideration the technology (simulator for snowplow driver training), the organization (INDOT) and the environment (Indiana) it affects.

After the drafting of the initial considerations, validation interviews with DOT representatives from two states that utilize simulators for snowplow driver training for 5 or more years were conducted as part of Task 7. The goal of the validation interview was to verify and adjust recommendations made as part of Task 6, and also obtain additional information about the use of driving simulators in snowplow driver training. Recruitment for the validation interviews was conducted by email and phone. Participants who have agreed to participate were invited to a video conference meeting, during which the researchers inquired about participants' perceptions of the simulator and information on current simulator, simulator training and long-term effects. Appendix E includes the questions asked to participants in Task 7.

Following, based on the feedback received, recommendations and considerations to INDOT were made in Task 8 regarding the potential use of driving simulators for snowplow driver training. Additionally in Task 8, the researchers included a business case with cost comparison for potential scenarios including the use of driving simulators for snowplow driver training specifically for INDOT. These considerations and recommendations were presented to INDOT at the end of October 2022. Based on the information, INDOT requested the research team to assess a pilot training in December 2022 (Task 9). Information about the results of the pilot study is included in Appendix F and was used to revise the recommendations and considerations made in Task 8.

3. BACKGROUND LITERATURE

Specialty vehicle operations are complex and require drivers to perform multiple actions concurrently, especially in emergency situations. In the case of snowplow operations, drivers are often asked to perform several different tasks (such as treat roads prior to snowfall, plow snow off roads, or scrape ice that has compacted on the road), to adapt to various and changing weather conditions (Elhouar et al., 2015). These conditions may even require that multiple drivers be involved in plowing at once, such as tandem plowing. The tandem formation requires two or more snowplow vehicles to drive diagonally to fully plow the snow to the roadside. Such skills usually require a number of hands-on practices on actual roads to get familiarized with, and continuous training for all snowplow operators (Elhouar et al., 2015). To train drivers in complex scenarios, simulators have been used in many industries, such as airline travel and safety vehicles, as a tool to provide an inexpensive, relatively realistic, and risk-free environment for training the specialty vehicle operators as well as for road safety awareness (Bernard, 2012; Prohn & Herbig, 2020; Strayer et al., 2004).

Despite this importance, literature about driving simulators for snowplow driver training is limited mainly to reports commissioned by Departments of Transportation across the United States since the early 2000s, primarily focusing on the needs and conditions of each respective state. The reports made for the various states' Departments of Transportation (DOTs) covered different aspects of the driving simulators, and short- and long-term considerations of this type of training. Examples include research on training format and evaluation (Masciocchi et al., 2007), fuel and maintenance long-term impact (Kihl et al., 2006), and costs of training (O'Rourke et al., 2011). The latest of these commissioned reports was made for the Ohio DOT and investigated further into the technical aspects of simulators, such as beneficial hardware and software features, as well as the customization ability for different scenarios and route designs (Ash et al., 2022). In general, efforts made by DOTs offer insights into the use of snowplow driving simulators from a practical and empirical perspective.

In addition to the work contracted by DOTs, academic literature about the use of driving simulators in general also provide important information on the topic. This includes physical reactions to the simulator technology, such as cybersickness. Also, some researchers investigated the effectiveness of adopting high-fidelity graphics and physics features to improve user experience (Ojados Gonzalez et al., 2017). Furthermore, other academic research evaluated perceptions related to the engagement of drivers, using eye tracking technology, self-assessments, and observations (Underwood et al., 2011).

The present background literature is divided into two subsections—one for academic literature and one for previous DOT works. Thus, by evaluating previous work about driving simulators for snowplow driver training, the authors focus on three main areas as outlined in Figure 3.1.

- Simulator equipment—including software and hardware considerations.
- Training consideration—format of training, content, trainee perceptions, and cost of training.
- Long-term implications—previous work that explores how the use of simulators can impact safety, maintenance costs, fuel efficiency, speed of operations, and long-term cost analysis.

3.1 Previous DOT Work

Many Departments of Transportation (DOTs) have investigated the effects of deploying snowplow driving simulators in driver training process. From a series of comprehensive examinations in both technological and human development aspects, the technical reports analyzed the use of driving simulators, suggesting that simulators can improve driver safety awareness, fuel savings, and better maneuverability under emergency conditions. The complexity of factors affecting the performance and safety of winter operations, such as variability in winter seasons, accident locations, and conditions, require a large amount of data set and participants to validate some correlations among these factors, hence making conclusions difficult to make. In the following sections, a number of reviewed technical reports from different states' DOTs will be presented, which include reports from Utah (Strayer et al., 2004), Iowa (Masciocchi et al., 2006), Arizona (Kihl et al., 2006), Illinois (O'Rourke et al., 2011), and Ohio (Ash et al., 2022). The review of each report will contain an overview, methodology, results, and conclusion in order to present a broad overview of the previous state DOTs' commissioned research. A report from the Pennsylvania DOT was found to be the first report about the use of driving simulators for snowplow driver training. However, it was not found to be available online; therefore, information about the report is based on Kihl et al. (2006).

3.1.1 Pennsylvania (Vance et al., 2002, as cited in Kihl et al., 2006)

The Pennsylvania study seems to be the earliest identified record of a state DOT research endeavor into using driving simulators for snowplow driver training. Unfortunately, the report is not available openly online. However, Kihl et al. (2006) provided information about the main findings of that report. The simulator used in this study was a motion-based unit from the Pennsylvania State University, which was primarily used for research purposes.

In evaluating the perception and performance of training within simulators using different scenarios, researchers found that certain scenarios were easier to learn in a simulator than others. Furthermore, when comparing simulator performance without simulator training to performance with training, the findings indicated that training was found to help drivers to perform better on simulator runs.

The study also measured consistency between simulator measures and trainers' perceptions, where ratings indicated a good consistency between the two. Finally, when comparing participants who were trained using the simulator on actual driving tasks, the results were found inconclusive or lower. By further analyzing this result, it was found that measures were different for simulator and real-world driving; therefore, comparisons should be limited. Despite these findings, the researchers from this study were optimistic about the driving simulator technology and its use in training. Still, they cautioned PennDOT about the potential costs, and recommended that any action towards using a simulator for training be based on careful planning (Vance et al., 2002, as cited in Kihl et al., 2006).

3.1.2 Utah (Strayer et al., 2004)

The report prepared by Strayer et al. (2004) was the earliest state DOTs published report that was fully publicly available. This report studied the potential effects of adopting driving simulators into snowplow driver training. The main goal of that study was to develop and assess the impact of a customized training program incorporating high-fidelity simulation developed for the Utah Department of Transportation (UDOT) maintenance operators in a collaborative research project with the University of Utah and General Electric Driver Development (GEDD).

The training development was guided by the following two techniques from the psychological literature that were identified as having potential to improve the training activities: (1) part-task training, which mainly focuses on low-frequency events like tire blow-out or blade catching, and (2) variable priority training where drivers are encouraged to multitask and pay attention to all critical components of plowing.

In this study, Strayer et al. (2004) first assessed drivers' needs based on meetings with the Technical Advisory Committee (TAC), expert drivers, and ride-along. The information collected in these tasks was used to customize a driving simulator to mimic winter conditions and allow for the training of snowplow drivers by, for example, adding removable snow from existing driving scenarios. Eighteen short simulation

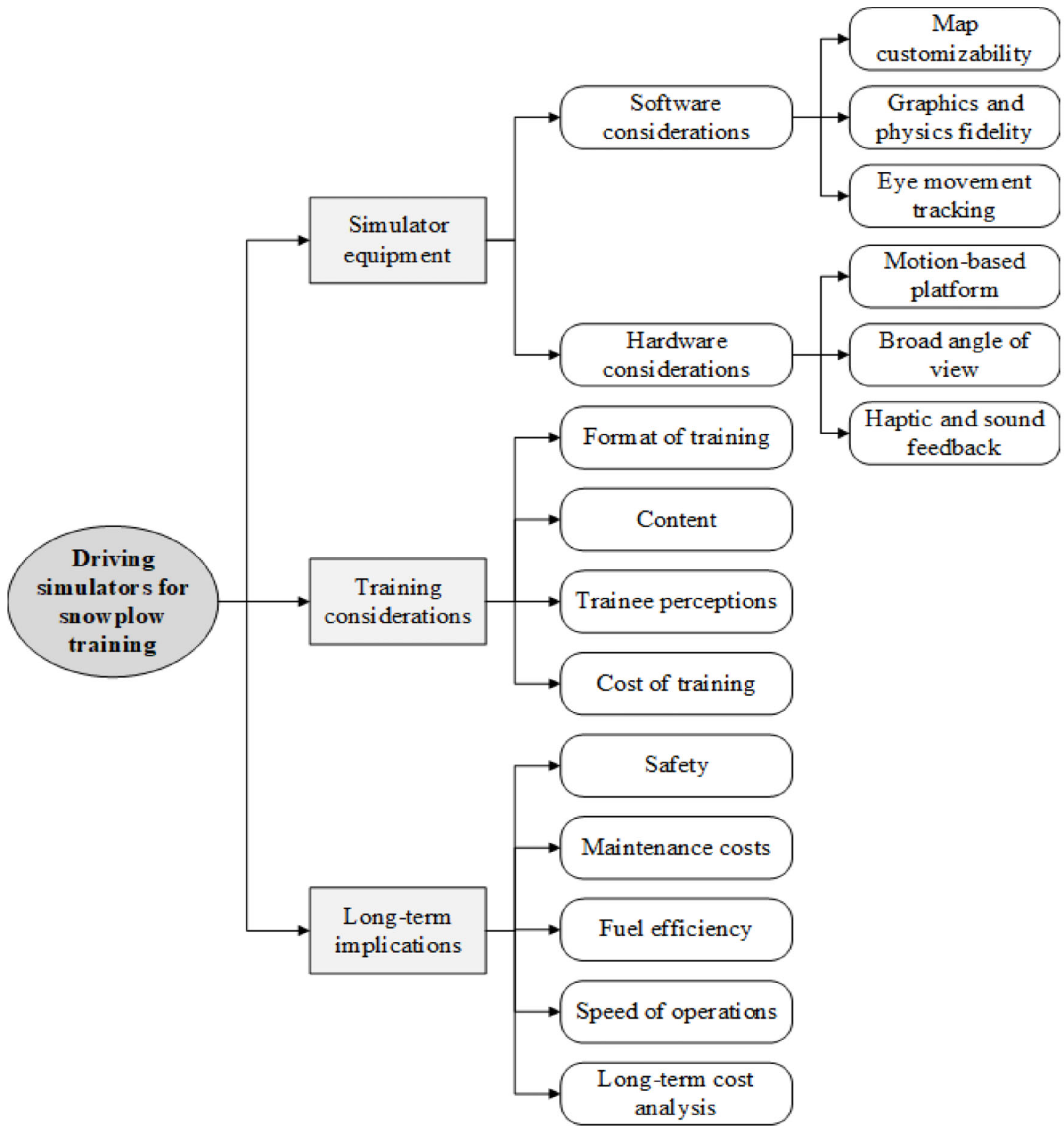


Figure 3.1 Research focuses for literature review.

scenarios (including urban interstate and rural mountain scenarios) were created, focusing on space management, speed management, crew communication, and fuel management.

Additionally, a new 4-hour training that included a lecture and a simulator component was developed and tested with snowplow drivers. For the training evaluation, the researchers selected 80 UDOT snowplow drivers for the study and divided them evenly between the study group and the control group. Groups were formed so that the number of participants in each had similar ages, and years of snowplowing and driving history. Participants in the simulator group were trained using the material developed by the researchers, which included lectures and practice of concepts using Mark II and TranSim VS driving simulators (Strayer et al., 2004). Once the training on the simulator was completed, the driver completed a 25-item questionnaire designed to assess drivers' perceptions about the various aspects of simulator training. Findings from this survey indicated the training was well received by participants across the demographics (mean = 4.5 and standard deviation = 0.25, when combining all items). One interesting note was that the older drivers found lectures to be more useful than younger drivers, and novice drivers found the trainer to understand better their needs and issues than experienced drivers (Strayer et al., 2004).

The final phase of this UDOT project involved comparing the control and experiment group participants' performance in terms of accidents and fuel efficiency for the following 6-months after the training. Of the eighty drivers included in this phase, only five had accidents, with only one of them coming from the group that was trained using the simulator. Even though the results seemed promising, statistical analysis (chi-square test) was not found to be significant for the sample size included, probably due to lack of power in the test. Reviewing the results, the researchers suggested that for the study to have adequate power for analysis, it should include between 60 to 80 drivers in each group (study and control). Cost was also analyzed for the five accidents and showed that the accident in the study group did not result in monetary damages, versus an average of $2,611 in the control group. Again, Strayer et al. (2004) cautioned interpretation due to the unlikeliness of an accident resulting in no monetary charges.

Following, the researchers evaluated fuel usage and maintenance data for the drivers in the study and the control groups. Again, though the data suggested a reduction of 6.2% of fuel usage in the study group, the researchers caution against its use as final, due to issues in the interpretation caused by drivers not being assigned to unique vehicles (Strayer et al., 2004).

The researchers in this study also evaluated potential long-term implications for incorporating the simulator in training, in terms of accident costs, fuel efficiency, and training costs. For fuel efficiencies, researchers estimated between 2.8% and 6.2% savings per year. Also, when comparing three potential training formats (third party training in centralized location, third party training at drivers' location, and UDOT training at drivers' location), they indicated that UDOT training using a purchased simulator would be economically advantageous, starting with 300 drivers trained (Strayer et al., 2004).

The findings from this report are particularly helpful because they provided a baseline for other state DOTs considering the use of driving simulators for snowplow driver training. It was observed that the training was well received by drivers; however, issues with data reporting and interpretation make long-term implications related to the use of driving simulators for snowplow driver training hard to assess, specifically for accidents, maintenance, and fuel management.

3.1.3 Iowa (Masciocchi et al., 2006; Masciocchi et al., 2007)

Iowa DOT commissioned two reports from researchers at the Iowa State University about driving simulators for snowplow driver training. The first report by Masciocchi et al. (2006) serves as a literature review that aims to discuss the previous research involving the driving simulator, as well as psychological measures that could affect the effectiveness of training. This review of literature study also evaluated the main findings from Strayer et al. (2004) on Utah's driving simulator for snowplow driver training. The second report discusses the experimental findings related to the deployment of snowplow training that included a driving simulator in Iowa (Masciocchi et al., 2007).

The literature review provided by Masciocchi et al. (2006) starts with a review of current driving simulators, indicating the need for simulators to successfully mimic the experience of driving an actual vehicle. Their work reviewed previous studies, the importance of realism in the simulations, and the ability to provide sensory feedback through body movement (kinesthetic) and touch (haptic). These features are important to increase drivers' sense of immersion and presence in the virtual environment. Masciocchi et al. (2006) was particularly focused on previous studies on the validity of the use of driving simulators. They concluded that results in driving simulators and actual world scenarios should follow similar performance trends and perform comparably in both situations. Additionally, the researchers indicated that a wide field of view and driving simulators that have similar characteristics to real vehicles increase simulator fidelity. The researchers found that driving simulators are frequently used in training for dangerous or hard-to-control situations. In addition to trainees' perceptions of training, other ways to measure drivers' engagement in simulators were also reviewed, specifically eye and head movement, to gauge focus and fatigue (Masciocchi et al., 2006).

For training, Masciocchi et al. (2006) reviewed several studies and concluded that a randomized comparative study (with a control and an experiment group) is preferable to assess the effect of training. Furthermore, hands-on training is largely preferable by trainees over less active training formats, such as lectures and watching videos. Training considerations should also include differences between novice and experienced drivers, given that previous research suggested each of those groups have different scanning patterns when driving (Crundall & Underwood, 1998). Although these differences may reduce with training, they manifest themselves similarly in real-life and simulated driving scenarios (Masciocchi et al., 2006).

Researchers also indicated cybersickness as a variable of concern in the reliability of training and is a common situation, with about one-fifth to one-third of simulation participants experiencing a level of cybersickness. Some situations that seem to trigger feelings of cybersickness were lag between action and display, screen refresh rate not being fast enough, and disconnect between what an individual sees and what their bodies perceive.

Complementing their technical findings, Masciocchi et al. (2006) included the review of literature about personality traits, and more specifically, the NEO Five Factor Inventory (NEO-FFI) (McCrae & Costa, 2003) and Zuckerman's Sensation Seeking Scale (Zuckerman, 1994). The five traits measured in the NEO-FFI test are extraversion, emotional stability, agreeableness, conscientiousness, and openness to experience. The researchers explored that the NEO-FFI personality test is a good predictor of job performance and compatibility. However, depending on the employer and their intentions, other measures might be more adequate, including structured interviews (Masciocchi et al., 2006). Zuckerman's Sensation Seeking Scale, on the other hand, measures the following four subscales: thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility. Based on the characteristics of these two behavioral inventories, Masciocchi et al. (2006) suggested the use of these measures in conjunction with studies on simulator training.

The second study commissioned by the Iowa DOT to Masciocchi et al. (2007) then furthered into the development of a training using simulator for snowplow drivers and its assessment. The study was done with 174 participants separated into two groups with various demographic characteristics; an experimental group with only 124 participants was included in the performance analysis. This discrepancy is due to a simulator upgrade after the beginning of the study, so only trainees that participated after the upgrade were included in the performance analysis. Participants were trained in 4-hour sessions at the District One facility in Ames, Iowa. The session started with a 3-minute drive by the instructor, followed by a 3-minute drive by participants, during which no data was collected. Following, participants answered the three questionnaires, including the NEO-FFI, a modified version of Zuckerman's Sensation Scale, and an immersive tendencies scale by Witmer and Singer (1998). While some participants completed the questionnaires, they would take turns in driving a 10-minute driving scenario, which included plowing snow with a wing plow in traffic situations, such as passing vehicles.

After this first run, participants were separated into their assigned groups, and the control group did their second run on the same scenario immediately after their first 10-minute run. The experiment group received additional training with a 20- to 25-minute lecture, computer exercise, and two 5- to 10-minute simulation scenarios using trucks (not snowplows or conducting snowplow operations), followed by a 5- to 10-minute summary given by the instructor. All participants completed the following three questionnaires after the training: a modified version of a presence questionnaire, a simulator sickness questionnaire, and a modified version of the questionnaire used by Strayer et al. (2004). The study design aimed to determine whether the training had any immediate impact on performance, fixation behaviors, or both, and participants' satisfaction with the training provided.

Findings from the initial questionnaires suggested that presence was similar across all levels of experience of participants; training was well received by participants at all levels with high marks for realism, and cybersickness was low (with five participants having to withdraw due to excessive sickness). Interestingly, the lecture was liked more frequently by participants than the simulator training; for the simulation portion, participants noted the low responsiveness of simulator equipment and suggested the ability to control the wind and the inclusion of a salt spreader (Masciocchi et al., 2007). Overall, the findings also indicated that the experimental group participants performed better than the ones in the control group during their second drive. Eye-tracking measures told that low-experienced drivers changed view patterns from their first to their second drive, and that the simulator was less demanding for more experienced drivers than low-experienced drivers (Masciocchi et al., 2007).

For personality and other behavioral measures, only minor differences were found between groups and those were deemed insignificant once controlling for age factor. Overall, these scales suggest that snowplow drives may have slightly different patterns for personality and sensation seeking than the average American population. However, the authors caution that the generalization of this finding before further research is conducted could be premature. For performance, it was found that low-experienced drivers were more frequently involved in crashes in the two experimental drives, which can be related to the ability of more experienced drivers to use training material in practice more easily. Furthermore, all drivers in the experimental group drove faster than the control group while using a similar amount of fuel, which prompts further studies on fuel management. Also, the authors note that all findings from Masciocchi et al. (2007) were based on simulation drivers and not actual drives; even though previous research suggests the transferability of the performance of driving simulators, no study at that time has provided information specific to the transfer of snowplow driving skills.

3.1.4 Arizona (Kihl et al., 2006, 2007)

Similar to the studies commissioned in Iowa, Arizona's DOT (ADOT) also commissioned two reports about the use of simulators in snowplow driver training to the Arizona State University (Kihl et al., 2006, 2007). However, in Arizona, even though the first report included a literature review, it also evaluated quantitatively and qualitatively 2 years of using simulators in snowplow driver training in the state (Kihl et al., 2006), while the second report focused on evaluating potential fuel and maintenance gains to the use of driving simulators in snowplow driver training (Kihl et al., 2007).

The first study commissioned by the Arizona DOT to Kihl et al. (2006) used a longitudinal approach to evaluate the use of snowplow driving simulators in the driver training process in that state over the course of two years (year 1 being 2004–2005 snow season, and year 2 being 2005–2006 snow season). The focus of this first report was twofold—(1) to assess drivers' perceptions about the training and (2) potential long-impacts of the training on the safety of the public and operational costs.

A brief literature review was included in the first report and covered topics such as the use of simulators for training, the validity of driving simulators, and the transfer of the training from the simulation to real-world scenarios. Furthermore, Kihl et al. (2006) also explored previous state DOTs' experience with driving simulators for snowplow driver training, including information from PennDOT (Vance et al., 2002 as cited in Kihl et al., 2006), UDOT (Strayer et al., 2004), and Iowa DOT (Masciocchi et al., 2006). In their report, Kihl et al. (2006) highlighted the lack of external validity in the use of driving simulators from the previously commissioned state DOT reports, and the fact that only Masciocchi et al. (2006) included qualitative measures in addition to quantitative measures. The addition of qualitative information in Masciocchi et al. (2006) helped understand issues with transfer between simulator and real-world driving.

Furthermore, when discussing study procedures, Kihl et al. (2006) mentioned the several components of the study, including surveys, focus groups, interviews, observations, and ride-along. This was the first commissioned state DOT report that used a more extensive qualitative approach. The first year of training included a third-party trainer using a simulator mounted on a trailer, which could be moved around the state to train drivers in a 2.5-hour training session. In the first year, 149 drivers were trained in five ADOT districts. In this first season, connectivity issues, as well as hardware and software issues, were experienced. Drivers in this first cohort used the simulator for a minimum of 15 minutes to 45 minutes. In year 2, the training was conducted by four snowplow drivers in a fixed-based simulator located in the Globe ADOT district. The training duration was 4 hours and included a classroom and simulator. Year 2 training was performed for 60 drivers, and all trainees spent 45 minutes in the simulator, working on scenarios of increasing difficulty.

Findings from the surveys and focus groups indicated that the training was well received by participants, but realism of the simulator was lacking, as well as more local scenarios. The issue of more local scenarios was even more relevant to more experienced drivers. Less experienced drivers were more enthusiastic to use the simulator in training prior to the actual snow season. More experienced snow drivers missed more complex scenarios that would require them to multitask while driving. Using the model described previously, Kihl et al. (2006) suggested that this type of driver training is better for tactical skills (namely those tasks that involve choice of maneuver and focus on end destination), but not as much for control skills (defined as moment-to-moment operational tasks in the vehicle). The transfer of tactical skills, due to their complex nature, are naturally harder to measure than control skills.

In addition to the driving training in years 1 and 2 of this study, in the spring of 2006, training specific to fuel management and shifting was given to snowplow drivers in the Globe District. However, it was not perceived as applicable by drivers in automatic transmission vehicles, focusing more on teaching drivers about control skills. In this training, each driver spent 15 to 20 minutes in the simulator, but training also included lectures and computer exercises. The effectiveness of the training was measured using pre- and post-trip drive in the simulator. Findings were inconclusive for all drivers but showed an improvement for drivers that used automatic transmission and were unaware of proper shifting techniques.

Parallel to evaluating the training sessions and outcomes, the researchers also studied historical data from ADOT for the past five winter seasons (starting at the end of 1999 to the spring of 2004), to establish baselines for comparing the effectiveness of the training. Similar to previous reports, due to the little data on accidents and high variability between snow seasons and the location of accidents, no conclusion was reached when comparing the cost and number of accidents of drivers that had the simulator training versus the ones that did not. Furthermore, Kihl et al. (2006) warns that "accident avoidance is very difficult to quantify" (p. 3), though, in their view, the results seemed positive in terms of cost of liability and repair compared to exposure. Kihl et al. (2006) also evaluated the impact of costs of commercial shipping delays and accidents involving the public (including injury and fatality).

Based on those findings from the report, Kihl et al. (2006) made fourteen short-term recommendations, including suggesting the full use of simulators (even beyond just snowplow driver training), increasing simulator "seat time" for novices, using more scenarios that are relatable to drivers' needs and experience level, separate training for novices and experienced as well as developing more advanced classes for the latter and allowing novices to have more open "seat time" in the simulator. Six long-term recommendations were made, including establishing consistency of training among ADOT districts and improving simulator realism to address local issues, such as more local-based scenarios and equipment operation that better mimics what drivers find in real-world operations.

The second report by Kihl et al. (2007) was conducted during the winter of 2005–2006 and focused on assessing potential savings in fuel and maintenance. The training object of the report was given in the Globe ADOT district to all drivers in 2006 (n = 50), and new drivers in 2007 in Globe (n = 5). Two other districts were included in this study in 2007 as well, Holbrook (n = 18) and Flagstaff (n = 32). Findings from the simulated pre- and post-trip were inconclusive, and Kihl et al. (2007) suggest an issue with software, given that the information is provided by the simulator software. Furthermore, trainees in 2007 were mentioned to struggle with hardware in the actual shifting of the gear in the simulator.

To test the transferability of the training to real-world drivers, Kihl et al. (2007) proposed a 168-mile test run using two snowplow trucks. Similar to the simulator, this test run was subject to issues that compromised the validity of the comparisons. Some of the issues they have found included equipment overheating, inconsistent driver behavior, and changes in temperature and weather conditions. Results, which should be taken with caution, suggest a 4.5% improved fuel economy for manual transmission trucks. In contrast, results for automatic transmission showed a decreased economy, which could be related to the inconsistent driver behavior noted previously.

To further study the impact of the fuel management training, Kihl et al. (2007) attempted to compare the fuel consumption of trained drivers before and after the training, using two snow seasons in each. Again, due to the various factors and inconsistencies in data reporting, conclusions were difficult and suggested a decrease in fuel economy, although not statistically significant. A similar approach was taken to compare maintenance costs and found similar inconsistent results. Researchers also warned about comparing different snow seasons or even different times in the same snow season, given that weather conditions, road surfaces, and configuration may have a direct impact on fuel consumption.

In their conclusion, Kihl et al. (2007) made four recommendations to ADOT, including the need for improving data collection and reliability related to fuel and maintenance costs, improving gear shifting training, as well as training for automatic transmission techniques for fuel economy, and considering simulator downtime, as well as maintenance, given several issues faced by ADOT during the study years.

3.1.5 Illinois (O'Rourke, 2011)

The report was commissioned by Illinois DOT (IDOT) to the University at Illinois at Urbana-Champaign. It aimed to evaluate the effectiveness of the simulator training in two phases—(1) right after the training program and (2) end-of-snow-season follow-up evaluation. The report also reviewed previous state DOT reports, such as the ones prepared for Utah (Strayer et al., 2004), Iowa (Masciocchi et al., 2006, 2007), and Arizona (Kihl et al., 2006, 2007), as well as additional anecdotal information from other state DOTs.

The training object of this study was performed by a third-party trainer in three locations in late 2009. Driver feedback was collected right after the training and again at the end of the snow season (spring 2010), and supervisor feedback was collected at the end of the same snow season. Seventy-seven drivers were trained, but only 50 of those drivers completed the post-training and post-season questionnaires. Similar to what was found in previous reports, overall feedback was positive, but the simulator seemed to lack realism for the participants and, more concerning, participants seemed to be less excited about training with simulators after the end of the snow season. When analyzing open-ended feedback provided by participants, some suggested this type of training should be focused more on novice drivers. O'Rourke (2011) indicates some explanations for the discrepancies between end-of-training and end-of-season data, including participants' lived experience, discussion with other drivers, and reliance on recall. This IDOT report is the only one of the state DOT commissioned reports evaluated in the present study that focuses on "long-term" retention and feedback about the driving simulator.

When further analyzing potential correlations between drivers' feedback and their age, years with IDOT, and years in plowing snow, none of the analyses showed a statistically significant correlation.

The results from supervisors at the end of the snow season were positive. Furthermore, supervisors would recommend simulator training for more novice drivers compared to all drivers or experienced drivers. When asked to provide more information about their training, supervisors mentioned that drivers usually are trained with a median of 8 hours behind the wheel and an additional 8 hours with other types of training. During training, drivers drive a median of 95 miles, and no accidents, injuries, or costs associated with those were mentioned by supervisors.

The information provided by the supervisors was also used by O'Rourke (2011) to provide comparative scenarios for simulators (onsite and offsite) and behind-the-wheel training costs. The costliest was the offsite training with simulator, followed by the onsite training with simulator, and then behind-the-wheel training was the most cost-effective. However, the researcher acknowledges that other factors need to be considered by IDOT, such as opportunity costs and trade-offs in the use of simulators, the reduced safety risk of using simulators, and added flexibility, given that drivers could train off-season.

Similar to previous researchers (Kihl et al., 2006, 2007; Masciocchi et al., 2007), O'Rourke (2011) attempted to compare accidents rates and damage costs of simulator-trained drivers and drivers that only had traditional behind-the-wheel training. The results were also inconclusive due to the small number and issues with date recording from IDOT.

Based on the results, O'Rourke (2011) recommended that further evaluating and testing should be performed in order to assess the effectiveness of simulators for snowplow driver training. Other recommendations made in the Illinois DOT report included more time actually using the simulator during the training sessions, and potentially using the simulator as a complement to "behind-the-wheel" training (and not as a replacement for it) (O'Rourke, 2011).

3.1.6 Ohio (Ash et al., 2022)

The latest release of the commissioned reports about the use of driving simulators for snowplow driver training was from Ohio DOT (ODOT). Two reports were commissioned, in a similar approach to the studies commissioned by Iowa and Arizona. The first was focused on literature review and assessment of ODOT's needs for training snowplow drivers. The assessment included the analysis of drivers in operation, as well as a questionnaire about driver behavior. The full report from Phase 1 is not available openly online, but presentation slides based on the findings are (Adebisi et al., 2019). Some of the challenges identified by the authors of that report include the retirement of more experienced drivers, the increased use of occasional snowplow drivers for winter operations, and the need to conduct training before the winter season, without snow.

Additionally, four simulator models were reviewed and compared (VS 600M, TranSim 7, SP 550, and SP 650), three of which had base costs varying from $105,000 to $266,890—no cost was provided for the VS 600 M simulator). The authors of the presentation also provided a benefits comparison to a contractor-led training. Recommendations made in Phase 1 included the acquisition of a driving simulator, building ODOT-specific route scenarios, and mounting the simulator in a trailer that could be moved to training locations.

The second report, by Ash et al. (2022), focused on Phase 2 of the project, which consisted of customizing the scenarios to Ohio-based routes and trucks, as well as developing training materials that could be used to train drivers in those customized routes. For Phase 2, the simulator was stationed at the University of Cincinnati so that researchers could work on developing the customized scenarios. Three ODOT districts were selected to have customized routes included in the simulator.

After the initial set-up of the driving simulator, the researchers began the development of virtual scenarios that include (1) 3D modeling of roads with similar conditions and environments to the roads where ODOT snowplows operators will plow; (2) 3D modeling of a series of customized scenarios requested by ODOT for different training applications; and (3) development of customized Ohio snow maps and relevant training manuals. The three main tasks identified at the end of Phase 1 are outlined, and each is briefly discussed as follows (Ash et al., 2022).

Snowplow Simulator Setup: The setup consisted of the following four major components: (1) the visual system, (2) the seat and motion system, (3) the transmission and controls system, and (4) the control room. The first three components were an integral part of the simulator; however, the control room comprised all the space behind the simulator cab in the trailer. This room consisted of an instructor's workstation, an air-cooled cabinet to house four PCs that were needed to control the simulator, a sitting bench to host other members, additional space for a few members to stand, and some storage space. The researchers worked along with Doron (the driving simulator manufacturer) staff to install the setup. All the systems were run, and it was verified that all the components of the simulator and trailer were working correctly. The researchers also documented the procedures on how to use/interact with different components of the simulator. These procedures were also demonstrated to ODOT training staff (Ash et al., 2022).

Simulation Scenario Development: The development was done in two parts. First, the development of virtual environments using 3D modeling software. These virtual environments were created and modeled as per existing ODOT facilities to allow drivers to get acquainted with the roads they will be plowing. These virtual environments were based on the routes from three counties in Ohio. They included features like terrain, roads, bridges, tunnels, trees, buildings, traffic signs, utility poles, and mailboxes, among others. The data needed for developing the aforementioned scenarios were collected through various open-source databases such as Geographic Information System (GIS) maps, USGS terrain data, Bing Maps aerial photos, Google Maps, Google Earth, and Google Street View. The collected data was used to construct maps using software such as Autodesk Civil 3D and AutoCAD. The compiled OSG files containing visuals, and the physics model were then imported into the correct directory inside the DoronIG engine and then assembled in the Stage program to create "Maps." Secondly, the development of series of scenarios for use in training applications. Several scenarios were built in vendor-provided environments as well as in customized ODOT environments. These scenarios were the combination of a specific map, truck begin/end points, static objects, and dynamic objects. One major issue was faced while implementing plowable snow in the custom environment, which could not be solved even with the consultation from both Doron and a former software developer at Doron (Ash et al., 2022).

Training Material Development and Evaluation: This section aimed to develop training material for use in the ODOT snow and ice driver education program, as well as suggest evaluation procedures. Five modules were created for the training and summarized into guidebooks—one for trainees and one for instructors. Module 1 covers the basics of plow operation in simulators; Module 2 discusses the basics of plowing techniques; Module 3 then moves to advanced plowing techniques; Module 4 focuses on safety and plowing in traffic, and Module 5 uses the customized routes for training. No information was available on the suggested duration for these training, and the report did not cover testing of the training (Ash et al., 2022).

The report concludes by making recommendations to ODOT for the implementation of the developed customized routes and training materials for snowplow driver training. Risks for the implementation of the training outlined by Ash et al. (2022) included cybersickness and potential hardware and software malfunctioning. Furthermore, the researchers also recommended that ODOT track the performance of simulator-trained drivers against conventionally trained drivers.

3.2 Academic Literature

As mentioned previously, most of the research specific to the use of snowplow driving simulators for winter operations has been commissioned by state DOTs. Though not specific to snowplow simulator training, many other academic studies have been conducted to test the effectiveness of deploying simulators in the training of special vehicle operations. These studies can complement those reports by providing essential information regarding the latest technologies, such as hardware and software features, as well as recent training-related research on the use of driving simulators.

3.2.1 Learning and Workforce Development Using Simulators

From a learning and workforce development perspective, previous research suggests many human-related benefits to train using simulators. For example, Prohn and Herbig (2020) conducted a study to evaluate the use of driving simulators to train ambulance drivers. The experiment included training and measurements taken during the participants' normal shift hours. For this experiment, simulators were configured to simulate ambulance cabins with features such as sirens and lights so that participants could be fully immerse in their training. The simulation software in the experiment contained realistic driving conditions for emergency vehicles. Also, scenarios of critical incidents were included. For each iteration of the training, participants were given two 5-minutes simulator runs. The first one was to get the participant familiarized with the simulator and its basic operations, and the second run simulated real driving scenarios with emergency task stress. Results were evaluated subjectively and objectively by questionnaires and physical measurements. At the end of the experiment, the researchers concluded that most of the participants showed increased awareness of road conditions, reduced reaction time to potential hazards, and safer driving behaviors (Prohn & Herbig, 2020).

Furthermore, a study by Underwood et al. (2011) revised the effectiveness of adopting driving simulators in training. By analyzing several previous research studies, Underwood et al. (2011) identified the use of similar eye patterns between simulated drives and actual drives, suggesting that trainees transfer skills between simulator equipment and driving vehicle. Furthermore, they have cautioned that certain hazards seem to allow for a better assessment of novice and experienced drivers than others in a simulated drive and this should be taking into consideration when planning for training. Another study by Calvi et al. (2020) suggested that the adoption of augmented reality (AR) cues in the driving simulator can improve safety when drivers are maneuvering left turns. The authors indicated that left turns are very dangerous maneuvers based on the available accident data, as many drivers can not properly assess the distance between incoming traffic from the opposite lane and their cars. Therefore, adding a visual cue using AR can be beneficial in driver training. During the experiment, the researchers designed an AR-based warning system that can provide signs and signals to indicate if the left-turn gap is sufficient. The drivers were placed onto four different routes with intersections, in which each of them had different AR configurations, and one of them did not contain any AR presentations. The test results were recorded from multiple perspectives including driving performance analysis and surrogate safety measures such as post encroachment time (PET), data representing the time interval between two vehicles entering and leaving the same area. From the results, Calvi et al. (2020) concluded that the adoption of AR cues into vehicle driving can effectively increase drivers' safety by enhancing drivers' judgment while reducing the decision time (Calvi et al., 2020).

Transferring the findings from the studies previously discussed to the use of driving simulators for snowplow driver training, it is reasonable to consider this type of training beneficial to drivers. Some of the benefits of using simulators in training from previous research include enhanced safety awareness of road conditions, improved driving behaviors, and reduced reaction time (Prohn & Herbig, 2020). In addition, the AR experiment by Calvi et al. (2020) suggests that a feature like AR cues can be an effective tool for improving driver's safety training as more intuitive information is provided.

3.2.2 Driving Simulators' Technology

From a technological point of view, driving simulator technology can be analyzed from two perspectives—(1) the *hardware* that provides the realistic and immersive operating experience for the driver; and (2) the *software* that simulates feedback from the driver's inputs, as well as providing a realistic visual experience.

3.2.2.1 Hardware. Despite several simulator options being available on the market, some of them might not bring a pleasant and realistic experience. Research by Goodge et al. (2021) explains that some people using simulators may exhibit different levels of cybersickness in Virtual reality (VR) based simulations, due to the inconsistency and conflicts between different sensory information. Their research also shows that a wider view angle in an immersive environment may not increase cybersickness, though four (of the 77 total) participants in their study still felt sick and had to be removed, acknowledging that work in mitigating cybersickness should continue.

In addition to wider view angles for simulator screens, other features such as motion-based platforms and realistic haptic feedback are now included to mitigate such inconveniences in the use of driving simulators. For example, the study by Lucas et al. (2020) proposed a novel solution to reduce cybersickness by adding some vibrations to the driver's seat as they can provide noise for vestibular and proprioceptive senses. To test this feature, the researchers divided the participants into the following three groups: (1) reference group with no vibrations added, (2) group with realistic vibrations based on vehicle speed and road conditions added, and (3) group with random vibrations added. By the end of the experiment, researchers concluded that some vibrations were helpful in reducing the cybersickness of participants, and though the group with realistic vibration pattern had better scores than the one with random vibrations, their scores were not significantly different, prompting further research to identify the specific types of vibration that could help with mitigating cybersickness (Lucas et al., 2020).

Another potentially beneficial feature from the hardware perspective is the enhanced simulation of real-world dynamics, which refers to the motion of the vehicle generated by the inputs of a steering input by the driver (Abe & Manning, 2009). Previous research by Kharrazi et al. (2019) explored the potential of using a motion-based platform to assess and compare the performance of different heavy vehicles. The authors pointed out that traditional driving simulator lacks a series of simulated cues such as graphics fidelity and feedback from inputs, hence limiting the validity of testing results. Therefore, the authors adopted a driving simulator that is capable of providing six degrees of freedom (roll, pitch, yaw, surge, heave, sway), which is shown in Figure 3.2. For the study, the simulator cabin was mounted on a sled-like rail, which provided two additional degrees of freedom in linear movement along the longitudinal and lateral directions. The simulator could hence physically move forward and backward based on the projectors, delivering a total front view of 210°. Also, the steering wheel contained an electric motor to provide steering feedback.

During the experiment, 55 professional truck drivers were invited to test drive several different trucks on the simulator. The test trucks were modeled based on the data from manufacturers in order to assure the highest simulation quality. The drivers were placed to drive on designated routes consisting of both straight and curve sections. During the simulator driving, drivers were also asked to perform emergency maneuvering actions to assess the vehicle dynamics, such as off tracking, rearward amplification, and load transfer ratio. Based on objective and subjective measures obtained from participants, the authors concluded that the simulator was able to provide satisfactory and authentic feedback based on drivers' inputs, hence benefiting the field of vehicle dynamics testing (Kharrazi et al., 2019).

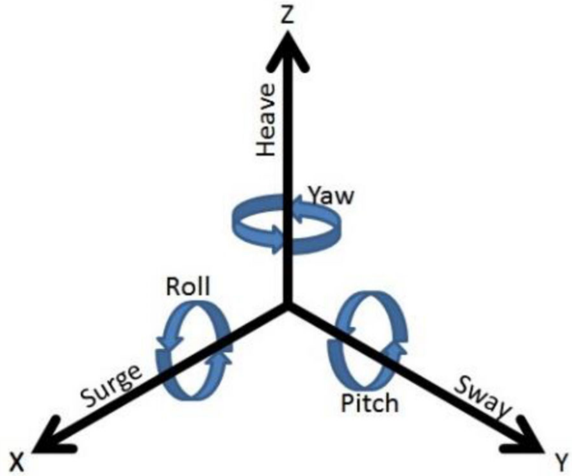


Figure 3.2 Six degrees of freedom in simulator motion.

The studies above indicate the importance of new hardware features in improving driver's comfort and, consequently, more accurate results in using driving simulators. Though cybersickness does not affect everyone, it is a major concern in terms of the reliability of training (Goodge et al., 2021). Some hardware features seem to mitigate these issues, as well as provide a more realistic driving experience, such as wide view angles, realistic vibrations, and haptic feedback (Kharrazi et al., 2019; Lucas et al., 2020). Previous research indicates that understanding the technological features of a simulator is important for the interpretation of assessment results in terms of fidelity, validity, and reliability (Campos et al., 2017).

3.2.2.2 Software. In addition to benefits from the hardware perspective, features included in the software also play an essential role in providing an immersive driving simulation experience for the driver. The study by Ojados Gonzalez et al. (2017) investigated the effectiveness of using a simulation software with high-fidelity graphics and realistic physics to train tractor drivers. The researchers first developed the virtual tractor model using Solidworks2014, an industry leading modeling software known for its high-fidelity graphics, as well as highly customizable features of physics.

All parts of the selected tractor model were created individually to mimic the real-world scenario, and a series of physics features such as mass, center of gravity, and moment of inertia were added to best simulate the actual operating experience. Driving scenarios were developed on Unity5, which is a game engine providing powerful physics features. One hundred and twenty-seven participants, divided into three groups with different levels of safety knowledge were asked to perform several tasks related to tractor operations on the designated routes in the simulator. To validate the effectiveness of the simulation software, participants were asked to answer several questions related to their safety awareness, perception of risks, and confidence level after operating the simulator. Researchers concluded from the questionnaire's results that most participants from the three groups showed an increased level of perception in all aspects. The results also indicate that the group with rich prior knowledge of safety operations showed fewer errors compared to the other two groups. Also, all participants considered the test with the simulator as a very positive experience and indicated that the use of tractor simulators would help them drive more safely in the future (Ojados Gonzalez et al., 2017).

Furthermore, a study by Yahoodik and Yamani (2021) tested the effectiveness of a specific software used in a driving simulator to train drivers to improve their ability to identify latent road hazards. Latent road hazards include those that are hidden or partially hidden from views, such as a pedestrian or animal crossing behind a vehicle. The focus of Yahoodik and Yamani (2021) study was on the effectiveness of Risk Awareness and Perception Training (RAPT), and their results indicate participants that have received the training had better hazard anticipation performance than the ones that received a placebo training which only included a PowerPoint presentation and quizzes. But, more interesting to the goal of the present report was the use of eye tracking to measure participants visual engagement with the simulation, including eye fixation and eye movement. This feature allowed researchers to measure the effectiveness of specific aspects of the training, which included adding different variations of hazards (such as a still visual of a potential hazard, or a moving visual of a potential hazard) (Yahoodik & Yamani, 2021).

Similarly, Bobermin and Ferraira (2021) proposed a novel method to create a dynamic and effective virtual environment for driving simulator experiments by analyzing real-world crash data so that risky road conditions can be identified to model the simulated scenarios. In their experiment, a consistent and feasible approach based on traffic crash data, road inventory, and traffic volume was established to support generating simulated scenarios. To establish the framework, the authors found that clustering analysis has been proven to be an effective way to identify patterns of crash data. The data was obtained from the Brazilian Road Federal Police and the National Department of Transportation, and it included 488 crash reports on rural highways from 2017–2019. By applying the cluster analysis, four clusters were identified, that is cluster 1 represented accidents during daytime on single-lane roads with shoulders in long straight and slightly inclined stretches with traffic; cluster 2 included accidents at night time, on single-lane roads with shoulders at curves and less traffic; cluster 3 included accidents in two-lane roads at steep inclines and at curves, during low traffic and good lighting conditions; finally, cluster 4 included accidents in single lane roads with no shoulder curves, during day and low traffic conditions. The authors then suggest using the framework created in this study to guide the creation of simulation scenarios for driver training (Bobermin & Ferreira, 2021).

In summary, software features on the snowplow simulator serve as crucial parts to create an effective training process. In this case, the studies stress the importance of creating realistic and immersive driving scenarios (Ojados Gonzalez et al., 2017), and the importance of data for determining customizable scenarios for accurate training (Bobermin & Ferreira, 2021). Furthermore, studies also evaluate how to use eye tracking ability to enable more in-depth analysis of drivers' perceptions and driving strategies (Yahoodik & Yamani, 2021).

3.3 Summary of Considerations for Using Driving Simulators in Snowplow Driver Training

Based on the literature review of academic publications and state DOTs reports, several factors should be considered when evaluating the use of driving simulators for snowplow driver training. These factors are summarized in Table 3.1 and are used in the drafting of the survey questions for state DOTs in a later phase of the present study. Obtaining updated information about these factors can help understand decision-making processes related to, and the current state of the practice in, the use of driving simulators for snowplow drivers in state DOTs.

TABLE 3.1
Summary of factors affecting the decision and use of driving simulators for snowplow driver training

Type	Name of Factor	Potential Effect(s)	Source(s)
Hardware	Broad field of vision	Increased realism	Goodge et al. (2021); Masciocchi et al. (2006)
	High refresh rate	Increased realism; reduce cybersickness	Lucas et al. (2020); Masciocchi et al. (2006); Strayer et al. (2004)
	Motion-based platform (preferably with six degrees of freedom)	Increased realism and driver engagement	Kharrazi et al (2019); Lucas et al. (2020)
	Haptic feedback, including vibrations mimicking real-world conditions	Increased realism and driver engagement; reduce cybersickness	Lucas et al. (2020)
	High fidelity graphics	Enhanced realism	Ojados Gonzalez et al. (2017); Kharrazi et al. (2019)
Software	Physics properties	Increase realism and driver engagement	Ojados Gonzalez et al. (2017)
	Variety of software features	Enhanced adaptability: ability to collect training data	Ash et al. (2022)
	Eye and head tracking capability	Ability to collect training data	Underwood et al. (2011); Yahoodik and Yamani (2021)
	Effective route design and variable scenarios	Improved road safety; provide more information for decision making	Bobermin and Ferreira (2021)
	Augmented reality cues	Intuitive warnings that can improve driver training	Calvi et al. (2020)
Software/Training	Route customizability	Increased realism and driver engagement	Ash et al. (2022)
Software/Hardware/ Training	Simulator equipment maintenance issues and cost	Simulator downtime	Kihl et al. (2006); Ash et al. (2022)
Training	Time on simulator	More seat-time on the simulator may improve its effectiveness	Masciocchi et al. (2006); O'Rourke (2011)
	Cost of training	Cost of using a simulator varies per number of trainees	Strayer et al. (2004); O'Rourke (2011)
Long-Term	Increased fuel efficiency (suggested)	Reduced operation costs	Kihl et al. (2006, 2007)
	Decrease maintenance costs (suggested)	Increase in fleet reliability	Kihl et al. (2006, 2007); Masciocchi et al. (2007)
	Increased public safety (suggested)	Reduced number and gravity of accidents; reduced cost of accident damages	Kihl et al. (2006); Masciocchi et al. (2007); Strayer et al. (2004)
	Need for plan to collect validation data	Consider that effectiveness of simulator training in real-world scenarios is difficult due to issues in data reliability	Kihl et al. (2006, 2007); Masciocchi et al. (2007); O'Rourke (2011)

4. CURRENT INDOT CONTEXT

In the following section, current INDOT context will be reviewed. This includes current training format, information about accidents involving snowplow operations, visuals from current snowplow driving operations, and risky situations as perceived by INDOT snowplow drivers and supervisors. The main goal of this phase is to (1) identify risks and opportunities associated with the current training format and (2) identify risky situations that snowplow driver trainees are faced with during driving. This information is used in understanding decision factors related to the adoption of driving simulators for snowplow driver training.

Furthermore, to understand INDOT winter operations, it is necessary to understand the composition of their current workforce. In addition to regular maintenance professionals, INDOT may request drivers from other departments and other occupations to help with snow plowing, which are called "transfer drivers." These transfer drivers accounted for 51% of labor hours of snow assignments in all INDOT districts in 2016 and have slowly decreased to a low of 41% in 2021. However, certain districts seem to rely more on the use transfer drivers. For example, Greenfield was the district with the highest use of transfer drivers (n = 55.89%), while Seymour had the lowest usage (n = 37.67%) during the analyzed period (2016 to 2021). Despite not being their usual work assignment for INDOT, transfer drivers and regular drivers seem to drive similar hours per day during a snow season, which is close to a median of 8 hours per day during snow events.

4.1 Current INDOT Training Information

Any commercially licensed driver (CDL) working for the Indiana State Department of Transportation (INDOT) may plow snow for INDOT. Therefore, all CDL INDOT drivers attend a yearly training (also known as "Snow School"), deployed by INDOT in the Fall. Training topics and format vary slightly for each INDOT district or subdistrict, but usually include a lecture presentation, a practical component (such as checking pre- and post-trip procedures) and driving the plow on assigned routes. Experienced drivers in some districts may have an abbreviated version of the training, especially driving the plow on assigned routes. Table 4.1 summarizes the information about the format of training in each of the INDOT six districts.

4.1.1 INDOT Snow School Lecture Content

This section summarizes the main topics presented in the lecture portion of the yearly Snow School at different INDOT district offices. The training materials were obtained from three of the six INDOT districts (Fort Wayne, Crawfordsville, and LaPorte) and one subdistrict (Gary). The main purpose of the lecture is to familiarize the drivers with INDOT winter operation procedures and policies, plowing techniques, and safety. Various themes are covered in these presentations providing drivers with useful information for their day-to-day operations, as well as emergency and accident situations. Examples from real-life accidents and damages involving snowplow trucks are included to highlight the importance of safety during plowing operations. The following topics exemplify the major themes included in the analyzed presentations.

- *General Duties and Expectations:* This theme focused on educating drivers on their general responsibilities as INDOT snowplow drivers and familiarizing them with their daily duties. Additionally, this theme covered pre-trip inspections and preventive maintenance; shop callouts and procedures; vehicle cleaning expectations; the importance of communication; common radio codes used during plowing; tracking material usage throughout shifts; maintaining fuel tickets; and use of cell phones while driving.
- *General Safety:* This theme focused on safe plowing techniques to minimize risk. This section also includes information on plowing road centerline and shoulders on single and multiple lanes for maximum efficiency and safety. Speed guidelines and strategies for safely plowing ramps, bridges, overpasses, turn lanes, intersections, and crossovers are also covered in this section. Vehicle upkeeping for improved visibility while driving, such as cleaning windows and headlights.
- *Non-Plowing Risks:* This theme covered drivers' exposure to different risks before getting on the vehicle; safe methods of entering and exiting the vehicle; safety against slips. Trips and falls, procedures to be followed while backing, and ground safety concerns were emphasized.
- *Frequent Accidents:* This theme covered the most frequently observed accidents such as sliding, overturning the plow truck, truck stuck in a ditch, mid-operation detachment of plow blades, disengagement of material holder, and backing, among others involving snowplow drivers. Several photos of risky situations and accidents were used in slides covering this theme. This theme also covered the tricks which can help drivers to minimize their exposure to such accidents.
- *Damages Caused by Plow Drivers:* This theme focused on educating drivers on damages that can be caused during plowing operations. Some of the damages include hitting the sign boards, throwing snow on pedestrians, and hitting curbs.
- *Policies and Procedures:* In this theme, the drivers were briefed on the different types of reports and forms required to be filled out after accidents or injuries.
- *Winter Equipment and Materials:* This theme covered the introduction of different types of equipment and materials required for snow plowing operations. The main topics covered were safe loading and unloading procedures; salt dome loading procedures; storing plows on block; compositions of brine, sand/salt mix, liquid magnesium chloride, liquid calcium chloride, and IBG magic; application rate and purpose of application of each of these materials during specific weather conditions.
- *Cold Exposure Hazard:* This theme covered the severe cold exposure hazards and discussed driving emergency preparedness during plowing. It covered the health damages involved and preventive measures that can be taken to protect themselves for healthy well-being.

In addition to the previously mentioned topics, some districts or subdistricts include information on specific equipment. For example, the LaPorte District had a separate training presentation to educate drivers plowing using tow plows. This presentation covered maintenance inspection and operation of tow plows. Also, the drivers were shown different parts and components of tow plows using images to further their familiarity with the top plow.

4.2 Visuals from Current Snow Operations (February 2022)

Between February 2nd and 4th, 2022, a winter storm passed by the state of Indiana (National Weather Service, 2022), requiring a high level of coordination of

TABLE 4.1
Summary of INDOT district snow school formats

District	No. of Drivers Trained	Hours of Training	Average Cost/ Employee/Hour	# of Locations
Crawfordsville	291	7.5 hours of classroom. Drivers with 3 years or less experience will have 22.5 hours of hands-on training. Drivers with 4 or more years of experience will have 7.5 hours of hands-on.	22.97	Classroom conducted at 5 subdistrict locations. Hands-on conducted at 17-unit locations
Fort Wayne	295	7.5 hours classroom. New drivers will have an additional 18 hours in-truck/on ground.	22.97	Classroom at 4 subdistricts. Hands-on at the 14-unit locations.
Greenfield	350	7.5 hours of classroom. 15 hours hands-on.	22.97	Classroom conducted at 5 subdistrict locations. Hands-on conducted at 25-unit locations.
LaPorte	~325	7.5 hours classroom. 7.5 to 15 or more hours of hands-on practice, depending on experience and driver comfortability. 7.5 to 12 hours of ride-along/route training with a trainer.	22.97	17 units. Due to COVID-19, most locations trained individually. Prior the classroom was held at 5 subdistricts, then hands-on was broken down by the 17 units.
Seymour	335	7.5 hours of classroom. 15 hours hands-on.	22.97	Classroom conducted at 5 subdistricts. Hands-on training held at 16-unit locations.
Vincennes	266	7.5 hours classroom. 7.5 to 15 or more hours of hands-on practice including, truck and loader training, route familiarization, and local operating practices and procedures. 7.5 to 15 hours of ride-along/route training with a trainer.	22.97	Classroom conducted at subdistrict locations. Hands-on conducted at 16 locations.

INDOT winter operations to maintain the state's roads open to the public. This section includes visuals taken from dashboard cameras installed on INDOT snowplows for monitoring purposes. These dashboard cameras are installed on all INDOT snowplows and capture still images every minute. These images are uploaded in near real-time at the INDOT Trafficwise website for monitoring purposes. The visuals illustrate the following four main conditions that affect snowplowing: (1) road surface conditions, (2) weather conditions, (3) lighting conditions, and (4) road type (mainly interstates and highways). All photos included in this section were made publicly available on the INDOT Trafficwise website, maintained by the State of Indiana between February 2nd and February 4th, and were retrieved from that website by the researchers, unless noted otherwise.

4.2.1 Road Surface Conditions

During winters, snowplows offer significant danger for others driving on the road that is being plowed (Yonas & Zimmerman, 2006). Furthermore, weather precipitation results in a reduction of pavement friction, which in turn increases the frequency of collision (Abohassan et al., 2021). Different road surface conditions can be seen during the winter season. Figure 4.1 (left) shows a road surface under normal conditions, which is free from snow, ice, or water. On the other hand, Figure 4.1 (right) shows a road surface covered with compacted ice. Despite no visuals captured, it is worth noting that the formation of black ice on the road surface is considered to be very dangerous for drivers (Abohassan et al., 2021).

With increased snowfall and changing temperature, the road surface can accumulate slush (Figure 4.2, left) and snow (Figure 4.2, right). These types of wet as well as snow and ice-covered road surfaces are very slippery and tend to reduce the traction and hamper the braking performance of the vehicles (Gouda & El-Basyouny, 2020).

Besides the risk of vehicle sliding, the visibility of road markings is also compromised due to the surface conditions indicated here. For example, in Figure 4.1

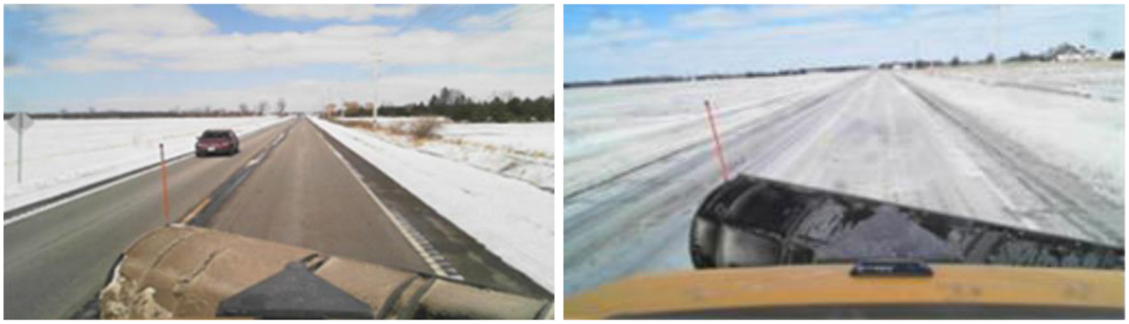


Figure 4.1 US-35 with clear road surface (left) and IN-101 with ice coverage (right).

Figure 4.2 IN-205 with slush (left) and US-6 with snow coverage (right).

(left), lane markings are clearly visible on road, which helps the driver to maintain the lane and driver safety. However, in Figure 4.1 (right) and Figure 4.2, lane markings have been covered in snow, ice, or slush. The visual obstruction makes it difficult for drivers to maintain their lane and know where the location of the edge of pavement is, which can lead to trucks sliding into side ditches.

4.2.2 Weather Conditions

The weather variable includes the combination of precipitation types and intensity, wind speed, and visibility, which may create hazardous driving conditions during snowstorms (Abohassan et al., 2021). These conditions contrast what a snowplow driver sees on a normal clear sky day (Figure 4.3).

In fact, visibility can be drastically reduced during a snowstorm. Figure 4.4 shows that visibility was significantly reduced when compared to the normal clear day, to near white-out conditions. The blowing snow drastically reduced the visual contrast, which can affect how drivers detect motion on the roads (Yonas & Zimmerman, 2006). Moreover, during snowstorm events, a snowplow driver may have to perform various concurrent tasks, and one of them is staying on the road, which is sometimes a difficult task during white-out conditions (Steinfield et al., 1999).

Elhouar et al. (2015) also warn about training snowplow drivers for blowing snow and freezing rain scenarios, including an understanding of the correct road treatment for each of these situations. Furthermore, blowing snow needs to be taken into consideration by drivers while plowing, so that efforts in snowplowing are maximized.

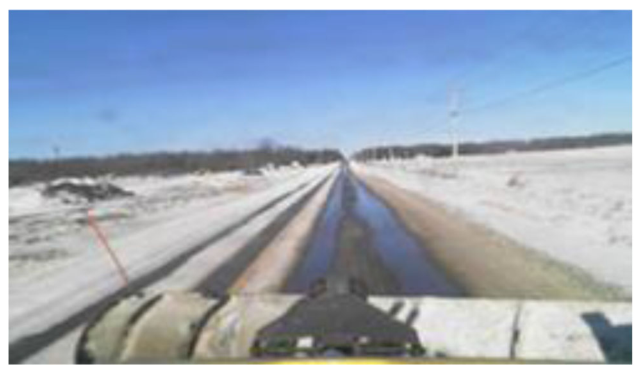


Figure 4.3 IN-10 on a clear sky day.

4.2.3 Lighting Conditions

Lighting conditions are known to affect snowplowing. The differences are even more accentuated between day and night plowing conditions. On a clear day, such as the one portrayed in Figure 4.5 (left), traffic and other elements surrounding the road can be seen. Figure 4.5 (right), on the other hand, shows a day situation with reduced light conditions. Still, in both visuals, traffic is observed. Reduced visibility can be caused by various reasons, such as "white outs, malfunctioning or iced headlamps, or a soiled windshield" (Steinfield & Tan, 1999, p. 2).

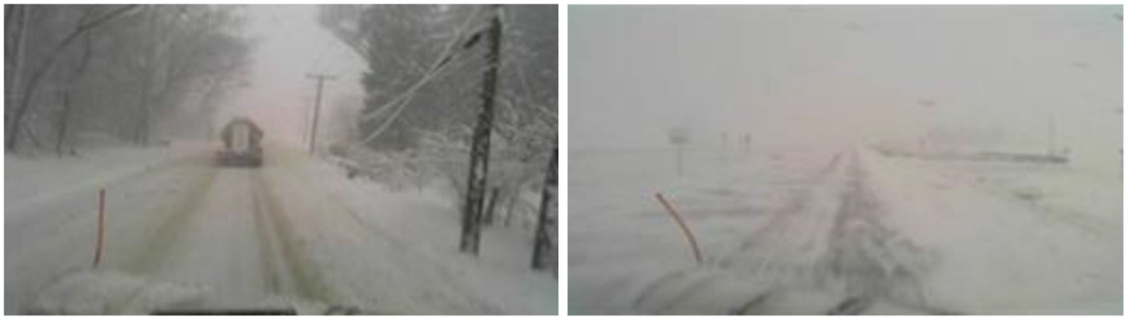


Figure 4.4 IN-101 during a snowstorm (left) and US-35 with near whiteout conditions (right).

Figure 4.5 US-231 in clear sky, daylight conditions (left), and US-20 during the day with reduced lighting conditions (right).

Figure 4.6 IN-32 on a clear night (left) and US-A4 during a night with blowing snow (right).

Though plowing at night usually has less traffic considerations, nightshifts should take into consideration the driver's level of alertness, as well as decreased visibility (Elhouar et al., 2015). This is because visibility at nighttime is already reduced, even when skies are clear (Figure 4.6, left). Blowing snow at night drastically reduces the visibility of drivers (Figure 4.6, right). The blowing snow and fog can mislead drivers about vehicle speed, distance, and the location of road limits. Moreover, the lower temperature at night may increase the formation of ice on roads (Elhouar et al., 2015).

4.2.4 Roadway Type

Previous research shows that traffic volume during snow events significantly increases crash frequency (Khattak & Knapp, 2001). Different types of roads also may dictate the speed of driving, with interstates allowing for a higher speed than secondary roads (Elhouar et al., 2015). Moreover, interstate highways in multilane configurations may require two plow trucks plowing together to cover lanes (Figure 4.7, left), and traffic can be higher (Figure 4.7, right) than on secondary roads and one-lane roads. Keeping the state's main transportation arteries is key during snow removal operations.

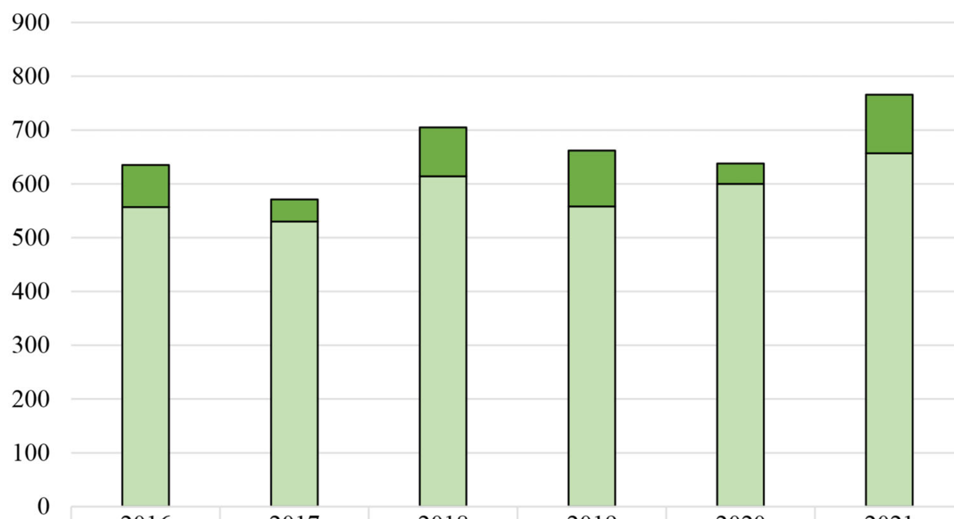
One-lane roads pose different challenges to snowplow drivers. For example, Figure 4.8 (left) shows light poles very close to the road. Plowing close to these elements needs to be carefully undertaken. Also, on one-lane roads, traffic can be passing or incoming from the other lane (Figure 4.8, right). Thus, while plowing such roads, drivers must consider many things, such as intersections, traffic coming from both directions, mailboxes, pedestrians, and animals, among others.

4.3 Identification of Frequent Snowplow-Related Accident Conditions

Data gathered by INDOT also helps to understand risky solutions during snowplow operations and can

Figure 4.7 I-65 tandem plowing—photo by authors (left) and IN-14 at night with traffic (right).

Figure 4.8 I-205 with poles close to the road (left) and US-20 with incoming traffic (right).



	2016	2017	2018	2019	2020	2021
Snowplow Related	78	41	91	104	38	109
Other Accidents	557	530	614	558	600	657

Figure 4.9 Snowplow operations-related accidents between 2016 and 2021.

help in the selection of scenarios for snowplow driver training. For the past 5 years (2016–2021), INDOT has had a total of 3,516 safety occurrences, of which 461 were related to snowplowing operations (13.11%). A breakdown of incidents per year can be found in Figure 4.9. The number of cases in Figure 4.9 includes accidents, incidents, and near misses, caused by INDOT employees as well as the general public. Though the data may provide helpful insight into risky situations, it is limited to what is included in INDOT reports.

Of the snowplow-operations-related occurrences, the overwhelming majority were crash only (n = 387), followed by a few incidents (n = 35) and crashes with injury (n = 29). A few occurrences (n = 10) were unassigned, near misses and injury or illness only. Furthermore, 92% of the occurrences (n = 423) were classified as having no applicable severity. According to INDOT, these occurrences were not subject to injury costs. Of the remaining, nineteen were serious accidents, followed by non-serious (n = 13), incidents (n = 4), and unassigned (n = 2).

As expected, districts that have a higher population were the ones with the most occurrences (LaPorte: n = 156; Greenfield: n = 123), and the districts further south had fewer (Vincennes: n = 20; Seymour: n = 29).

The remaining two districts had a similar number of occurrences (Fort Wayne: n = 68; Crawfordsville: n = 63). Two occurrences were related to the INDOT central office, which could be related to the use of transfer drivers.

When risky situations were reviewed, the general findings reveal that in many cases (n = 147), occurrences happened because the snowplow was struck by another vehicle, usually a personally owned vehicle (n = 125). Several occurrences included traffic situations (n = 108). Interestingly, wing plows were related to 16 cases.

Furthermore, weather conditions were indicated in 107 cases, with icy road conditions accounting for almost half of those (n = 57). Poor visibility was found mentioned in 22 cases, followed by accounts of blowing snow (n = 9), heavy snow (n = 9), and snowy roads (n = 9). Other weather conditions mentioned included drifts (n = 8), white out (n = 7), slush (n = 6), and freezing rain (n = 5).

Two hundred and nine cases mentioned damages. The most frequently mentioned were vehicle (n = 89), followed by guardrail (n = 30), salt dome (n = 18), overhead door (n = 17), poles (n = 12), and curbs (n = 10). Salt dome and overhead door accidents usually are linked to snowplow trucks with raised beds. Ten cases mentioned obstacles on the road, with four of them related to bridge joints, followed by animals on the road (n = 2), and raised manholes (n = 2). Only one case mentioned pedestrians on the road.

INDOT information also described the broad location of the accident and the driving action taking place when the accident happened (Table 4.2). The main broad location for cases included roadway shoulder, followed by intersections and INDOT unit. Occurrences that happened inside INDOT units were mainly related to raised bed issues. For driving action, most occurrences were related to either the sliding of one or more vehicles or loss of control, which are both related issues. This includes sliding and loss of control of any vehicle involved in that case. Speeding and cases that clearly involve traffic (such as rear-ending, passing, and following too close) were also frequently mentioned.

Moreover, the information provided suggested very little difference between driver type and case conditions, with a few exceptions that should be monitored by INDOT to verify trend and establish specific training needs.

4.4 Interview with INDOT Snow Operations Workers

The section summarizes details of the interviews conducted with INDOT workers, including safety managers, crew leaders, and snowplow drivers. The goal of this phase was to identify risky situations INDOT snowplow drivers usually encounter, as well as gather high-level perceptions of drivers and supervisors about the use of driving simulators for snowplow driver training. For this phase, researchers aimed to interview one to two supervisors for each of the six INDOT districts and three to five snowplow drivers in each of the following categories.

- *Experienced:* Defined as those with 3 or more years of regular snowplowing experience
- *Novice:* Defined as those with less than 3 years of snowplow driving experience
- *Transfer Drivers:* Defined as those with 3 or more years of occasional snowplowing experience.

4.4.1 Winter Operation Supervisors

Winter operation supervisors for the purposes of this research are crew leaders and safety managers at INDOT districts. Upon finalization of the interview, 8 supervisors were interviewed—two from Greenfield District, two from LaPorte, two from Crawfordsville, one from Seymour, and one from Fort Wayne (Figure 4.10). Unfortunately, the research team was unable to interview a supervisor from the Vincennes District but given that a participant from Seymour was interviewed and similar conditions can be found in both districts, the researchers decided to move forward with other phases without Vincennes District supervisor input. Additionally, all the supervisors that were interviewed were also very experienced snowplow drivers, with an average plowing experience of 17.5 years.

TABLE 4.2
The most frequent risky situation locations and driving actions from 2016 to 2021

Risky Situation Location (n = 218)	Frequency	Risky Situation Driving Action (n = 327)	Frequency
Shoulder	53	Sliding vehicle	85
Intersection	47	Loss of control	55
INDOT Unit	35	Speeding	55
Ditch	35	Rear-ending	42
Edge of Pavement	15	Passing	38
Gas Station	9	Backing	34
Turning Lane	8	Following too close	33
Parking Lot	7	Raised bed	31
Merging Lane	7	Maneuvering	22

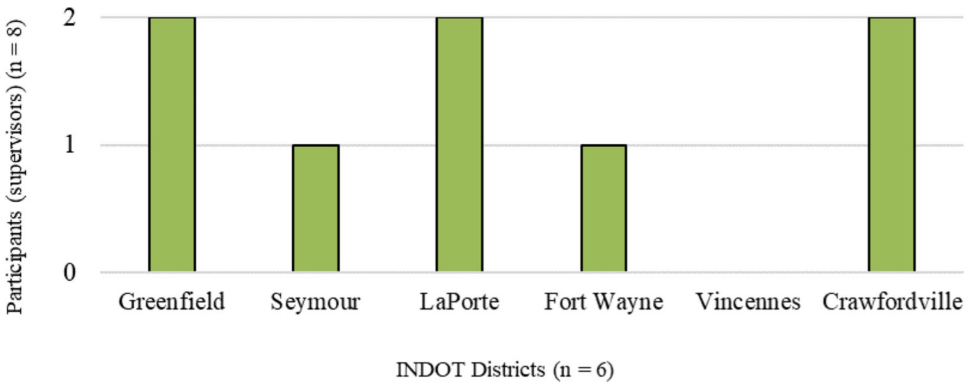


Figure 4.10 Interview participants (supervisors).

Next, we summarized the general course structure of the snow school, participants' perceptions regarding the snow school, risky situations, training using snowplow simulators, as well as things that could be done in training to replicate driving conditions more accurately.

Based on the eight responses for INDOT supervisors, the snow schools across the five districts share a similar course structure. For example, Greenfield, Seymour, and LaPorte mentioned similar topics covered and had similar formats. When asked for perceptions regarding the snow school, they mentioned that the snow school is very good for beginners and gives them a good understanding of snowplowing for INDOT. One interviewee from Crawfordsville mentioned that the snow school also served as a good refresher for experienced drivers. When asked for key components in the snow school training, responses from interviewees revealed that snow school training generally consists of the following four topics: safety, plowing techniques, hands-on practices, and general introduction to the snowplow truck equipment (Table 4.3). From the table, the general introduction of the snowplow truck equipment was the most frequently mentioned topic, this topic includes the introduction to the liquid system for anti-icing liquid application, Muncie system for controlling conveyor and the salt, installation of plows and blades, as well as the walk-around inspection of the truck. Plowing techniques was the second most frequently mentioned topic, which covers blade control, timing of salt deposition, and the appropriate plow speed. Safety and hands-on practices were also mentioned in the survey responses, in which the safety includes the understanding of different weather, safety features of snowplow trucks, as well as the appropriate way to climb in and out of the truck, etc.

INDOT winter training also includes a practical, hands-on experience. This it is usually set up after the in-classroom presentation and short videos covering the topics mentioned in Section 4.1.1. During the hands-on session, drivers get familiar with the equipment, such as hooking and unhooking of plow blades, material loading, and pre- and post-trip procedures. Additionally, during the training period, the day or following days after the in-person training (lecture and hands-on portion), novice drivers usually go out on routes along with an experienced driver to learn their assigned routes.

Some differences in training of snowplow drivers were noted during interviews. For example, in Greenfield, drivers with 3 years or more of plowing experience do not receive a classroom portion of snow school; and in Seymour, drivers with more than 5 years of plowing experience do not receive the road training. Furthermore, supervisors such as ones from Greenfield and Crawfordsville Districts mentioned their districts conduct an outdoor course around the unit which helps drivers to maneuver plows between cones, backing up, and several different scenarios.

In addition to describing the current format and curriculum, two suggestions were made to improve it—one suggestion was to update some of the videos used during training with more up-to-date scenarios; and a second suggestion to include more information fuel efficiency.

When asked about using driving simulators to train snowplow drivers, six participants expressed a positive attitude (Table 4.4), of which two pointed out that simulators could be a great tool for new drivers to get more training opportunities before the winter season. Furthermore, they mentioned being especially beneficial to simulate risky situations that cannot be done during regular training, and to expose novice snowplow drivers to a wide range of scenarios. On the other hand, two interviewees expressed their concerns about the effectiveness of the adoption of simulators, citing "no simulator is going to give you that feel of the truck" and "most people don't realize how hard plowing is."

The participants in this group emphasized that several of the accidents were due to reckless public driving. In fact, one participant perceived that 90% of the accident in their district were caused by the public. Examples given by the participants included over speeding, complex driving conditions, and passing dangerously close to the plow truck. Sliding due to black ice or icy roads was also mentioned by participants, and this is a cause of concern for the public and snowplow drivers, especially if drivers are over speeding or break their vehicles abruptly, which may cause their

TABLE 4.3
Table of key components in snowplow training

Type	LaPorte (n = 2)	Greenfield (n = 2)	Crawfordsville (n = 2)	Fort Wayne (n = 1)	Seymour (n = 1)	Total (n = 8)
General Introduction of the Truck Equipment	2	2	2	0	1	7
Plowing Techniques	1	1	1	1	1	5
Hands-On Practices	2	0	1	0	1	4
Safety	1	1	0	0	1	3

TABLE 4.4
Perceptions regarding the use of a snowplow driving simulator

Type	LaPorte (n = 2)	Greenfield (n = 2)	Crawfordsville (n = 2)	Fort Wayne (n = 1)	Seymour (n = 1)	Total (n = 8)
Helpful and Beneficial to Training	1	2	1	1	1	6
Doubtful Regarding Effectiveness	1	0	1	0	0	2

TABLE 4.5
Frequency of risky situations mentioned by supervisors (n = 8)

Type	LaPorte (n = 2)	Greenfield (n = 2)	Crawfordsville (n = 2)	Fort Wayne (n = 1)	Seymour (n = 1)	Total (n = 8)
Public Driving–Over Speeding	1	2	0	1	1	5
Complex Driving Conditions	1	2	0	0	0	3
Sliding of Vehicles	0	2	0	0	1	3
Public Driving–Bypass	1	0	0	0	1	2
Hitting Small Objects (Mailboxes, Road Signs, Manholes…)	0	2	0	0	0	2
Ice Storm	0	0	1	0	0	1
Hitting Large Objects	0	0	0	0	1	1

vehicles to slide and lose control. Complex driving conditions for snowplow drivers were also mentioned as a concern by three participants, which refer to circumstances when multiple actions are required for drivers to execute concurrently. For example, when plowing on hill roads, drivers must be watching for both narrow lanes and incoming traffic, while operating the blade and depositing the salt. In addition, hitting large and small objects were also frequently mentioned by interviewees. One suggestion made by an interviewee was that drivers should watch for their speed because "pushing snow into the mailbox is going too fast." Table 4.5 presents a summary of risky situations, and the frequency supervisors mentioned them.

Participants were also asked for things that could be done to replicate the driving conditions more accurately during training. Half of the interviewees expressed their concerns that it would be hard to replicate, citing "You can't replicate it. I mean, unless you have like what you got every kind of looking into some sort of, you know, simulator. It's like asking a race car driver to get around the track that he or she has never been to before." On the other hand, three interviewees pointed out that the use of driving simulators could help drivers by providing more training opportunities and scenarios. Some additional suggestions were also provided by the interviewees, which include practicing at different times of the day and to practice under actual snowy conditions. Table 4.6 presents a summary of suggestions made by participants on how to accurately replicate snowplow driving conditions during training.

4.4.2 Snowplow Drivers

As mentioned previously, participants for this set of interviews were categorized into three groups based on their experience and their main duties to INDOT. Novice drivers had less than 3 years of snowplow driving experience, experienced drivers were those that regularly engage in snowplow driving and have 3 or more years of experience, and transfer drivers were those who occasionally do snowplow driving assignments and have 3 or more years of plowing experience. Upon the finalization of the interview phase, ten interviews were conducted—four with transfer drivers,

TABLE 4.6
Suggestions to improve training accuracy for snowplow driving conditions

Type	LaPorte (n = 2)	Greenfield (n = 2)	Crawfordsville (n = 2)	Fort Wayne (n = 1)	Seymour (n = 1)	Total (n = 8)
Practice Under Icy and Snowy Roads	1	0	0	0	0	1
Practice at Different Times of the Day	0	1	0	0	0	1
Hard to Replicate	1	0	2	0	1	4
Driving Simulator	1	1	1	0	0	3

TABLE 4.7
Perception of the snow school training

Type	Experienced (n = 4)	Novice (n = 2)	Transfer (n = 4)	Total (n = 10)
Training is Appropriate but Has Limited Effectiveness	2	1	4	7
Good Amount of Information on Snowplow Topics	1	2	1	4

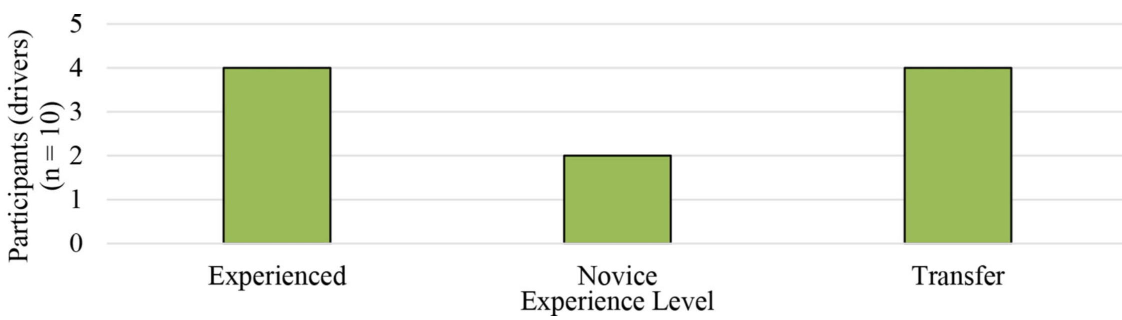


Figure 4.11 Experience level of interview participants (drivers).

four with experienced drivers, and two with novice drivers, as shown in Figure 4.11.

All experienced drivers interviewed were over 40 years and they had an average snowplowing experience of 6.33 years. Interviewed transfer drivers' ages ranged between 25–49 years and they had an average snowplowing experience of 8.25 years. Finally, novice drivers interviewed were aged between 25–59 years and had an average plowing experience of 1.5 years. All drivers interviewed mentioned plowing interstates, and one transfer driver also mentioned having experience plowing highways.

Most of the participants felt that the current snow school training covers most of the aspects of snowplowing operation and is a useful tool for drivers. They felt it gives them a good overview of what to expect for the coming season during winter weather conditions. Moreover, most of the drivers, including the novice drivers, mentioned it is hard to compare the snow school with actual plowing operation. One experienced driver also pointed out that "There's no comparison because until you get out there and do it yourself and have hands on, you really don't know what's going to happen. Hands on is the best way to do it." Therefore, the effectiveness of the training is limited, given that the snow school occurs prior to the snow season, usually during early fall months. On the other hand, drivers mentioned that the snow school could add more training on salt spreading techniques for different speeds and conditions, and preparedness for unexpected events. Table 4.7 summarizes drivers' perceptions toward the snow school training.

When asked about their typical snowplowing days, seven participants mentioned starting off with a pre-trip inspection and walk-around of the truck. In addition, five drivers indicated that they would typically load up the trucks with salt after inspection. One driver mentioned that sometimes he needs to calibrate the equipment as most of them are not calibrated. One driver mentioned also speaking with the driver of the previous shift to have an overview of the current driving situation for that day. After the inspections, drivers mentioned loading their trucks with materials such as salt, and then attaching a plow, if that is not already attached to the truck. Drivers then go on to their assigned routes and duties until the end of their shift.

After the end of their trip, they conduct a post-trip inspection, fill out the required forms for material use and clean the vehicles.

To improve their snowplowing techniques, all drivers mentioned seeking advice from their colleagues and veteran drivers, in addition to hands-on experience, as the most useful resource to improve their skills. Experienced drivers also mentioned asking questions as advice for novice drivers. Other advice from interviewees for novice drivers included being aware of their surroundings and staying within the safe speed limit to have better control over the plow truck. Table 4.8 presents drivers' resources used to improve plowing techniques.

When asked about using a driving simulator in training, only two of the ten interviewees mentioned having previous experience in using driving simulators. Feedback from the drivers that have used a simulator was positive—one driver mentioned it felt realistic, especially due to the haptic response, while the other described the experience as enjoyable. Eight of the ten interviewees expressed their excitement and interest to train their skills using snowplow driving simulators, citing the following.

> I think if it is done right, it could be a great tool, because like I said, there's not a lot of like actual training other than getting out there and experiencing it. I guess what I'm trying to say is right now, the best training is experience. However, if we could create a way to do that type of training, I think it would be a huge bonus to everyone or to new employees.

Participants were also interested in the possibility of training a wider range of scenarios, covering different lighting, weather, and road surface scenarios. On the other hand, one of the drivers who was unsure to train using a driving simulator suggested that the equipment may not be realistic enough, and learning won't happen until drivers are exposed to real snow and actual driving conditions. The other driver indicated that using driving simulator would be challenging for him. Table 4.9 presents drivers' impressions of using driving simulators.

When discussing risky situations, sliding of vehicles, hitting small objects, and over speeding are among the top three factors mentioned by the drivers. An interesting thing to note is that transfer drivers account for most of the responses regarding risky situations. One possible reason could be transfer drivers tend to pay more attention to the road conditions, because snowplowing is not their main assignment at INDOT. Drivers also indicated that risky situations could differ based on the type of road plowed. Traffic was the main issue mentioned when plowing interstates and highways, though drivers who plow at night mentioned this was not as much of a concern to them, due to decreased flow of vehicles compared to daytime. Over speeding and passing of public vehicles from blind spots, as well as unexpected movements of vehicles were felt to be particularly concerning. Some drivers also mentioned plowing curves is particularly risky as they cannot see the pavement and it becomes difficult to stay on the road. Furthermore, examples of other concerns included some common and other not-so-common situations such as plowing within construction zones and being careful not to hit temporary concrete barriers, sudden temperature changes leading to faster freezing, black ice on bridge decks, and the risk of sliding and rollover when plowing hilly areas. For a full list of mentioned risky situations, see Table 4.10.

When it comes to road conditions that could affect plowing, responses from the interviews revealed that the traffic condition is the top reason, with eight interviewees expressing their concerns about it. This result aligned with the results from the interviews with supervisors. However, one transfer driver indicated that heavy traffic could be potentially beneficial for snowplowing activity, citing "Traffic conditions can be a hindrance, but traffic can also be a great positive, For instance, before rush hour, we always try to a round of salt down onto our roadway because when rush hour starts, there is a huge advantage to us because the

TABLE 4.8
Resources used to improve plowing techniques

Type	Experienced (n = 4)	Novice (n = 2)	Transfer (n = 4)	Total (n = 10)
Self-practice and personal experience	1	0	1	2
From colleagues, veteran drivers	4	2	4	10

TABLE 4.9
Impressions of driving simulators

Type	Experienced (n = 4)	Novice (n = 2)	Transfer (n = 4)	Total (n = 10)
Interested in Simulator Adoption	2	1	1	4
Beneficial and Helpful for Training	1	0	3	4
Neutral or Unclear	1	1	0	2

TABLE 4.10
Frequency of risky situations mentioned by drivers (n = 10)

Type	Experienced (n = 4)	Novice (n = 2)	Transfer (n = 4)	Total (n = 10)
Sliding Vehicles/Rollover	0	1	4	5
Hitting Small Objects (Mailboxes, Road Signs, Manholes…)	1	1	3	5
Public Driving–Over Speeding	1	0	3	4
Hitting Large Objects/People on Road (Pedestrians, Stranded Cars, Etc.,)	1	0	3	4
Complex Driving Conditions	1	1	1	3
Plow During Whiteouts	1	0	2	3
Others (Construction Zone, Railroad Tracks, Etc.,)	1	0	2	3
Public Driving–Bypass	2	0	0	2
Public Driving–Unindicated Turns	0	0	1	1
Backing	0	0	1	1
Hitting Guardrails	1	0	0	1

TABLE 4.11
Road conditions affecting plowing

Type	Experienced (n = 4)	Novice (n = 2)	Transfer (n = 4)	Total (n = 10)
Wet Road	0	0	2	2
Hilly, Curly, and Narrow Roads	1	0	1	2
High Traffic	2	2	4	8
Excessive Deposition of Slat	1	0	0	1
Build-Up Snowpacks	0	0	2	2

TABLE 4.12
Weather conditions affecting plowing

Type	Experienced (n = 4)	Novice (n = 2)	Transfer (n = 4)	Total (n = 10)
Precipitation	0	0	3	3
Low Temperature	1	0	1	2
Icy and Heavy Snow	2	1	1	4

traffic will get out and they will be down that fall, helping to work the salt into the pavement and break up any arms." Other road conditions include slippery road surfaces, hilly and curly roads, build-up snowpacks, etc. Participants also responded to weather conditions that could affect plowing, in which the icy and heavy snow is the top concern, followed by precipitations and low temperatures. See Table 4.11 and Table 4.12, respectively, for road and weather conditions that could affect plowing.

Our results from the INDOT supervisors' and drivers' interviews seem to be consistent with Elhouar et al. (2015) about the complex nature of the snowplow driving activity. For example, interviewees in the present study mentioned that changes in weather lead to a change in their strategy to plow snow. Temperature and precipitation such as freezing rain or blowing snow, road conditions such as the formation of slush or pack ice, and traffic flow are all factors to be considered by drivers when choosing treatment techniques.

Moreover, Camden et al. (2020) further supports our interview results and accident data received from INDOT. In their report results, Camden et al. (2020) focused on mitigating snowplow operators' risk of crash by developing safe and defensive driving strategies into training modules after examining the key causes of collisions involving snowplows. Notable risky situations identified were fixed-object strikes, run-off road crashes, backing crashes, wing plow strikes, and crashes where another vehicle rear-ended the snowplow. For these crash types and others, training modules were grouped into sections, namely, general defensive driving practices, improving conspicuity, safe operating characteristics, hazard identification, proper backing, limiting distractions, and fatigue management (Camden et al., 2020).

5. STATE DOTs SURVEY

In order to capture the current state of practice of American state DOTs, the researchers developed a survey. The goal of the survey was to obtain information about current typical training practices for snowplow drivers in all state DOTs with winter operations, as well as capture information about states that are currently using or have used driving simulators in those training efforts. The survey was developed based on previous literature, review of current INDOT training materials and snow operations data, initial findings from the interviews of INDOT workers which were outlined in the previous sections and was piloted with stakeholders involved in the training, research or managing winter operations for state DOTs.

The draft survey piloted tested included six blocks. Four blocks to be answered by all respondents about general information, current winter operations in their state DOTs, current snowplow driver training, and snowplow simulator use and perceptions. These four blocks were followed by a block focused only on state DOTs with current or past use of driving simulators for snowplow driver training. Finally, a concluding block with an open-ended question for further comments was included for all participants.

5.1 Pilot Interviews' Findings

The draft survey was tested with four relevant stakeholders, namely one researcher with experience in driving simulators, one driving simulator trainer, and two states' DOTs personnel with experience in winter training and operations. All four interviewees from this phase provided positive responses on the use of snowplow driving simulators in the training process. Particularly, one interviewee from the DOT and one interviewee with a simulator training background expressed highly positive feedback for the snowplow driving simulator for its effectiveness in terms of improving crew safety awareness, reducing costs, improving fuel efficiency, as well as reducing wear and tear for the equipment. Moreover, the researcher with experience in driving simulators discussed the benefits of maps and route customizability, suggesting that such features can be very useful when it comes to developing tailored training materials based on different DOTs' needs. Utilizing Table 3.1 factors identified during the literature review, Table 5.1 presents the list of factors mentioned during pilot interviews. These factors included simulator features that would potentially help for training, in which cost of simulator and training, variety of software features, and ease of operations are among the top three factors.

For suggestions and concerns, one interviewee from a state DOT suggested that one cannot solely rely on the driving simulator for training. Therefore, it is important to combine different training modes such as behind-the-wheel experience to get the most effective training results. In addition, it is worth noting that two interviewees expressed changes in perception, from doubtful to positive, toward snowplow driving simulators before and after their adoption. For example, one interviewee thought that the snowplow driving simulator was just a "glorified video game" at the beginning. However, after using the snowplow driving simulator for a period, the interviewee thought that the snowplow driving simulator could be a very useful tool in the training process. Also, interviewees were asked to provide long-term and short-term metrics to track operation improvement, in which some of them were associated with training costs, equipment damage, and collisions. Table 5.2 presents a full list of long-term and short-term metrics identified by pilot interview participants.

TABLE 5.1
Factors mentioned by pilot interview participants about snowplow driving simulator training and research

Name of Factors	Mentioned Frequency (n = 4)
Cost of Simulator and Training	4
Variety of Software Features (Customizability)	3
Ease of Operations	3
Graphics Fidelity	2
Haptic Feedback	2
More Training Opportunities	2
Potential Fuel Savings	2
Motion-Based Platform	1
Broad View of Vision	1
Improve Crew's Safety Awareness	1

TABLE 5.2
Long-term and short-term metrics to track cost-benefit mentioned by pilot interview participants

Type of Metrics	Name of Metrics	Mentioned Frequency (n = 4)
Short Term	Training costs	2
	Simulator costs	1
Long Term	Equipment damages	2
	Collisions	2
	Employee injury costs	1
	Fuel savings	1
	Property damages	1

At the end of the interview section, interviewees were asked to review and provide suggestions on the state DOT survey, in which they indicated that most questions and options were able to collect required information on the use and perception of snowplow driving simulators in different states. The following is a list of received suggestions and comments.

- Changed a question about the coverage area of snowplow operations to one based on the mileage of roads being plowed.

- Added more options regarding types of risky scenarios involving snowplow drivers in terms of frequency in your state.
- Added more options regarding the types of snowplow operations (organizational aspect) to cover different situations as much as possible.
- Added more options regarding different training modes that snowplow drivers receive per year.
- Added more options regarding factors for DOT to consider the use of snowplow driving simulators for driver training.
- Added a question regarding factors for DOT *not* to consider the use of snowplow driving simulators for driver training.
- Added more options regarding potentially effective driving scenarios for snowplow driving simulators.
- Simplified the survey logic and workflow.

Based on the comments of the interviewees and on the review of the researchers, the survey instrument was revised. The final version sent to state DOTs can be found in Appendix B.

5.2 State DOTs' Survey Results

During the data collection phase, 48 states with routine or occasional snowplow operations were contacted, in which 20 of them started the survey. Of those 20, 15 were members of Clear Roads. However, we note that not all respondents answered all the questions. It is also worth noting that among the twenty participants, ten of them indicated that they are knowledgeable about driving simulators. On the other hand, five participants indicated that they are not knowledgeable regarding driving simulators at all. The remaining five participants did not provide their opinions regarding this question.

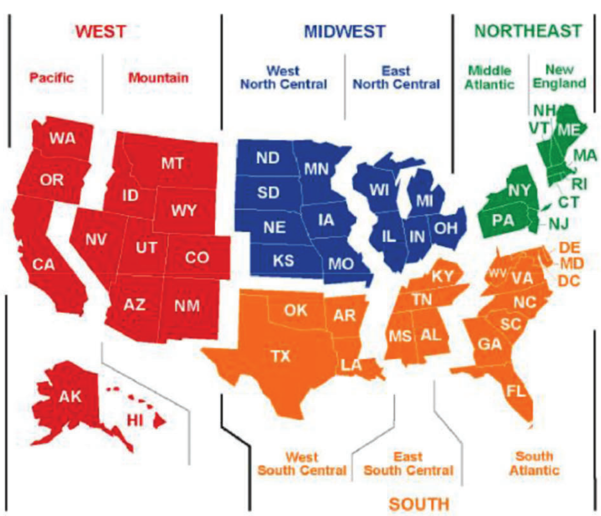
Figure 5.1 summarizes the survey respondents' regions according to the US census region (see Figure 5.1). We note that no participants from the Pacific or the West South regions participated, while all other regions had at least one participant. The West North Central, Mountain, and South Atlantic regions had the most participants (n = 4). However, we acknowledge that not all participants that have started the survey provided answers for all the questions.

5.2.1 Winter Operations Size Information

Following, participants were asked about the size of their winter operations, defined as snow and ice removal activities. Based on the answers of 17 respondents, state DOTs participating in the survey plow an average of 28,699 miles of roads, with a minimum of 7,700 and a maximum of 96,185.5 miles.

Next, respondents provided the estimated size of their respective state DOT winter operations fleet. The answers indicate a wide range of sizes of winter operations fleet. For example, for the number of snowplow truck owned by the state DOTs, numbers ranged from a low of 24 snowplow trucks to a maximum number of 3,750 snowplow trucks. For the number of full-time snowplow drivers employed, respondents ranged from a low of 0 full-time snowplow drivers to a high of 4,700 full-time snowplow drivers. It is noted that one significant outlier was observed and removed during data screening process for this specific question. For transfer drivers, the numbers ranged from a low of 22 transfer drivers and a maximum number of was 3,500 transfer drivers. Table 5.3 presents of the summary of estimated size of state DOT winter operation fleet.

Seventeen respondents answered the question about risky situations for snowplow drivers in their state. Results indicate that most respondents perceive the harsh weather conditions to be the top risky situation in snowplow operations (n = 6), which was then followed by sliding due to icy road conditions (n = 4), passing traffic (n = 4), the rear-ended collisions (n = 4), and low visibility on the surrounding environment (n = 2). Such rankings align with parts of the results from previous interviews with INDOT workers and DOT representatives, in which sliding of vehicles and over



US Census Region	Total (n=20)
West North Central	4
South Atlantic	4
Mountain	4
New England	3
East South Central	2
East North Central	2
Middle Atlantic	1
West South Central	0
Pacific	0

Figure 5.1 Survey respondents by US census regions (US census figure source: US Energy Information Administration).

TABLE 5.3
Estimated size of state DOT winter operations fleet

Category	N	Mean	Standard Deviation	Minimum	Maximum
Snowplow Trucks	16	996	968	24	3,750
Full-Time Drivers	15	956	1,250	0	4,700
Transfer Drivers	14	813	1,065	22	3,500

speeding are among the top reasons. Based on the findings from the interviews and the DOT survey, it is suggested that scenarios such as icy road conditions, harsh weather, speeding of other vehicles should be reinforced during yearly training procedures.

5.2.2 Current Snowplow Driver Training

When it comes the standardization of training mode, three options were provided to the participants.

- *Very Standardized:* All districts or units follow the same training format and content
- *Somewhat Standardized:* All districts or units have a similar structure suggested by the central office, but adaptations in content and format may be done at the district or unit level
- *Not Standardized:* Each district or unit manages and deploys their own winter operations training, including format and content, without the involvement of the central office

Based on the results, a total of 16 participants provided inputs for this question with a majority of which indicated that the training mode in their state DOTs is very standardized (n = 8). Moreover, seven respondents (n = 7) expressed that their training mode is somewhat centralized; and one state indicated that their training mode is not standardized (n = 1). Table 5.4 presents the summary of findings in terms of standardization of training mode.

Fifteen respondents provided input on the numbers of training events (1 to 4 or more training events) their state DOTs provide for different categories of drivers. Based on the results and as expected, novice drivers received the greatest number of training events with an average of 3.2, while experienced drivers receive the least number of training events with an average of 2.15 training events. Table 5.5 provides the summary of training events snowplow drivers received per snow season.

For this question, participants were asked to provide input (in terms of hours) for different winter operations training delivery modes such as in-person lecturers, pre- and post-trip checks, route driving, driving simulator, and self-paced computer-based training for different categories of drivers. From the results, novice drivers received the most hours of training for all five delivery modes, while the experienced drivers received the least amount of training in all delivery modes. Table 5.6 provides summaries regarding hours of training by

TABLE 5.4
Standardization of training mode

Mode of Training	Mentioned Frequency (n = 16)
Very Standardized	8
Somewhat Standardized	7
Not Standardized	1

different delivery modes for novice drivers, experienced drivers, and transfer drivers, respectively.

Fourteen respondents provided information regarding risky situations covered in the current snowplow driver training of their respective state DOT, except for the risky situation "plowing near ditches and edges" that had 13 respondents. Respondents were provided with nine topics and asked to rate these topics based on amount of coverage from "not at all" to "a great deal." For our analysis of the results, the research team assigned a value of 1 to "not at all" and 5 for "a great deal," and provide descriptive statistics for the findings in Table 5.7. The results indicate that the training for backing, traffic, plowing near ditches and edges are among the top three most covered factors in state DOT training. Other relevant topics covered in their training are wing plow, multitasking, and speeding, etc. When asked for any additional factors to be included in this table, one participant suggested salting/sanding, and a different other one suggested that snowplow operators should be trained to deal with road rages from other drivers.

5.2.3 Status Regarding Use of Simulator in Snowplow Driver Training

When asked for status regarding use of simulator in snowplow driver training, 16 respondents provided their inputs. Based on the result, a majority of respondents (n = 10) indicated that they were either using the simulator or currently exploring this option. Furthermore, four respondents indicated that they previously explored or used the simulator in the past, and the remaining two respondents stated that they have never considered the simulator option. Table 5.8 presents the summary on the use of simulator in snowplow driver training by the total number of respondents and those from states that are Clear Roads members.

When asked for any additional information regarding the current status of adopting simulator in snowplow driver training, three states that are currently

TABLE 5.5
Number of training events snowplow drivers received

Types of Snowplow Drivers	N	Number of Training Events			
		Average	Standard Deviation	Minimum	Maximum
Novice Drivers	15	3.20	1.05	1	4
Experienced Drivers	15	2.15	1.03	1	4
Transfer Drivers	15	2.38	1.31	1	4

TABLE 5.6
Hours of training by different delivery modes and types of transfer drivers

Types of Delivery Modes	Hours Allocated					
	Novice		Transfer		Experienced	
	N	Average (SD)	N	Average (SD)	N	Average (SD)
In-Person Lecturers	11	15.45 (15.47)	7	6.57 (4.62)	7	5.29 (4.77)
Route Driving	9	18.2 (14.89)	7	5.87 (2.85)	7	4.88 (2.61)
Pre- and Post-Trip Checks	10	9.1 (11.42)	8	3.71 (3.41)	8	3.14 (2.95)
Driving Simulator	7	4.42 (8.51)	6	3.00 (4.28)	6	2.66 (3.59)
Self-Paced Computer Training	6	1.75 (2.00)	6	1.64 (1.94)	7	1.58 (2.09)

TABLE 5.7
Topics included in current state DOT snowplow driver training

Topics	N	Coverage[1]			
		Mean	Standard Deviation	Minimum	Maximum
Backing	14	3.86	1.06	2	5
Traffic	14	3.86	0.64	3	5
Plowing Near Ditches and Edges	13	3.85	1.03	2	5
Wing Plow	14	3.64	1.11	1	5
Speeding	14	3.43	0.98	2	5
Multitasking	14	3.29	1.10	1	5
Tandem Driving	14	3.07	1.16	1	5
Tow Plow	14	2.86	0.99	2	5

[1]Coverage measured from 1 = not at all; 2 = moderate amount, 3 = moderate amount; 4 = a lot; 5 = a great deal.

TABLE 5.8
Status of simulator-use by respondents

Status	Number of Respondents	Number of Clear Roads' Members Respondents
Currently in Use	5	4
Exploring	5	4
Previous Use or Exploration	4	4
Never Considered	2	1
Total	*16*	*15*

using the driving simulator in training further provided the reasons for such an approach.

- One state DOT stated that simulator could offer more training time during the summer, as well as extra safety when compared to training in an actual snowplow truck.
- One state DOT explained that the simulator could offer various training scenarios and different weather settings.
- One state DOT indicated that simulator provided realistic training to a large group of staff in a "very controlled environment." Also, students can get immediate feedbacks from instructor and fellow students. Response from this state DOT also indicated that "utilizing the simulator also saves fuels and equipment maintenance."

Moreover, states that are not currently using driving simulators or have not explored this option utilized the open space to provide more information about their rationale.

- Two states mentioned the cost of simulator was a major concern.

TABLE 5.9
Summary of decision factors for adopting a simulator in snowplow training (n = 13)

Factors	Perceived Level of Importance[1]			
	Mean	Standard Deviation	Minimum	Maximum
Perceived Long-Term Effects on Public Safety	4.31	0.82	3	5
Cost of Simulator-Based Training	4.23	0.58	3	5
Ability to Replicate Vehicle Dynamics and Characteristics	4.00	0.88	2	5
Ease of Relocation of Simulator for Training Purposes	4.00	0.96	2	5
Simulator Equipment Maintenance Concerns	3.92	1.00	2	5
Ability to Conduct Training in a Controlled Environment	3.77	0.96	2	5
Variety of Software Features (Ability to Collect and Analyze Training Data)	3.77	0.80	2	5
Acceptance by Drivers	3.77	0.80	3	5
Motion and Sound Realism	3.62	1.00	2	5
Perceived Long Term Effects on Operational Costs (Fuel and Maintenance)	3.54	0.84	2	5
Graphics Realism	3.46	1.01	2	5
Customizability (Including, But Not Only Route Customization)	3.31	1.20	1	5
Variety of Manufacturer-Provided Routes	3.23	0.70	2	5
Lack of Data on Simulator Return on Investment by Peers	3.08	1.00	1	5

[1]Importance level measured from 1 = not at all important; 2 = slightly important, 3 = moderately important; 4 = very important; 5 = extremely important.

- One state explained that hands-on training was found to be much more effective than simulator training.
- One state indicated that the small scale of their winter operations prevented to consider driving simulators for snowplow driver training as a priority.

During the survey, participants were asked to rate the decision factors when it comes to the adoption of using simulator in training, in which 13 participants provided their feedback. For this question, participants were asked to rate fourteen previously identified decision-making factors, from "not important at all" to "extremely important." For the analysis, respondents' answers were assigned a value from 1 ("not important at all") to 5 ("extremely important"). Based on the results, perceived long-term effects on public safety, cost of simulator-based training, and ability to replicate vehicle dynamics and characteristics were among the top three ranked factors in terms of decision factors on simulator adoption. Also, when asked for providing any new factors for this table, all participants indicated that no new factors would be included. Table 5.9 presents a summary regarding the decision factors on the adoption of simulator in snowplow training.

The survey allowed respondents to provide additional comments to the factors provided. Three respondents provided the following valid inputs.

- One state DOT indicated that snowplow driving simulator was a great option as it can put drivers into extreme conditions to learn.
- One state DOT did not recommend purchasing the simulator considering the ongoing maintenance concerns, as well as the dedicated staff who would be taken away from their normal duties. This DOT suggested that contracting the simulator can waive all of the associated problems of owning the system.
- Similarly, another state DOT suggested that it would be more cost-effective to contract the simulator manufacturer to do the training instead of buying out the software and the equipment.

5.2.4 Previous Simulator Use

Only one of the four state DOTs with past simulator use provided more input about their experience. The responding state DOT utilized the simulator from 2000–2008. When the simulator was in use, an experienced trainer, who was also knowledgeable about snowplow operations conducted training sessions around the state for new and experienced drivers. This state DOT found out that in-person and hands-on training were more effective than simulator training. The participant also pointed out factors leading to the decision to stop using the simulator in training, which included no observed skill transferability from simulator to real-world driving, issues with equipment operability (too much down time), as well as the cost of simulator maintenance.

5.2.5 Simulator Use (currently using or will be using simulator in the upcoming snow season)

Three state DOTs that are currently using snowplow driving simulator provided their inputs for this question, in which one participant indicated that driving simulator has been used for 15 years in their state DOT, one participant indicated 5 years of use experience, and one participant has just started using the driving simulator in training in 2021. Of the three that provided more information, two utilize training services from manufacturers or vendors (2-hour long training with

TABLE 5.10
Summary of simulator scenarios based on their rated perceived effectiveness (n = 3)

Scenarios	Perceived Effectiveness[1]			
	Mean	Standard Deviation	Minimum	Maximum
Urban Simulation	4.67	0.47	4	5
Passing Traffic	4.67	0.47	4	5
Rural Simulation	4.33	0.47	4	5
Interstate, Freeway Scenarios	4.33	0.47	4	5
Storm Events	4.33	0.47	4	5
Night Operations	4.33	0.47	4	5
Bridges and Overpass	4.33	0.47	4	5
Intersections	4.00	0.82	3	5

[1]Importance level measured from 1 = not effective at all, 2 = slightly effective, 3 = moderately effective, 4 = very effective, 5 = extremely effective.

TABLE 5.11
Summary of beneficial outcomes based on perceived effectiveness (n = 3)

Adoption Outcomes	Perceived Effectiveness[1]			
	Mean	Standard Deviation	Minimum	Maximum
Increasing Employee's Awareness About Safe Snowplow Driving Procedures	4.27	0.47	4	5
Providing a Safe Environment for Novice Snowplow Drivers	4.23	0.47	4	5
Improving Overall Driver's Performance	4.23	0.47	4	5
Reducing Overall Fleet Fuel Consumption	4.23	0.47	4	5
Reducing Overall Fleet Maintenance	4.20	0.82	3	5
Reducing the Overall Number of Snowplow-Related Accidents	4.13	0.47	3	5

[1]Importance level measured from 1 = not effective at all, 2 = slightly effective, 3 = moderately effective, 4 = very effective, 5 = extremely effective.

simulators mounted on trailer), while one indicated that the state DOT would be in charge of the training (with simulator installed inside a building).

The three respondents from state DOTs currently using simulators were then asked to rate the perceived effectiveness of eight training scenarios from "not effective at all" to "extremely effective." Responses were assigned a value from 1 (not effective at all) to 5 (extremely effective) for analysis that is summarized in Table 5.10. Results indicate that urban simulation and passing traffic were ranked as the top two most effectiveness training scenarios.

Following, the three same respondents were asked to rate six previously identified potential outcomes of adopting snowplow driving simulator in training from "not effective at all" to "extremely effective." Responses were assigned a value from 1 (not effective at all) to 5 (extremely effective) for analysis that is summarized in Table 5.11. The results show that the increase of employees' awareness about safe snowplow driving procedures as the most effective outcome. Furthermore, when asked about overall feedback on the use of driving simulators for snowplow driver training, two participants indicated feedback was extremely positive, while the remaining one indicated the state DOT was somewhat positive for the adoption of snowplow driving simulator. No responses for negative feedback were observed.

6. CURRENT DRIVING SIMULATOR OPTIONS ON THE MARKET

This section covers current options for snowplow driving simulators on the U.S market. An initial online search was conducted, and ten manufacturers were found offering different levels of hardware and software features for their simulator products. Further analysis indicated that only four of those consistently produced driving simulators that are specific for training snowplow drivers. Most of the additional manufacturers produced other types of driving simulators that could be customizable to snowplow driver training or were not available for further clarification. Because the present research was focused on products that are currently available on the market, they were not included in this analysis.

Additionally, for reference purposes, Table 6.1 outlines the models in the previous state DOT reports reviewed in the present study, and their main characteristics. As indicated in the survey, most simulators used in the states reviewed in the literature are from L3 Harris Technologies, INC.'s TranSim product line with three exceptions—one of the models used by Utah was a Mark II (also L3 Harris) and ODOT's simulator was a Doron Precision Systems (P660 model). Finally, O'Rourke (2011) does not include clear information about the maker and model of the simulator(s) used for the IDOT study.

In the following section, results from a survey of snowplow driving simulator manufacturers identified by the online search will be presented. Results were collected between May and July of 2022.

6.1 Manufacturers' Survey Results

From the survey, four manufacturers provided information on their snowplow driving simulators through an online questionnaire. Two of these four manufacturers included two different simulator models in their response, bringing the total number of evaluated simulator models to six. The results are discussed as follows.

- *Company A:* This company only offers one driving simulator for snowplow driver training. Their model is a multiple-configurations plow with network capabilities that allow up to four operators in four different simulators to train in tandem operations. It features a 180-degree field-of-view on 4K Ready LCD displays, aimed to optimize scanning and create an immersive driving environment. This is supported with full motion seat base haptic feedback and amplified by an audio interaction system that simulates relevant sounds, even that of crunching snow under the tires if desired during customization. For its scenarios, 25 distinct ones come with purchase, but if the manufacturer's training services are used, over 100 scenarios can be accessed. Its training services come as an add-on during purchase and installation (which can be fixed, to only be moved by the manufacturer, or in a mobile trailer) with a 3-day "Basic, Maintenance & Operations" course. This model has a 1-year warranty and has sold an estimated 200 units (including all driving configurations) in its avail-

TABLE 6.1
Simulator equipment used in previous DOTs' reports

State	Reference	Maker	Model	Main Characteristics
Utah	Strayer et al., 2004	L3 Harris	Mark II	Motion-based simulator. 180° horizontal viewing area. Audio and vibration systems included. No information on refresh rate. Fixed base.
		L3 Harris	TranSim VS	Used for fuel efficiency training. No additional information included in report. Fixed base.
Iowa	Masciocchi et al., 2007	L3 Harris	TranSim VS III	Truck and snowplow simulator. 180° horizontal viewing area, refresh rate 70 Hz. Automatic transmission for simulation. Digital sound mimicking operations. Under the seat vibration for road vibrations. Fixed base.
Arizona	Kihl et al., 2006	L3 Harris	TranSim VS III	Year 1: mounted on a mobile trailer that could be driven to training locations. Year 2: mounted at ADOT districts. No further information is included.
	Kihl et al., 2007	L3 Harris	TranSim VS III	Installed at ADOT districts. No further information is included.
Illinois	O'Rourke, 2011	No clear information was provided in report.		
Ohio	Ash et al., 2022	Doron Precision Systems	P660	Offered with trailer housing for ease of transportation of simulator equipment and training crew. 240° horizontal viewing area. Digital steering system, radio dispatch, adjustment for side-view mirror, adjustable seat, auto and manual transmission. Surround sound system.

ability period of over 10 years now. It is used by 15 US DOTs for yearly training services and outrightly purchased by 5. Furthermore, this company focuses now on training services, delivered through a mobile unit equipped with the simulator, offering a basic 2-hour course and an advanced 4-hour course.

- *Company B:* This company also only has one driving simulator model capable of snowplow driver training. Company B's simulator is a spreader simulator with instructor customizable plows (front, right, and left). It also features a 180-degree field of vision, with motion and vibration as its haptic feedback, and sound cues expected in a driving environment. The simulator's snowplow training scenarios include snowplow and spreader (basic controls, backing maneuvers, precision maneuvers, snow plowing, intersection, railroad crossing, overpass and bridges, and plowing procedures) and lead plow, rear plow, and ramp plow—all increasable through customization by the manufacturer for an extra charge as it comes with ScenarioBuilder capacities. This model comes with a 1-year warranty, advised preventive maintenance during usage, and training service (to train local trainers) which accompanies purchase and installation (fixed, but equipment can be relocated by client or a mobile trailer installation), as a requirement. It has sold an estimated 500 units (combined all types of simulator, including non-snowplow driving simulations) since its availability within the U.S market for over 10 years, and no information was provided on its usage by state DOTs in the U.S.
- *Company C:* This company has the following two models for snowplow driver training.
  - *Model 1:* Company C's entry level simulator is equipped with a 3-screen (each rendered native 4k) open-air cab, with Dolby 5.1 surround sound providing aural cues from other vehicles in the scenario. The simulator has a 3-DOF motion platform, seat traducer, and force haptic feedback steering, with over 70 scenarios, from acclimation to skill builder, and advanced maneuvers. For customization, scenario toolbox is used to modify scenarios and create realistic world conditions at an additional cost. Moreover, upgrades such as motion platform, air brakes, custom vehicle model (dynamics), after-action scenario review, manual transmission, power conditioner, and instructor tablet are not included in the primary package. This model has a 1-year factory warranty that covers all parts replacement, labor, and on-site visits, after which extended warranty is based on purchase. Recommended maintenance for the simulator equates to keeping the area clean of debris, food, drinks, and a minor software patch periodically. The hardware is configured to last over 20 years, bearing no plastic components, but rather all aluminum bodies with powder-coated frames. Its training services (training of local trainers) are included with the simulator purchase and installation (fixed, once installed, can only be moved by the manufacturer or a mobile trailer installation), but stand-alone training sessions are popular and available. In its over 4 years of availability within the U.S market, the simulator has sold an estimated 10 units, while no information on its use by DOTs was provided by the manufacturer.
  - *Model 2:* The second snowplow driving simulator model by Company C is an upgrade to their entry model, fitted with an 8-channel VDU configuration, 340-degree field of view, 4K UHD screen, and a Dolby 5.1 surround sound with aural cues. It has a full motion platform and force feedback steering for haptics, with over 70 scenarios, from acclimation to skill builder advanced maneuvers. For customization, scenario toolbox is used to modify scenarios and create realistic world conditions, at an additional charge, depending on the complexity. In the same breadth, upgrades such as motion platform, training repeater monitor, manual transmission, after action scenario review, and 2-way radio are not included in the primary package. This model comes with a 1-year factory warranty, which covers all parts replacements, labor, and on-site corrective visits, while an extended premium warranty (involving preventative maintenance visits), is offered on a per-year basis afterward. Its training services are included with the simulator purchase and installation (fixed, once installed, can only be moved by the manufacturer, or a mobile trailer installation). It is noteworthy that while this model has been available for over 4 years, no units has been sold.
- *Company D:* This company also has the following two simulators for snowplow driver training.
  - *Model 1:* Company D's entry level snowplow driving. It comes with a 3-screen simulator, 225-degree field of view, no unique audio interaction besides engine sounds, over 75 training scenarios, and an optional three-degree of freedom motion base haptic feedback, which is full motion including screens. For customization, the system can be equipped with optional Scenario Developer which allows users to create own scenarios, at an additional charge on a per scenario basis. Also, motion base, SkillTrak, modular driving positions, camera and PES are not included in the primary package. This model comes with a limited 1-year warranty, which is renewable each year for as long as the system is owned. Its training services (train the local trainer) are included with the simulator purchase and installation (fixed, once installed, can only be moved by the manufacturer or a mobile trailer installation). In its over 4 years of availability within the U.S market, it has sold one unit, and no information is provided on U.S DOTs currently use the model.
  - *Model 2:* The upgraded model for Company D is fitted with four 55″ high-definition LED displays, 1920 × 1080 screen resolution, 240-degree field of view, a Dolby 5.1 surround sound but no unique audio interaction besides engine sounds, an optional 3-degree of freedom motion base haptic feedback, which is full motion including screens, and over 75 training scenarios. For customization, the system can be equipped with optional Scenario Developer, which allows users to create own scenarios, at an additional charge on a per scenario basis. Also, motion base, SkillTrak, modular driving positions, camera and PES are not included in the primary package. This model comes with a limited 1-year warranty, which is renewable each year for as long as the system is owned. Its training services (train the local trainer) are included with the simulator purchase and installation (fixed, once installed, can only be moved by the manufacturer or a mobile trailer installation). In its over 4 years of availability within the U.S market, it has sold six units, and two U.S DOTs currently use the model.

TABLE 6.2
Summarized manufacturer's survey results

Company/Model	Cabin Type	Haptic Feedback	Virtual Scenarios	DOTs Use	Base Cost
Company A/ Only Model	Open-air cabin	Full motion seat base	25 if purchased; over 100 with training services	15 yearly service for training; 5 own simulators	From a low of $110,000 to a high of $300,000 depending on manufacturer and model
Company B/ Only Model	Open-air cabin with real truck parts	Vibration and motion	Over 50, with more upon customization	Not provided	
Company C/ Model 1	Open-air cabin	3-DOF motion platform, seat traducer	Over 70 scenarios (acclimation, skill builders, advance maneuvers, etc.)	Not provided	
Company C/ Model 2	Fully enclosed cabin with real truck parts	Full motion platform, force feedback steering	Over 70 scenarios (acclimation, skill builders, advance maneuvers, etc.)	0	
Company D/ Model 1	Open-air cabin	Third-degree of freedom motion base	Over 75 scenarios, with optional Scenario Developer	Not provided	
Company D/ Model 2	Fully enclosed cabin with real truck parts that will match fleet vehicle	Third-degree of freedom motion base with full motion	Over 75 scenarios, with optional Scenario Developer	2	

Table 6.2 summarizes the manufacturer's survey results on the six snowplow driving simulator models, comparing considerations such as cost, cabin type, haptic feedback, virtual scenarios, and market spread.

7. CONSIDERATIONS FOR THE USE OF DRIVING SIMULATORS IN SNOWPLOW DRIVER TRAINING

After reviewing the findings from previous literature, and our current results, the research team drafted recommendations to INDOT related to the adoption of simulators for their snowplow driver training. These recommendations included considerations about the Technology, Organization and Environment (T-O-E) contexts in which driving simulators would be used, which is aligned with the T-O-E framework developed by Baker (2012). Table 7.1 outlines the factors considered under each of the T-O-E contexts, and it references which tasks provided input to the factors' list.

Each factor is explained in the following list.

- *Simulator Fidelity:* Technology seems to have improved greatly since the first DOTs studies on the topic. Six of the reviewed driving simulators in Task 5 include haptic and sound feedback high-fidelity graphics, high refresh rate and more than 180° monitor view that allow for greater scenario immersion. In addition, all simulators reviewed are equipped with motion-enabled seat that allow simulator to replicate vehicle dynamics and characteristics to some extents. Furthermore, three of the simulators reviewed can reproduce the plow's truck and cabin design and controls, including salt spreader, wing plow controls, and blade control. Yet, the findings from our interviews of INDOT workers suggest that simulator realism is a major concern. This seems to be related to simulating winter conditions and snowplow physics accurately, so that they are able to train safely with simulated adverse weather.
- *Vendor Support:* Vendor support typically refers to trainer training services, availabilities of training scenarios, maintenance of the simulator, as well as the warranty provided by the manufactures. Based on responses of four manufacturers surveyed, all of them indicated that certain level of trainer training services was included within the purchase of simulator; however, add-on sessions required additional purchases. As for the availability of training scenarios, four manufacturers offered certain amount training scenarios for basic snowplow operation training, however additional or customized training scenarios required additional purchases. Maintenance, on the other hand, includes minor software updates and patches, as well as preventative annual inspection by the manufacturer, which is covered by the warranty. All manufacturers who answered our survey mentioned that the purchase of the simulator includes 1-year warranty and additional periods can be purchased separately.
- *Relative Advantage:* Current INDOT training format typically consists of a 2-day course that includes a lecture-based class followed by the hands-on practice session in the following day. Driving simulators could be beneficial and helpful when adding as a supplementary tool to the current training format (O'Rourke, 2011). Snowplow driving simulator can provide relatively realistic driving experience, extra training opportunities prior to winter season, as well as some challenging training scenarios that would be too dangerous to replicate in real-life training (de Winter et al., 2012).
- *Evaluation of Technical Benefits:* This factor includes multiple technical data that could be measured after the

TABLE 7.1
T-O-E considerations for adopting simulators in INDOT snowplow driver training

Context	Factor	Task 1 Review of Literature	Task 2 INDOT Interviews	Task 3 Pilot Interviews	Task 4 State DOT Survey	Task 5 Manufacturing Survey
Technology	Simulator Fidelity	×	×	×	×	×
	Vendor Support	×	×	×	×	×
	Relative Advantage	×	×	×	×	
	Human-Technology Interaction	×		×	×	×
	Evaluation of Technical Benefits	×	×	×	×	×
	Costs	×	×	×	×	×
Organization	Organization Mission	×	×	×		
	Structure of Training	×		×	×	
	Management Support	×	×	×	×	
Environment	Normative Pressure		×	×		
	Mimetic Pressure		×	×		

adoption of snowplow driving simulator in training. Such technical data could be measurements of fuel efficiency, safety, as well as equipment wear and tear before and after the adoption. However, previous technical reports indicate difficulty in making sense of the data due to low number of accidents and the confounding actions of other variables (Kihl, 2006, 2007; Masciocchi, 2006; O'Rourke, 2011).

- *Human-Technology Interaction:* During the simulator training, there is a chance that users may experience physical discomforts such as sweating, headache, or nausea. These symptoms are caused by conflicts of different sensory inputs, which are commonly referred to as cybersickness (Goodge et al., 2021). During the simulator training, for example, the driver perceives the truck as a moving object based on the first-person perspective. However, if his or her body could not feel the vibrations from the plow blade or engines as they may experience in real-life, in which such a circumstance can cause conflicts for brain to process, therefore resulting in cybersickness symptoms.
- *Costs:* Depending on the vendors, costs for adopting the snowplow driving simulator can be divided into two types—(1) one-time simulator purchase, (2) subscription-based training. For the one-time purchase, the front-end costs may include storage area, development of training materials, set-up costs, purchase of simulator equipment, as well as the depreciation overtime. Long-term costs include maintenance, software updates, as well as material updates. On the other hand, the costs for a subscription-based training can vary by the level of services and the hours of training services needed per year. Subscription-based training usually consists of training services and equipment being entirely provided by the vendors, though some level of customization may be arranged.
- *Organization Mission:* By providing a realistic, yet relatively low-risk training environment along various training scenarios (de Winter et al., 2012), the adoption of snowplow driving simulator can be a good supplement to the snowplow training process. This also matches the mission statement from the INDOT, in which the goal is to "collaboratively plan, build, and maintain safe and innovative transportation infrastructure that enhances quality of life, drives economic growth, and accommodates new modes of transport" (INDOT, 2022).
- *Structure of Training:* Structure of training refers to the compatibility of the organization, which include transition to a more centralized operation mode and the number of trainers available. A more centralized operation mode can be helpful for the adoption process of the snowplow driving simulator by standardizing the training schedule and better managing the trainers available.
- *Management Support:* The management support can be divided into two aspects—(1) maintenance of the simulator (2) positive attitudes and social influences from other supervisors. Maintenance of the simulator includes the support from the IT department in case of occurrence of software issues during training and to maintain the equipment. In addition, there should be a space provided where driving simulators can be properly stored. On the other hand, supervisors can be provided with information sessions so that can be more involved and informed with the transition process of adopting snowplow driving simulator in training.
- *Normative Pressure:* The normative pressure refers to pressure from the societal part and the economic part. In the case of adopting the snowplow driving simulator in training, the societal pressure comes from snowplow operation's mission to keep the roads in a safe driving condition, as well as improving safety for the snowplow drives, especially in the harsh weather conditions. On the other hand, the economic pressure refers to the reliability of the operations, which indicates the level of whether the snowplow operations can be performed with its intended purposes during a certain period of time.
- *Mimetic Pressure:* Mimetic pressure in this case refers to the number of other state DOTs considering or having adopted the driving simulator in snowplow driver training.

A draft version of these considerations was shown to DOT representatives from two states that have been utilizing driving simulators for at least 5 years in the snowplow driving training program. Both state DOTs that participated in the validation interview utilize driving simulator training through training services provided by a manufacturer. Furthermore, specifically to winter operations, both states do not use yearly simulator training for all employees—one state only uses simulators to train new snowplow drivers or drivers that have not plowed "for a long time," which amounts to about 40 new drivers per year; the other state mentioned all drivers train one third, or about 500, of their drivers with a driving simulator every year utilizing a multi-year contract. One of the participant states used to own a driving simulator, however maintenance and upgrade costs were challenging and then decided to switch to a training-service type of contract.

Specific comments made related to the draft recommendations included the following.

- Validation interview one.
  - Having a centralized location at each district for the simulator makes mobilization of drivers easier.
  - Outright purchase is challenging.
  - Training in simulator may help in legal disputes to show that DOT has provided adequate training.
  - Some drivers may experience cybersickness.
  - Customization of simulator training at the district level is difficult and statewide standardization of training is recommended.

- Validation interview two.
  - Identifying employees that could champion the use of driving simulators is recommended.
  - Measuring the impact of simulator training in the reduction of snowplow-related accidents is challenging. It is suggested to focus on the improvement of drivers' confidence level (especially new drivers) in plowing snow.
  - Do not space out simulator training and hands-on training too far apart, so that information learned on the simulator can be reinforced, and vice-versa.
  - Starting to explore the use of driving simulators in a small scale is a good idea.
  - Cost is a challenge with both training services and in-house, owned simulator equipment.

7.1 Business Case

In the present report, the research team also explored different scenarios, in case INDOT moves forward with utilizing driving simulators for snowplow driver training. To do that, we describe the scenarios that were considered, our assumptions and limitations and our analysis. We note that, based on our results, we will not compare the cost of the current training format to the cost of training with a simulator given that previous research suggests that providing this option in addition to regular training is a better option that replacement of current behind-the-wheel training (O'Rourke, 2011). Furthermore, our interview results show that drivers and crew supervisors see great value in the current yearly training provided by INDOT.

7.1.1 Simulator Training/Equipment Acquisition Options Included

Four options were included in our analysis.

- *Option 1:* Outright Purchase of Simulators, Fixed Installation—for this option, our results suggest that there are at least three manufacturers that can be considered for purchase in the United States. Furthermore, with a fixed installation, it will be necessary for INDOT identify a space for the location of the equipment strategically located to minimize trainee displacement from original work location to training location. This space needs to have air and temperature control for the equipment, and also be able to fit at least a trainee and a trainer.
- *Option 2:* Outright Purchase of Simulators, Trailer Installation—for this option, mobile trucks housing the simulators must be procured separately. Suitable 32-foot-long semi-trucks are priced at an estimated cost ranging from $110,000 to $150,000, depending on their condition and requirements from manufacturers. We note that not all manufacturers may recommend trailer installation and moving of trailer with sensitive equipment (simulator) may cause increased maintenance and reduced lifetime.
- *Option 3:* Hiring Training Services—in this option, instead of delivering the equipment, a vendor will be providing a (training) service that includes lecture and in-simulator training time.
- *Option 4:* Utilizing Indiana Local Technical Assistance Program (LTAP)—the Indiana LTAP located in West Lafayette, IN has recently acquired a Virage driving simulator. CDL-specific training modules that incorporate driving simulator use are currently being developed to train local agency drivers in CDL best practices, including defensive driving, gear shifting, backing, and parking, winter operations and refuse truck. In this case, training for winter operations is mainly focused on providing current CDL drivers with basic information; therefore, this option was not further considered in the analysis. Partnerships between LTAP and INDOT for simulator and training space access could be discussed in the future.

7.1.2 Assumptions, Delimitations, and Exclusions

Assumptions included in our analysis relate to the following.

- *Number of Drivers:* Based on information provided by INDOT referring to 2022 year, there are 2,053 (1,062 transfer and 991 regular) snowplow drivers mobilized for winter operations by INDOT in the state of Indiana. The state is structured into six districts and 104 subdistricts (or units). The number of drivers in each district is La Porte (n = 396), Greenfield (n = 384), Fort Wayne (n = 344), Seymour (n = 342), Crawfordville (n = 310), and Vincennes (n = 277). Training and crew management usually happens at the subdistrict level.
- *Hours of Simulator Training:* Previous research indicated a range from a minimum of 2 hours (O'Rourke, 2011) to a maximum of 4 hours (Strayer et al., 2004), for simulator training. This training was usually performed in groups, during which trainees alternate to use the simulator. To standardize comparisons, we have assumed

on all comparisons the use of a 2-hour simulator training with a throughput of 16 drivers per day per every two simulators.

- *Number of and Cost of Simulators:* Our analysis compares Options 1, 2, and 3 use of 2, 4, and 6 simulators. For options where INDOT buys the simulator equipment, a cost of $128,000 was considered per driving simulator. For the trailer mounted option, we assume that two simulators may be mounted in the same trailer and each trailer will cost an average of $135,000.
- *Cost to Develop New Curriculum:* We have assumed 160 hours of employee time for a team of four INDOT safety trainers to develop a new curriculum for training snowplow drivers using driving simulators, for a total cost of $3,840, at $24/hour.
- *Cost of Training Services:* For this option, we assumed a cost of $450 per trainee, per year. This includes material development, trainer cost and simulator equipment. Depending on the number of relocations necessary for the training trailer, additional cost may be included. We have assumed a one-time cost of $6,000 for logistics to be added to the total yearly cost of training services.
- *Remodeling Cost for Simulator Storage:* We have assumed a cost of $8,000 for remodeling and operating for the space in which the simulator will be installed. We also note that heating, ventilation, and air-conditioning (HVAC) systems in the room where the simulator will be installed should be monitored for best performance of the equipment.
- *Fuel Cost for Trailer Relocation:* For Option 2, each INDOT district has between 17 and 22 subdistricts. Because some of these subdistricts do not have enough drives to justify trainer relocation, we have assumed 15 relocations per district, each spaced approximately 45 miles at a cost of $41.44 per relocation ($5.525 per gallon of diesel and assuming 6 miles per gallon performance); or 6 relocations when considering a centralized location option at 120 miles distance of each other, for a total cost of $110.50. It is also assumed that trainers will be drivers for the simulator trailer in Option 2.

Our delimitations include the following.

- Our analysis provides a comparison for 1 year of training and for training of all INDOT snowplow drivers (novice, transfer, and full time) every year. It is possible that some savings would be included, such as trainer refresher courses may not be needed every year with using the simulator every year. Similarly, cost reductions would be included if the simulator is not used to train all drivers every year, but only a portion of drivers.

The following are excluded from our analysis.

- Future maintenance costs and downtime costs are not included because those difficult to predict.
- Only base models were included in the cost analysis, though two companies provided upgraded models, which may include advanced features. Most other state DOTs utilizing driving simulators opt for the base models.
- Cost for scenario customization was not included in the analysis.
- Simulator equipment insurance for Options 1 and 2 is not covered in the analysis. Trailer equipment insurance and trailer maintenance for Option 2 are not included in the analysis.
- No economies of scale or negotiations were included in any of the options.

Finally, we note that costs are subject to change without notice. The current analysis should only be used for INDOT exploratory purposes only and it is not generalizable.

7.1.3 Analysis

The cost of Options 1, 2, and 3 alternatives for Indiana Department of Transportation (INDOT) in setting up snowplow driver simulation training are evaluated and compared. The comparisons were inspired by the analysis provided in O'Rourke (2011). The first scenario includes training for all INDOT drivers (n = 2,053), while the second explores the option to train only new drivers (n = 480), and the final one compares cost per employee trained.

7.1.3.1 Comparison of alternatives to train all INDOT drivers. In this scenario, Options 1 and 2 vary greatly depending on the number of simulators purchased, therefore the researchers explored the acquisition of 2, 4, and 6 simulators. An initial exploration of the use of 2 and 4 simulators resulted in 129 and 65 business days to train all INDOT snowplow drivers, respectively. This amount of time was deemed unacceptable by the research team and therefore these two options were removed from further analysis.

Furthermore, for Option 3 (hiring of training services), the yearly cost to train all 2,053 drivers would be $929,850.00. This does not include the cost of time drivers' time for taking the additional training. Scheduling of training to guarantee that all INDOT drivers are trained in a timely manner should be negotiated with vendor.

When considering the use of six simulators, INDOT would need *43 days* to train all 2,053 of their snowplow drivers. Table 7.2 presents the summary of this analysis. Moreover, for Option 1 (fixed installation), the simulators would be strategically placed in each subdistrict to minimize travel time, therefore we removed cost of travel for Option 1 in this analysis. For the trailer mounted option (Option 2), it is assumed three trailers would provide services to all INDOT districts.

To further develop the comparison, the research team evaluated a cumulative cost projection for a 5-year period for Options 1 and 2 using 6 simulators, and Option 3 in Figure 7.1. A 10% inflation rate was considered in years 2 through 5. We note that no maintenance costs were included in Options 1 and 2. The graph shows the high cost of Option 3 (training services), which is mainly due to the recurring yearly training costs. Furthermore, we note that maintenance was not included in Options 1 and 2 because they can vary widely.

TABLE 7.2
Comparative analysis for six simulators

Item	Option 1	Option 2
One-Time Costs		
Simulator ($128,000 × 6)	$768,000.00	$768,000.00
Mobile truck ($135,000 × 3)	–	$405,000.00
Training material development	$3,840.00	$3,840.00
Space management and remodeling ($8,000 × 6)	$32,000.00	–
One-time Costs Subtotal	*$800,384.00*	*$1,176,840*
Recurring Yearly Costs		
Employee travel ($22.97 × 2,053)	Excluded	–
Average diesel fuel for trailer relocation (15 × 2 × $41.44)	–	$1,243.20
Trainer cost (6 at $24/hour each, for a total of 344 hours)	$49,536.00	$49,536.00
Subtotal	*$49,536.00*	*$50,779.20*
Cost of employee time in training ($22.97/hours × 2 hours × 2,053)	$94,314.82	$94,314.82
Driving simulator and mounting trailer maintenance	Excluded	Excluded
Total	*$947,690.82*	*$1,321,933.82*

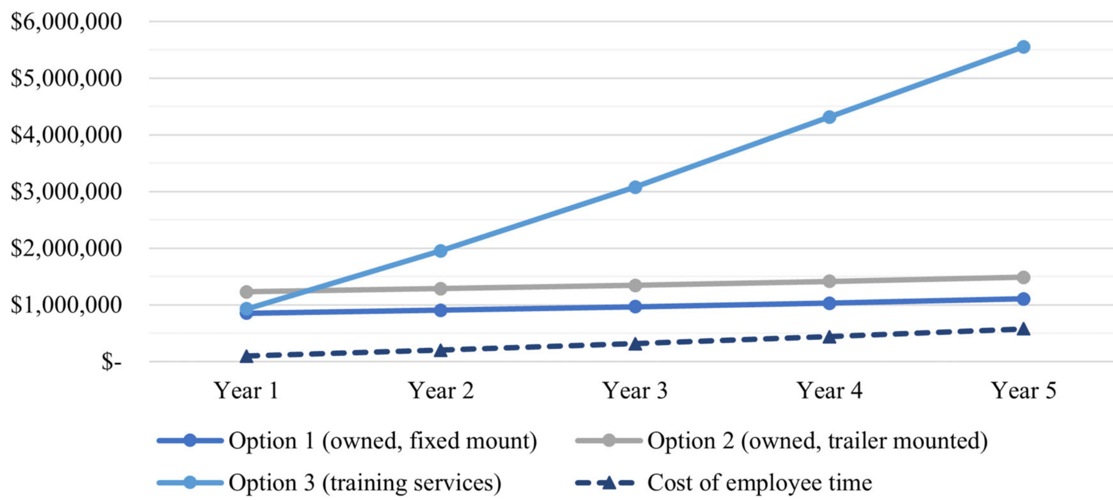


Figure 7.1 Cumulative cost comparison of Options 1 and 2 with 6 simulators and Option 3 over 5 years.

7.1.3.2 Comparison of alternatives for yearly training of 480 drivers. INDOT-provided data indicates that there are, on average, 40 new drivers per month. Therefore, this scenario considers the yearly training of all these 480 new drivers per year. In this scenario, the research team considered the use of two simulators for Options 1 and 2. For Option 1 (fixed installation), the simulators would be located in Fort Wayne (north) and Greenfield (center-south). These tentative locations result in an average travel time to and from the simulator of 2 hours per employee, and an average travel cost of $45.94 per employee for the 2 hours (assuming $22.97 average hourly rate for drivers from Table 4.1, not including fuel cost for employees). For the trailer mounted option (Option 2), it is assumed one trailer would provide services to all INDOT districts, making one stop at each district (estimated distance between locations 120 miles). With this option, *30 days* would be required to train 480 INDOT snowplow drivers per year. Table 7.3 presents the summary of this analysis. Moreover, Option 3 in this case would cost *$222,000.00* per year.

Based on the analysis presented in Table 7.3, which considers the yearly training of only 480 INDOT snowplow drivers, training services is the least costly option when only considering 1 year. In order to further develop this comparison, the research team provides a cumulative cost projection for a 5-year period for Options 1, 2, and 3 training of 480 INDOT employees in Figure 7.2. A 10% inflation rate was considered in years 2 through 5. We note that no maintenance costs were included in Options 1 and 2.

In this option, considering only 480 INDOT snowplow drivers to be trained yearly, the training services options seems the best option for years 1 and 2. Based on our validation interviews, we noted that not all state DOTs train all of their drivers every year with snowplow driving simulators, and for these states, utilizing training services offers the best cost-benefit. Furthermore, we note that maintenance was not

TABLE 7.3
Comparative analysis for the training of 480 drivers with two simulators

Item	Option 1	Option 2
One-Time Costs		
Simulator ($128,000 × 2)	$256,000	$256,000
Mobile Truck ($135,000 × 1)	–	$135,000.00
Training Material Development	$3,840.00	$3,840.00
Space Management and Remodeling ($8,000 × 2)	$16,000.00	–
One-Time Costs Subtotal	*$275,840.00*	*$394,840.00*
Recurring Yearly Costs		
Employee travel ($22.97 × 2 × 480)	$22,051.20	–
Average diesel fuel for trailer relocation (6 × $110.50)	–	$663.00
Trainer cost (2 at $24/hours each, for a total of 480 hours)	$11,520.00	$11,520.00
Subtotal	*$33,571.20*	*$12,183.00*
Cost of employee time in training ($22.97/hours × 2 hours × 480)	$22,051.20	$22,051.20
Driving Simulator and Mounting Trailer Maintenance	Excluded	Excluded
Total	*$331,465.20*	*$429,074.20*

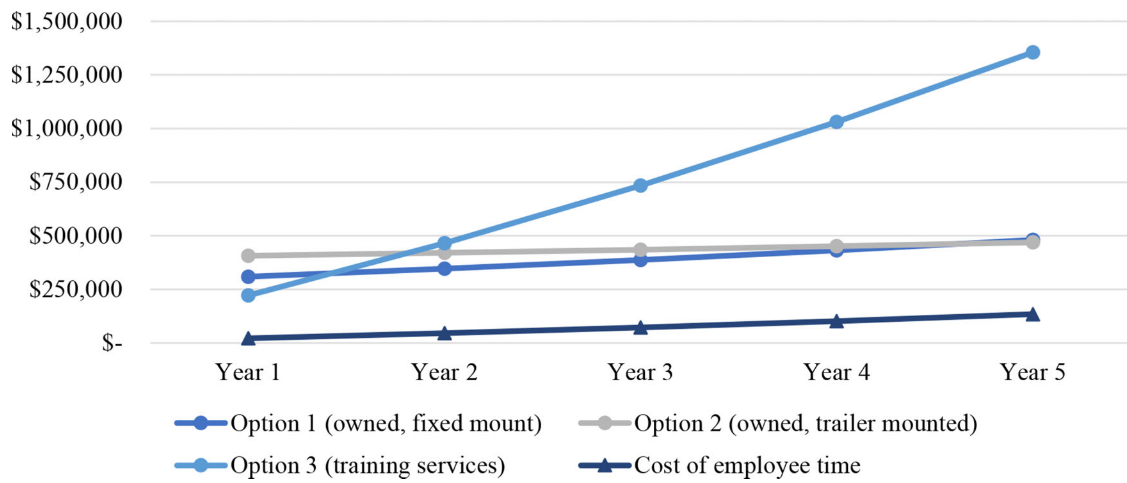


Figure 7.2 Cumulative cost comparison of Options 1, 2, and 3 over 5 years for the training of 480 snowplow drivers yearly.

included in Options 1 and 2 because they can vary widely, and neither does it consider cost (and issues) related with software upgrades or downtime in case of driving simulator malfunction.

7.1.3.3 Comparison of alternatives by number of trainees over 5 years. In this scenario, the research team compared owned fixed and owned, trailer mounted simulator with training services over a 5-year period by number of trainees. This comparison may be useful to INDOT if they consider training only a portion of their employees using a simulator. Figure 7.3 shows the comparison graphically. The comparison does not include inflation costs, nor it includes potential economies of scale with multi-year training service contracts. We note that training services seem to be the best option to use simulator to train a 150 or less employees yearly, while buying a simulator seems to be the best option for training for over 650 or more employees yearly. Considerations for the yearly training of a number of employees between the 151 and 649 should be examined closely.

7.2 Summary of Pilot Training Results

Upon finalization of Tasks 1 through Task 8, a pilot training event was performed in December of 2022, at two INDOT locations. Drivers were selected by INDOT, and the research team gathered their feedback at the two locations using a pre-and post-training questionnaire. A total of 64 drivers provided their input to the researchers. More detailed information about drivers' responses can be found in Appendix F. We note that the sample had an overwhelming majority of regular drivers (n = 49). However, in terms of experience, the sample was reasonably balanced, with an average experience of 5.74 snow seasons and a median of 3 snow seasons per driver. It is also worth noting that more than half of the participants (51.5%, n = 33) fell in the experience interval of 0–3 years,

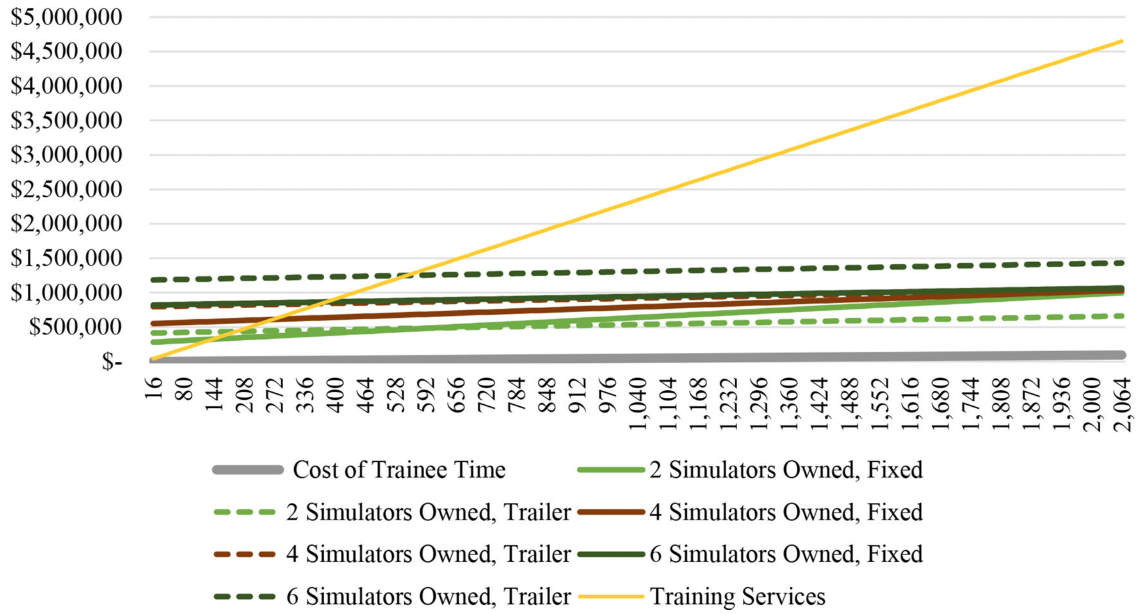


Figure 7.3 Cost comparisons of alternatives per trainee over a 5-year period.

which we considered as novice drivers. The age distribution for the 64 participants were found across a wide spectrum from 18 to 65+ years old, with the age group of 50–54 reported the most respondents.

The interest level of participants was high, with the overwhelming majority (n = 60) being slightly to extremely interested in training with a simulator. Furthermore, the comparison of the average comfort level of drivers for fifteen driving conditions pre- and post-training suggests positive growth for all individual items and a growth of 6.06% between the general pre- and post-training average for all items. Items that had the largest growth were (1) plowing near ditches and edges, (2) plowing during whiteouts, (3) multitasking to control equipment and (4) avoiding small objects. Several of these conditions are directly related to accidents faced by INDOT snowplow drivers. As for overall confidence level in plowing snow for INDOT, the pre- and post-training results show a growth of 9.2%, though we note that for the majority of drivers (n = 40) there was no change in confidence level. We also note that about 10% of the drivers faced moderate to higher levels of discomfort and this should be taken into consideration by INDOT when planning for this type of training.

The post-training survey asked participants for more perceptions related to the training. On average, all content was found to be very useful by drivers, and the overall training had an average of 4.25 and a median of 5 score on a 1 (not useful at all) to a 5 (extremely useful) Likert type scale. In terms of equipment the results note positive perceptions by drivers, with audio input being the best feature, while fidelity to INDOT snowplow truck controls was rated lowest (but still good, with a median of 4). The lowest score related to the equipment was given to its moderate capability of equipment to replicate real-world experiences.

Overall, the participants recommend the training to all INDOT snowplow drivers, though it seems more participants definitely recommend the training for novice drivers, followed by transfer drivers and then regular drivers. Open ended comments indicated participant's excitement about using the driving simulator in training and highlighted the portions of the training that were most helpful to them.

Following the descriptive statistics, the researchers performed inferential tests on the data to evaluate differences in confidence level between the pre-training and post-training using a sign-rank test. Unfortunately, due to the small spread on the Likert type scale used (from 1 to 5), most drivers (n = 40) did not see any difference. Due to the nature of the test, this lack of difference would not be accounted and therefore the results would be hard to interpret. Furthermore, the researchers attempted to run an ordinal logistic regression to verify how the difference between pre- and post-training scores varied by experience and type of driver (transfer or regular). The results indicate no statistically significant difference between the groups, but the result may also be unreliable give the large number of combinations that were not present in the actual data collected. Therefore, further tests should be performed with adjustments on the survey as recommended in Appendix F.

8. RECOMMENDATIONS

After careful consideration, the research team *recommends that INDOT continues to explore the use of driving simulators in snowplow driver training.* The team considered the factors presented in Table 7.1, especially those related to *(a) creating an additional training opportunity for drivers in a safe and controlled environment, (b) improving safety awareness of drivers during winter operations, and (c) creating a more immersive and engaging training environment for trainees*. Despite the lack of conclusive results in the statistical inferential tests related to the pilot training, our descriptive results indicate increases in average comfort and confidence of drivers to plow snow after their driver simulator training and a great interest from drivers to train using this type of equipment.

Furthermore, our recommendations align with previous DOT reports and our own research results suggesting *training with simulators increases trainees' safety awareness and provide a safe environment for training*. In the suggested approach, the simulator should not replace current training procedures, but rather be included as an additional training module to increase drivers' awareness to common (for novices) and uncommon (for experienced) risky situations.

8.1 Suggestion for Pilot Implementation (Initial 2 Years)

The research team suggests that a pilot implementation be established for two snow seasons to (1) develop and test training materials that are focused on INDOT needs, (2) evaluate initial INDOT drivers' acceptance of training with driving simulators, (3) evaluate perceptions of effectiveness of driving simulator training, and (4) explore driving simulator technology, potentially evaluating the use of the driving simulator for other INDOT driver training needs. Further suggestions include the following.

- *Utilize LTAP simulator for the pilot period, if possible.* Outright purchase of simulator for pilot use does not seem reasonable, given the high initial costs. Furthermore, because LTAP is a local resource that is already developing simulator training, synergies for curriculum development may be available. Also, exploring contracting simulator time with LTAP (for short- and long-term simulator use) or renting simulator time to LTAP may provide additional use for the equipment, helping make the case for buying the equipment. However, we note that for this option a new training, focused specifically in how snowplow driving should be developed.
- *If an agreement with LTAP is not possible, utilize training services*. Training services for a small number of drivers over 2 to 3 years may be enough to explore drivers' perceptions of effectiveness of confidence levels. In this case, there is no need for material development cost and some customization, but not full customization of training, is possible. Furthermore, in this option, trainers are likely to be non-locals designated by the service provider. The lack of local trainers or leaders might not be as well received by INDOT drivers, who seem to value peer interaction and feedback.

For specific pilot training procedures, we provide a suggestion for deployment assuming that LTAP will be used and there will be a need to develop new material.

1. Develop training material for novice INDOT snowplow drivers (if using LTAP).
2. Select 40 novice drivers to receive additional snowplow driver training using simulators. If not all INDOT novice drivers are scheduled to receive the training, then this group could be used as a control. A discussion may be needed to define "novice" in terms of INDOT snowplow driver, but current training procedures at INDOT seem to recommend additional training for drivers with 3 or less years plowing snow. The selection would ideally provide representation for drivers of all six districts.
3. Evaluate the intervention and control (if using) group members' perceptions of simulator and confidence levels in snowplow driving prior to the driving simulator training.
4. Provide a simulator training before (n = 20) and after (n = 20) to the drivers' yearly snow school training.
5. Evaluate drivers' perceptions of training, including mode, content, length, seat time, combination with snow school and perceptions of effectiveness.
6. After the snow season, interview, and survey intervention group to evaluate long-term retention and perceptions about the simulator training. Gather accident data from similar snow seasons to compare improvements to the number of accidents.
   - We recommend that a specific focus be to evaluate the effect of training over experience level, to determine the ideal number of drivers that should be trained with a simulator yearly (see Section 8.4 for suggestions for further research).
7. Adjust the driving simulator training utilizing driver feedback and recent reports from INDOT about past year's snowplow-related accidents.

8.2 Suggested Approach for the Deployment of Driving Simulators for INDOT Snowplow Driver Training After Pilot Implementation

Furthermore, the research team recommends the following strategies for implementing driving simulators in INDOT snowplow driver training, after successful pilot implementation.

- *Provide simulator training for novice snowplow drivers:* The focus of the training would be to improve drivers' technique and confidence level when driving in adverse conditions. Previous technical reports suggest that basic simulator training for experienced drivers is not as beneficial given that those drivers already experienced adverse conditions several times (Kihl et al., 2006; O'Rourke, 2011). Based on the findings from the pilot implementation a subset of drivers that current are considered novice (meaning 0 to 3 snow seasons of plowing snow) can be considered for yearly training.
- *Standardize simulator training across districts:* Current INDOT training is customized by each district (and sometimes subdistrict), and this seems to create a good rapport with trainees. However, due to training logistics, it might not be possible to separate trainee sessions per district or subdistrict, therefore a standardize curriculum

specific to the training with driving simulators for snowplow driving seems a better fit. Training customization on other winter maintenance training events could complement the standardized curriculum with district or subdistrict specific information.

- *Identify lead, experienced drivers that can act as technology leaders:* INDOT drivers rely a lot on tacit knowledge and learning from each other. Therefore, identifying certain drivers per subdistrict that can be more directly involved with training development or deployment is ideal. These drivers can be given additional time in the simulator and should be able to address concerns of drivers that are more reluctant to use the simulator.
- *Be prepared for some drivers to experience cybersickness:* Given the high number of INDOT drivers, some may be affected by cybersickness. Our results show that 10% of drivers that participated in the training and provided information have experienced greater than minor discomfort. This type of motion sickness may range from mild to severe discomfort that can prevent drivers to complete the in-simulator portion of the training.
- *Gather short- and long-term training retention and perceptions:* Continue to evaluate drivers' perceptions of the training immediately after the training and also after the snow season, as done by O'Rourke (2011). More important than the perception about the training is to understand which aspects of the training retention (and training scenarios) are affected by time. Furthermore, understanding short- and long-term retention allows for better long-term planning for INDOT. This includes assessing if there is a need for additional training sessions with snowplow drivers, which could reflect on training costs and making equipment acquisition more affordable for long-term.

8.3 Long-Term Recommendations

The research team makes the following four long-term recommendations.

- *Track precise location of snowplow-related accidents to establish high-risk locations.* These high-risk locations could be modeled utilizing GIS-based customization in partnership with research institutions or manufacturers and added to training modules for INDOT workers. Even though full virtual modeling of actual routes might be too resource intensive, the recurrence of accidents in one specific location may indicate a problem area that can benefit from a target modeling intervention.
- *Revise accident reports to facilitate knowledge management.* INDOT accident reports could include the most frequent types of accidents for employees to select, therefore facilitating the identification of training scenarios to be included in future pre-season training (snow-school). We additionally recommend adding some classifier about experience level, which may help identify training needs for different drivers.
- *Re-evaluate acquisition of driving simulator when technology is well established within training.* After 3 years of successful deployment of simulator in snowplow driver training, INDOT should evaluate the acquisition of driving simulator equipment, especially if INDOT can use the equipment for several programs, and not only winter operations. Some of the equipment available on the market are able to replicate different truck types that can be used for training INDOT personnel. It is important to also analyze long-term maintenance and support for the equipment if a purchase decision is made.
- *If a simulator is acquired, develop advanced training for more experienced drivers.* Certain DOT reports have suggested more advanced level of training for experienced drivers. After the training has been established in all INDOT districts, provide additional training for more experienced drivers. These training could focus on uncommon risky situations, which could be trained in a controlled environment. Furthermore, additional benefits beyond the safety of drivers and public could also be included such as improved fuel efficiency and reduced vehicle maintenance.

8.4 Suggestions for Further Research

The research team makes the following four research recommendations.

- *Further analyze the impact of snowplow experience in perceptions of effectiveness of simulator driver training.* Previous reports and our own initial results indicate that novice drivers benefit more from driving simulator training than experienced drivers. However, our pilot implementation could not provide statistically significant results. Therefore, a gap remains to understand the effect of years of snowplow driving experience to the perceptions of effectiveness of driving simulator training. Comparisons based on research can help INDOT identify target drivers for driving simulator training based on their snowplow experience level.
- *Evaluate the ideal simulator "seat time" for increase in perceived trainee confidence levels.* A gap remains in understanding how long trainees should use the driving simulator in order to increase their confidence level in plowing snow This could be measured in three periods: pre-training; immediately post-training; and after the snow season. This information can inform determine the ideal duration of driving simulator training. Furthermore, it is possible that the lack of statistically significant results of our pilot implementation is related to the duration of actual simulator training.
- *Evaluate peer learning within simulator instruction.* While in some training modes, only a trainee and an instructor are present, other modes allow for additional trainee(s) to observe a simulated drive. This observation can also lead to learning, but no research on this matter has been provided, nor to explore how many trainees could observe the simulated drive and learn from the observation. This can provide insightful information as to how many drivers should be trained in one session.
- *Evaluate the effect of work assignment in the effectiveness of simulator training to increase snowplow drivers' confidence level in their snowplow driving skills.* Previous research focuses mainly on differences between novice and experienced snowplow drivers related to the use of simulator training. No previous research was found that explores the factor of work assignment, meaning full-time snowplow drivers and transfer drivers, in the effectiveness of simulator training. Our pilot results were inconclusive but could be replicated with a more balanced sample of regular and transfer drivers to evaluate this issue. This finding can help INDOT, and

other state DOTs determine if and how much simulator training can help to increase transfer drivers' confidence level in their snowplowing skills.

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APPENDICES

Appendix A. Interview Questions for INDOT Workers

Appendix B. Pilot Interview Questions

Appendix C. Survey of State of Practice for Snowplow Driver Training in State DOTs Questions

Appendix D. Equipment Considerations for Simulators for Snowplow Driver Training Questions

Appendix E. Validation Interview Questions

Appendix F. Pilot Training Results

Appendix G. Pilot Training Survey Questions

APPENDIX A. INTERVIEW QUESTIONS FOR INDOT WORKERS

Two sets of questions were prepared by the researchers to interview current INDOT workers. One of the sets was aimed at snowplow drivers, while the second was aimed at safety managers and crews.

Interview questions for INDOT snowplow drivers.

Demographics Block

1. Age group
    a. 18–25
    b. 25–29
    c. 30–39
    d. 40–49
    e. 50–59
    f. 60+
2. How many years have you been plowing snow?
3. Are you an INDOT transfer driver for snow plowing? *This means snow plowing is not your main responsibility at INDOT.

Experience and Training

4. How would you rate your experience level at snow plowing?
    a. Not experienced at all
    b. Somewhat inexperienced
    c. Neither experienced nor inexperienced
    d. Somewhat experienced
    e. Very experienced
5. How does the yearly snow school training (snowplow driver training by INDOT) compared to the actual snowplow driving conditions?

Snowplowing Perceptions

Now, answer the next questions based on your typical experience as a snowplow driver for INDOT.

6. Can you describe a typical snow plowing day?
7. Can you describe how weather conditions may affect how you plow snow? Can you give us some examples?
8. Can you describe how road and traffic conditions may affect how you plow snow? Can you give us some examples?
9. Which types of roads have you plowed before? Can you describe your general perception of plowing snow on each of them? We are specifically interested in any pinpoints that you may have found while driving on them.

    a. Rural
    b. Suburban
    c. Urban
    d. Interstates/Highways
10. Can you describe some [ideally 3 to 5] risky situations that you have encountered or known about when driving a snowplow?
    a. Why were those risky?
    b. Can you rate how often these situations happen in the snow season?
11. Now thinking of when you started plowing for the first season. Can you describe how your first season plowing snow for INDOT was?
    a. And which resources did you use to improve your plowing technique?
        i. Colleagues
        ii. Training
        iii. Other?
12. What do you think about snowplow driving now?
13. If you had to give advice to novice snowplow drivers, what would it be?

Simulator Perceptions

14. Have you ever used a driving simulator? If so, what were your impressions of it?
15. How do you feel about training your snowplow skills using a driving simulator?
16. Is there anything else you would like to add related to snowplow driver training?

Interview questions for INDOT safety managers and crew leaders

Main Block

1. What is your role at INDOT and at which INDOT district do you work?
2. Have you ever driven a snowplow?
    a. If so, for how long and how experienced would you rate yourself?
    b. And if so, how does the yearly snow school training (snowplow driver training by INDOT) compared to the actual snowplow driving conditions?
3. How is the yearly snowplow (snow school) training put together?
    a. What are the key components of this training?
    b. How long is the training?
    c. Is there any difference between experience levels?
4. In your opinion, which risky situations should be stressed to snowplow drivers during yearly training?
    a. 3–5 most common accidents
    b. 3–5 uncommon, but serious accidents that should be addressed
5. How hands-on/practical is the yearly training?
6. Do drivers receive any type of training (during yearly training or other training opportunities) to improve fuel efficiency or reduce truck maintenance? If so, how?
7. In your opinion, what could be done to more accurately replicate the conditions snowplow drivers will encounter while in training, which usually occurs before the first snow of the season?

8. How do you feel about the use of driving simulators in training snowplow drivers?
9. Is there anything else you would like to add, related to snowplow driver training?

APPENDIX B. PILOT INTERVIEW QUESTIONS

General Information Block

1. Which state do you currently work in?
2. Can you briefly describe the winter operations in your state?
3. What type of stakeholder below best identifies you, in relation to snowplow driver training for states' DOTs?
    a. DOT employee.
    b. Researcher
    c. Vendor / Manufacturer of Driving Simulators
    d. Third Party trainer
4. How many years have you been in your current position?
5. Do you have any professional experience in terms of managing/ operating snow plow operations? If so, for how long?

Snowplowing Driving Simulator Perceptions

6. What do you know about driving simulators in snowplow driver training?
7. Have you ever conducted research or analysis about the use of driving simulators for training, and specifically for snowplow driver training? If so, can you briefly describe your experience?
8. What is your general perception regarding the driving simulators and their use in training snowplow drivers?
9. What do you think are key factors to consider in deciding to use or not to use driving simulators for snowplow driver training?
10. Do you have any concerns about adopting driving simulators for snowplow driver training?
11. What (short- and long-term) metrics do you think should be used by DOTs to track a cost-benefit analysis of the use of driving simulators for snowplow driver training? Note: *Short-term* is same snow season; *Long-term* is anything longer than same snow season

Survey Review

12. We have prepared a survey to be sent out to U.S. DOTs about decision factors related to the use of driving simulators for snowplow driver training. Can you give us feedback about the questions and if anything should be changed, removed or added? Our goal with this survey is to gather updated information about the use of driving simulators for snowplow driver training in other DOTs.

Conclusion

13. Is there anything else you would like to add related to snowplow driver training?

APPENDIX C. SURVEY OF STATE OF PRACTICE FOR SNOWPLOW DRIVER TRAINING IN STATE DOTs QUESTIONS

Block: General Information (for all respondents)
Q1. In which state Department of Transportation do you currently work?

Q2. What is your current job title?

Block: Current DOT Winter Operations (for all respondents)
Q3. During a typical year, during which of the months below are winter operations (snow and ice removal) deployed by the [state] DOT? Select all that apply.

- ▢ January
- ▢ February
- ▢ March
- ▢ April
- ▢ May
- ▢ June
- ▢ July
- ▢ August
- ▢ September
- ▢ October
- ▢ November
- ▢ December

Q4. During a typical year, how many miles of roads are subject to winter operations (snow and ice removal) deployed by the [state] DOT?

Q5. What is the estimated size of your state DOT winter operations fleet (trucks and drivers)? Please only include numbers.

Snowplow trucks (including trucks with removable plow attachment): _______
Full time snowplow drivers: _______
Snowplow transfer drivers (drivers who occasionally do snow or ice removal), including contractor drivers working for your state DOT: _______

Q6. Is there anything else that you would like to add related to [state] DOT winter operations?

Q7. Please rank the following types of risky scenarios involving snowplow drivers in terms of frequency in your state.
______ Sliding due to icy road conditions
______ Snowplow truck speeding
______ Passing Traffic
______ Objects, animals, or people on the road
______ Rear-ended accidents
______ Low visibility on surrounding environment

______ Weather conditions
______ Stopped vehicles
______ Plowing near to road edges and ditches
______ Other. Specify:

Block: Current Training (for all respondents)

Q8. How standardized is the training for winter operations in [state] DOT?

- o Very standardized—all districts or units follow the same training format and content.
- o Somewhat standardized—all districts or units have a similar structure suggested by the central office, but adaptations in content and format may be done at the district or unit level.
- o Not standardized—each district or unit manages and deploys their own winter operations training, including format and content, without the involvement of the central office
- o Other. Please describe: ______________

Q9. Typically, how many training events do snowplow drivers in your DOT participate per snow season?

	1 training event	2 training events	3 training events	4 or more training events
Novice / low experienced snowplow drivers	o	o	o	o
Experienced snowplow drivers	o	o	o	o
Transfer, contract, or occasional snowplow drivers	o	o	o	o

Q10. Typically, how many hours of training using different delivery modes do snowplow drivers receive per year? If variations occur between district and units, please use an average.

	In-person Presentations or Lectures	Practical (pre- and post-trip checks)	Practical (route driving)	Driving simulator (actual driving time)	Self-paced computer training (review of PowerPoint, recorded videos, reading materials and/or quizzes)
Novice / low experienced snowplow drivers	_____	_____	_____	_____	_____
Experienced snowplow drivers	_____	_____	_____	_____	_____
Transfer, contract, or occasional snowplow drivers	_____	_____	_____	_____	_____

Q11. From a safety perspective, how much coverage do the following risky scenarios or specific equipment typically have during your state DOT's snowplow driver training?

	Not at all	A little	A moderate amount	A lot	A great deal

Backing	o	o	o	o	o
Speeding	o	o	o	o	o
Tandem driving	o	o	o	o	o
Traffic	o	o	o	o	o
Tow plow	o	o	o	o	o
Wing plow	o	o	o	o	o
Plowing near the edges and ditches	o	o	o	o	o
Multitasking	o	o	o	o	o
Others, please specify	o	o	o	o	o

Q12. Is there anything else that you would like to add related to snowplow driver training for [state] DOT's winter operations?

Block: Snowplow simulator use and perceptions (for all respondents)

Q13. How knowledgeable are you with the use of driving simulators for CDL or snowplow driver training?

- o Not knowledgeable at all
- o Slightly knowledgeable
- o Moderately knowledgeable
- o Very knowledgeable
- o Extremely knowledgeable

Q14. Does the [state] DOT use snowplow driving simulators for training snowplow drivers?

- o Yes, we currently use simulators, or we will use the simulators in the upcoming snow season
- o Not currently, but we have used it in the past
- o No, but we are currently exploring this option
- o No, but we have explored this option in the past. Please indicate an approximate year:__
- o No, and we have never considered this option

Q15. Could you provide more information about the reasons why [state] DOT chose the approach you have selected in the previous question?

Q16. Based on your work experience, how important are the factors below for a DOT to consider using snowplow driving simulators for driver training?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Graphics realism	o	o	o	o	o
Ability to replicate vehicle dynamics and characteristics	o	o	o	o	o
Motion and sound realism	o	o	o	o	o
Customizability (including, but not only route customization)	o	o	o	o	o
Variety of manufacturer-provided routes	o	o	o	o	o
Variety of software features (ability to collect and analyzing training data)	o	o	o	o	o

Ease of relocation of simulator for training purposes	o	o	o	o	o
Cost of simulation-based training	o	o	o	o	o
Ability to conduct training in a controlled environment	o	o	o	o	o
Perceived long-term effects on public safety	o	o	o	o	o
Perceived long-term effects on operational costs (fuel and maintenance)	o	o	o	o	o
Lack of data on simulator return on investment by peers	o	o	o	o	o
Acceptance by drivers	o	o	o	o	o
Simulator equipment maintenance concerns	o	o	o	o	o

Q17. Are there additional factors you would like to include in the list above?
- o No
- o Yes. Please specify: ________________

Block: Past simulator (only for respondents from state DOTs that used simulators in the past but no longer use them)

Q18B. You have selected that [state] DOT no longer uses driving simulators for snowplow driver training but has used them in the past.
Please provide the model/manufacturer information for the last driving simulator used for snowplow driver training.

Q19B. Please provide a year range for when the driving simulators were used for snowplow driver training.

Q20B. How was the simulator utilized for snowplow driver training? Please describe also the training of drivers of different experience levels, location of training, and who were their trainers.

Q21B. Please rate the factors below in terms of how much influence each of them had in the decision of stop using driving simulators for snowplow driver training.

	Not at all	A little	A moderate amount	A lot	A great deal
Cost of simulator equipment maintenance	o	o	o	o	o
Issues with equipment operability (downtime)	o	o	o	o	o
Lack of acceptance by drivers	o	o	o	o	o
No observed benefits for operational costs (fuel and maintenance)	o	o	o	o	o
No observed benefits for public and driver safety	o	o	o	o	o

No observed skill transferability from simulator to real-world driving	o	o	o	o	o
Other. Please specify:	o	o	o	o	o

Block: Current simulator use (only for respondents that use simulators now or will be using in the next snow season)

Q18A. You have selected that [state] uses or will be using a driving simulator for snowplow driver training in the next snow season.
Please provide (a) the number of simulators it currently has and (b) their most recent model/manufacturer information.

Q19A. Since what year has [state] DOT used a driving simulator for snowplow driver training?

Q20A. Who provides the training specifically with the driving simulator for snowplow drivers? If more than one stakeholder was used, please select all that apply.

▢ DOT
▢ Manufacturer or vendor of the driving simulator
▢ Third Party Educational Partner, such as Training Center or University
▢ Other. Please specify: ______

Q21A. Please elaborate on how the simulator is or will be utilized for snowplow driver training, including the training of driver of different experience levels.

Q22A. Where is the simulator for snowplow driver training located?

- o In a building
- o Installed in a mobile trailer, so it could be moved between state locations
- o Both
- o Other configuration. Please explain: _____________

Q23A. For states that currently use driving simulators for snowplow driver training, which driving scenarios included in the simulation were considered most effective during training?

	Not effective at all	Slightly effective	Moderately effective	Very effective	Extremely effective	Not included
Urban simulation	o	o	o	o	o	o
Rural simulation	o	o	o	o	o	o
Interstate, freeway scenarios	o	o	o	o	o	o
Storm events	o	o	o	o	o	o
Night operations	o	o	o	o	o	o
Passing traffic	o	o	o	o	o	o
Bridges and overpasses	o	o	o	o	o	o
Intersections	o	o	o	o	o	o
Other. Please specify:	o	o	o	o	o	o

Q24A. Based on the crew’s training experience and results, how effective were the results of using a snowplow driving simulator?

	Not effective at al	Slightly effective	Moderately effective	Very effective	Extremely effective
Increasing employee's awareness about safe snowplow driving procedures	o	o	o	o	o
Providing a safe environment for novice snowplow drivers	o	o	o	o	o
Improving overall driver's performance	o	o	o	o	o
Reducing the overall number of snowplow related accidents	o	o	o	o	o
Reducing overall fleet maintenance	o	o	o	o	o
Reducing overall fleet fuel consumption	o	o	o	o	o
Other. Specify.	o	o	o	o	o

Q25A. Based on the responses from the drivers, how is the overall feedback on the adoption of snowplow driving simulators?

- Extremely negative
- Somewhat negative
- Neither positive nor negative
- Somewhat positive
- Extremely positive
- Block: Conclusion (for all respondents)

Q18C. Is there anything else that you would like to add regarding the decision factors when purchasing the snowplow driving simulator for snowplow driver training or about driving simulators for snowplow driver training in general?

APPENDIX D. EQUIPMENT CONSIDERATIONS FOR SIMULATORS FOR SNOWPLOW DRIVER TRAINING QUESTIONS

Q1. Company's name: ____

Q2. Address of your company's office that is nearest to Indianapolis, IN: ______________

Q3. Company website (URL): ____

Q4. As mentioned previously, we are interested in gathering information about (a) driving simulators that can be used for snowplow driver training and (b) that are currently available in the United States market. Taking this into consideration, how many different driving simulators models for snowplow driver training does your company have? Add-on options should not be considered different options. The following questions in the survey will take your answer to this question in consideration and we will ask information for each model you have that can serve the purpose of snowplow driving simulations for training.

- 0
- 1
- 2
- 3
- 4
- 5

Q5. This set of questions will cover information about the [number of simulator]/[total number of simulators] driving simulator that your company provides for snowplow driver training.

Q6. Driving simulator model name and number: _____________________________

Q7. Enter a brief description of the model. If there are upgrades available, please do NOT include them here. If you have a website that includes this information, please include the URL in this box.

Q8. If you have a brochure for the equipment that you would like to share with us, use this space to submit a pdf file.

Q9. What is the base cost for this model? If possible, please give precise number, if not, give a range. Only include cost for equipment.

Q10. Does this equipment offer any type of haptic feedback, such as motion or vibration?

- Yes. Please describe type of haptic feedback: __________________________
- No.

Q11. Does this equipment offer any type of audio interaction, such as engine or cars passing?

- Yes. Please describe type of sound feedback: __________________________
- No.

Q12. Please describe the screen and visuals characteristics of the model, such as field of view, definition, and refresh rate.

Q13. List virtual scenarios available including critical events in this base model.

Q14. Can scenarios be customizable in this model, such as custom routes or critical events?
- o Yes. Please describe any requirements or limitations to the customization: _____________
- o No.

Q15. Are there additional charges for scenario customization?
- o Yes. Please explain: ____
- o No.

Q16. List any upgrades / add-ons that are not included in the primary package. _______________

Q17. Where can you install this equipment?
- ▢ Fixed installation. Once installed, equipment can only be moved by manufacturer
- ▢ Fixed installation, but equipment can be relocated by client
- ▢ Mobile trailer installation
- ▢ Other. Please describe: _______

Q18. Is the model covered by a warranty?
- o Yes – unlimited warranty. Please inform for how long: _____________________________
- o No – limited warranty. Please inform for how long: _________________________________
- o No
- o Other. Please explain: ____

Q19. Please describe any future maintenance considerations (hardware and software) recommended by your company for the model.

Q20. Are training services provided with the equipment?
- o Yes, and we only sell the equipment and the training combined
- o Yes, but training is an add-on option. Include average cost of training: _______________
- o No
- o Other. Please describe: ____

Q21. For how many years has this model been available within the United States market?
- o Less than 1 year
- o 1 to 3 years
- o 4 to 9 years
- o 10 or more years

Q22. Approximately how many units of the current model have you sold in the United States?

Q23. Do you know how many US DOTs currently use this model?

Q 24. Do you have any additional information you would like to tell us about this model?

APPENDIX E. VALIDATION INTERVIEW QUESTIONS

Block: General Information
Q1. In which state Department of Transportation do you currently work?

Q2. What is your current job title?

Q3. How much involvement do you have in the training of [state]DOT snowplow drivers?

Block: Current DOT Winter Operations and Training
Q4. Can you describe your state DOTs' typical winter operations in terms of reach (miles plowed per snow season) and fleet (plows and drivers)?

Q5. How are your state DOTs snowplow drivers typically trained in a year?
If not directly answered, follow up with:
Are these standards throughout the state or are there changes per district?
How many hours are drivers typically trained per year?
When does training typically happen?
Are there changes based on experience or assignment type (such as transfer drivers, or drivers whose main assignment is other than plowing snow)?

Q6. Can you elaborate on how your DOT uses driving simulators to train snowplow drivers?
If not directly answered, follow up with:
How long have you been using driving simulators to train snowplow drivers?
How were simulators incorporated in training?
Who owns the simulator used by [state]DOT for this purpose?
What is the current model used in your [state]DOT training?

Q7. Does [state] DOT track any data related to the success of using driving simulators in snowplow driver training?
If not directly answered, follow up with:
Has there been any relevant changes in winter operations due to the use of driving simulators? And if so, can you give some specific examples?

Q8. Before we show you some draft recommendations, we are proposing related to the use of driving simulators for snowplow driver training, we would like you to describe any *benefits* and *concerns* related to the use of driving simulators that you have identified in your experience working for [state]DOT.

Block: Validation of factors selection
Before we show you our recommendations, we would like to show you a graphical image (a mind map) that depicts that factors that were considered in this decision process. We have utilized an existing framework called Technology Organization-Environment that organizes organizational decision-making factors, which in our case is deciding or not to use driving simulators in the training of DOT snowplow drivers, along these three contexts. In our case, technology factors are related to the technology being considered; organization describes factors

related to the specifics of an organization, including size, resources, and current operations; and environment discusses factors that are linked to high-level socio-economic and regulatory aspects [show mind map]. You may ask questions if you want. [wait 1 min to see if they have questions]. Now we would like to ask you a few questions:

Q9. What do you think about the appropriateness of these contexts (technology organization-environment)? Would you suggest other type of arrangement?

Q10. What is your general perception about the factors included in this table? Any factors that you would include or remove from the following context?

Technological
Organizational
Environmental

Block: Validation Questions
Now, we would like you to read through our recommendations to INDOT related to the use of simulators for snowplow driver training (bullet point list format, two pages maximum).
[show visual of recommendations]

Q11. Based on your experience, what do you think about:

Overall recommendation
Specific approach for deployment
Specific long-term considerations

Q12. Is there anything we could be missing or have not considered?

Q13. Anything else you would like to add related to the use simulators in the training of snowplow drivers?

APPENDIX F. PILOT TRAINING RESULTS

A pilot implementation was conducted in December 2022 with the primary goal of gathering initial data on (1) effectiveness of using driving simulators for snowplow driver training, and (2) perceptions of current snowplow drivers about the use of simulator for training. Due to the short time to organize the training, training services were provided by one of the manufacturers of snowplow driving simulators. This training was considered a basic training for snowplow drivers and lasted for two hours, combining lecture and simulated drives. The training was delivered in a mobile (trailer) unit, in which two driving simulators were installed. Up to four drivers could attend the training for each session.

The training occurred at two INDOT locations from different districts, during two weeks in December. The researchers went to the training location and collected information from participants using two surveys: one pre-training survey and one post-training survey. The survey instruments can be found in Appendix G. 67 drivers were selected by INDOT and participated in the training in both weeks. Of those, 64 trainees participated in the study and completed the surveys.

The data gathered from the completed surveys was then tabulated and analyzed descriptively, and then inferentially. Inferential tests included (1) a sign test to evaluate significant differences in confidence level of drivers before and after the training (using a significance level of $\alpha = 0.05$), and (2) a logistical ordinal regression to evaluate the contribution of certain factors (age, gender, experience, work assignment and discomfort in using simulator) in the difference of confidence level of drivers before and after training.

It is important to note that the information was gathered immediately before and immediately after the simulator driver training. Long-term retention and perceived usefulness of the training by drivers were not measured during the pilot implementation. Furthermore, we note that the sample size consisted of 3.12% of the current number of INDOT snowplow drivers.

Demographic information of participants

Based on the responses received (n = 64), participants represented a wide spread of age. Each of the age groups presented in the survey had at least one response and the group with most respondents was the 50 to 54 age group (n = 10). Figure F.1 represents a summary of participants from various age groups. Furthermore, in terms of gender, male drivers where a majority of the total participants (n = 60) compared to female drivers (n = 4).

As for the experience, the drivers participating in this study had a minimum of 0 snow seasons to a maximum of 44 snow seasons driving a snowplow for INDOT. The results also show an average of 5.73 snow seasons and a median of 3 snow seasons per participant. This means that close to half of the participants (51.5%, n = 33) were within 0–3 years of experience and could be considered as "novice" drivers.

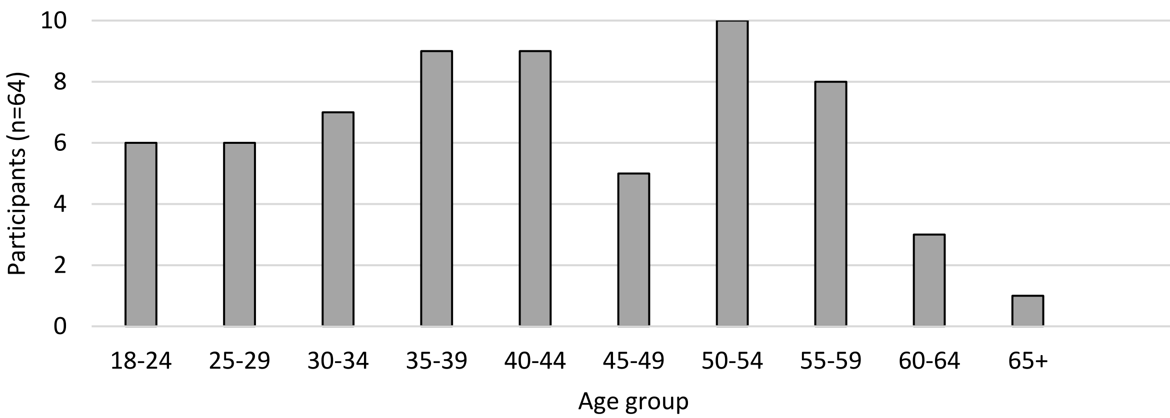

Figure F.1 Age groups of snowplow drivers.

When asked for participants' major task at INDOT, 64 responses were recorded, in which a large number of participants (n = 49) indicated that they were placed at the maintenance department where snowplowing is their primary winter work assignment. The survey allowed participants to indicate other departments, and fifteen participants utilized this option. Based on their answers, the researchers classified fourteen of these respondents as transfer drivers (which also included employees from heavy equipment operations, communications, and trainers). Moreover, one participant indicated that he was a "full-time employee" at the INDOT and could not be further classified into a regular or transfer driver.

Participants were also asked for any previous experience in driving simulator. Among the 62 collected inputs, most participants (n = 57) indicated that they did not have any experience with the simulator, while a small portion of them (n = 5) informed that previous experience with a driving simulator. Additionally, perceptions collected at the end of the pre-training survey from five respondents. The responses indicated that more hands-on training should be provided to novice drivers (n = 2), that training using the driving simulator could be very useful (n = 2), and that more education opportunities are welcomed (n = 1).

Descriptive statistics results

The pre-training and in the post-training survey included a question with fifteen items for participants to rate their comfort level while operating an INDOT snowplow truck. Items included routine driving actions, such as plowing near ditches and edges and overtaking vehicles. The rating used a Likert-type scale with five options from "extremely uncomfortable," to "extremely comfortable." Based on participants' inputs, positive observations regarding comfort in training using a driving simulator were noted across all fifteen items, with an average increase of 6.06%, from an average of 4.29 in the pre-training survey to 4.55 in the post-training survey. Moreover, plowing near ditches and edges recorded the largest average gain in comfort level (12.6%), followed by plowing during the whiteouts (11.8%), and multitasking to the control equipment (10.6%). An additional interesting finding was that the standard deviation (SD) of the responses reduced in all items. Table F.1 presents the mean and SD per item of before and after the simulator training.

Table F.1 Participants' comfort level* before and after the simulator training

Items	Pre-training*			Post-training*			Mean Difference (%)
	N	Mean	SD	N	Mean	SD	
Plowing near ditches and edges	62	3.98	1.08	62	4.48	0.64	+12.6%
Plowing during whiteouts	62	3.69	1.17	62	4.13	1.07	+11.8%
Multitasking to control equipment (salt deposition, blade, etc.,)	62	4.11	1.10	60	4.55	0.72	+10.6%
Avoiding small objects (such as mailboxes and road signs) when plowing	62	4.13	0.94	61	4.56	0.61	+10.4%
Overtaking other vehicles	64	4.11	1.05	63	4.43	0.76	+7.8%
Avoiding large objects (such as parked cars and pedestrians) when plowing	62	4.23	0.92	62	4.55	0.76	+7.6%
Reversing	64	4.27	0.91	62	4.56	0.56	+7.0%
Maintaining control of vehicle		4.44	0.78	62	4.65	0.72	+4.7%
Merging and exiting highway/interstates	64	4.38	0.89	63	4.57	0.61	+4.5%
Driving in tandem	62	4.32	1.01	62	4.52	0.88	+4.5%
Judging stopping distances	64	4.50	0.79	62	4.66	0.57	+3.6%
Changing traffic lanes	64	4.44	0.85	63	4.56	0.61	+2.7%
Turning right	64	4.61	0.76	63	4.71	0.55	+2.3%
Parking	64	4.64	0.65	62	4.74	0.51	+2.2%
Driving at appropriate speed for different road conditions	64	4.50	0.68	62	4.60	0.58	+2.2%

*Rate of comfort level measured from 1 = extremely uncomfortable; 2 = somewhat uncomfortable, 3 = neither uncomfortable nor comfortable; 4 = somewhat comfortable; 5 = extremely comfortable.

Following, participants were provided with a question asking for their confidence level while operating INDOT snowplow truck, in which a similar Likert-scale was provided with five options from "not confident at all" to "extremely confident". The pre-training average for this question resulted showed an average score of 3.91 (SD = 1.01, n = 64), while the post-training average for the same question showed an average of 4.27 (SD = 0.83, n = 62). Therefore, the results show a gain of 9.2% between the pre-training and the post-training mean scores.

Moreover, participants were asked to rate the level of interest when training with snowplow driving simulator. Similarly, a Likert-type scale was used in this question with five options from "not interested at all" to "extremely interested." From the 64 received responses, 4 participants did not seem interested in using a simulator, while the other 60 ranged from slightly to extremely interested. Respondents' average interest level for this question was 3.70 (SD = 1.14), with a median interest of 4 ("very interested").

The following paragraphs includes more results from the post-training survey, including participants' perceptions about the equipment, discomforts felt during training, and the training delivery.

Following perceptions of confidence, participants were asked for their perceptions regarding simulator's hardware and software. To do this, they were asked to rate items using a Likert-type scale with five options from "terrible" to "excellent." Based on the responses, audio input was the received highest average score, followed by the range of scenarios used in the training, and the equipment responsiveness. Table F.2 summarizes the participants' perceptions toward simulator hardware and software features. It was also noted that in terms of accuracy, the equipment was rated as moderate capability to replicate real-world experiences (n = 61, mean = 3.43, median = 3).

Table F.2 Participants' perceptions toward simulator software and hardware features

Items	**N**	**Mean***	**SD**
Audio input (sound)	60	4.32	0.76
Range of scenarios used in training	61	4.30	0.73
Equipment responsiveness (how quickly the simulated truck responded to your physical input)	61	4.22	0.84
Haptic input (vibration or other tactile sensation)	60	4.21	0.79
Believability of scenarios	61	4.18	0.82
Visual input (graphical quality)	61	4.18	0.90
Simulator fidelity to the controls of a INDOT snowplow truck	61	4.11	0.73

*Perceptions level measured from 1 = terrible; 2 = poor, 3 = average; 4 = good; 5 = excellent

When asking for any physical discomforts such as headaches, nauseas, or dizziness when doing the simulator training, 60 responses were recorded, Similarly, participants were provided with a Likert-scale with five options from "not at all" to "a great deal". From the collected responses, most drivers indicated that they did not experience any physical discomforts (n = 49), while we also noticed that three participants implied that they experienced a lot or a great deal of physical discomfort during the training. Table F.3 summarizes the number of participants experienced different level of discomforts during the simulator training.

Table F.3 Number of participants who experienced different levels of discomfort (n = 60)

Level of discomforts	**Number of responses**
Not at all	49
A little discomfort	5
Moderate amount (my driving was affected)	3
A lot (utilizing the simulator was difficult)	2
A great deal (I could not complete the training)	1

Following, participants were asked about aspects of the training they found most useful using a Likert-type scale with five options from "not useful at all" to "extremely useful" were given to the participants. Based on the 59 responses, the content about communication received the highest average score, then followed by the classroom and lecture portion, and the overall training. Table F.4 provides a summary of the participants' perceptions toward different aspects of the simulator training. In addition, using a Likert-type rating scale, participants were asked about the adequacy of time using the simulator during the training, which we will call here as ‘seat time’. Responses indicate the most drivers found the time to be probably or definitely adequate (n = 62, mean = 4.13, SD = 0.87).

Table F.4 Participants’ perceptions toward different aspects of the simulator training (n = 59)

Items	**Mean***	**SD**
Content about communication	4.31	0.81
Classroom / lecture portion	4.29	0.80
Overall training	4.25	0.93
Content about speed management	4.24	0.93
Content about space management	4.22	0.86
Content on non-routine situations	4.19	0.87

*Usefulness level measured from 1 = not useful at all; 2 = slightly useful, 3 = moderately useful; 4 = very useful; 5 = extremely useful

Upon the finalization of the post-training survey, participants were asked if they would make recommendations of the simulator training to drivers from different categories such as novice driver, transfer drivers, and experienced drivers. Following the previous approaches, a Likert-type scale with five options from “definitely not” to “definitely yes” were provided to the participants. Results from this question show that 45 participants would definitely recommend the simulator training to the novice snowplow drivers (mean = 4.71), followed by the transfer drivers (mean = 4.34). Table F.5 summarizes participants’ recommendations and perceptions regarding allocated time of the training.

Table F.5 Participants’ recommendations for the use of driving simulator training

	Number of respondents		
Items	**Drivers with ≤ 3 years of experience**	**Transfer drivers with ≥ 4 years of experience**	**Regular drivers with ≥ 4 years of experience**
Definitely not	1	1	1
Probably not	0	3	7
Undecided	0	4	4
Probably yes	13	16	19
Definitely yes	45	32	27
Total	59	56	58
Mean*	4.71	4.34	4.13
SD	0.64	0.95	0.87

* Recommendation and allocated time level measured from 1 definitely not; 2 = probably not, 3 = undecided; 4 = probably yes; 5 = definitely yes.

In the post-training survey, participants were provided with three open-ended questions, in which they could choose to provide more customized information. The first question asked for participants’ opinions regarding the most effective parts of the training, and a total of 49 responses were recorded and aggregated into major themes for analysis. Responses indicate that for all these 49 respondents at least some portions of the simulator training were helpful for them. To be more specific, 13 participants indicated that all portions of the simulator training were effective. In addition, 24 participants found that the simulator driving portion was particularly helpful for them because it consisted of hands-on practice opportunity along with various scenarios and driving conditions. The remaining 12 participants pointed out they found classroom portions along with the instructor were informative.

Finally, participants were asked for additional information regarding winter operations and simulator training, to which 21 provided valid inputs that were aggregated into major themes for analysis. Among them, various suggestions were made for the simulator training. For example, participants indicated that the simulator should be adopted by INDOT (n = 5) two of which further suggested that the simulator should be adopted at unit level for practice, suggested in general that the simulator training was great (n = 4), and they pointed out that the simulator training should be provided to new hires at the snow school (n = 3). Other feedback from the respondents (n = 9) included that more highway and interstate training scenarios should be added to the simulator training, adding common truck issues such as flat tires, plow breaks, as well as more time for simulator training.

Inferential Statistics Results

First, the researchers intended to perform an exact Sign test to evaluate if there was a significant median difference in confidence level of trainees before and after the training with the driving simulator. Sixty-four participants provided responses about their confidence level in the pre-test, but only 62 provided information about the same variable in the post-test, so only 62 cases were considered for the present analysis. Upon closer evaluation of the data, it is noted that of the 62 respondents, 40 participants did not experience any difference of confidence level from the pre-training test to the post-training test, while two respondents experienced a decrease in confidence level and 20 have experienced an increase. Though a sign test could be performed, the large number of respondents that did not experience a difference would have rendered the results irrelevant. Future replications could consider a larger sample size and a different scale (with a larger spread) to reduce the number of tied responses between pre- and post-training responses and we stress that the descriptive statistics showed a 9.4% increase between the mean pre-training confidence level and the mean post-training confidence level.

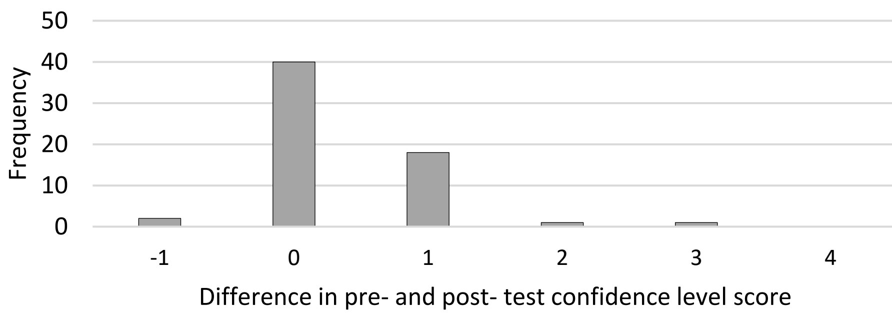

Figure F.2 Frequency of differences of confidence level from pre- to post-training test.

Following, the research team utilized SPSS software to run a cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of type of driving assignment (regular or transfer) and experience level (novice, average and experienced) on the difference between pre- and post-training confidence level on plowing snow for INDOT. The model tested is represented by the following equation:

$$Y_{difference} = \beta_0 + \beta_{1(experience)} + \beta_{2(type\ of\ driver)}$$

In preparation for this test, the researchers had to transform the difference score, which was originally measured by subtracting the pre-training score from the post-training score. The differences computed ranged from -1 to 3, as illustrated in Figure F.2. These differences were then classified into negative (-1 scores), neutral (0 scores) and positive (+1, +2 and +3 scores). For this analysis, the driver that provided "full-time employee" in the input for type of driver was categorized as a "regular driver," representing the median type of driver in the sample. Two drivers did not input a value for their comfort level post-training and were excluded of the analysis, resulting in a sample size of 62. Furthermore, experience level was grouped into novices (≤3 years of experience), medium (between 4 and 6 years of experience) and high (≥ 7 years of experience).

To do this, the researchers checked the model to assure the assumption of proportional odds using a test of parallel lines ($p = 0.266$). Upon closer inspection of the model, however, it was noted that about one third of the potential combinations were not represented in the actual data collected (about 33.3% of them). This can compromise the goodness-of-fit of the model, so interpretation should be taken with caution. The pseudo R^2 value for the model was (McFadden) pseudo $R^2 = 0.023$, furthering caution when interpreting results. For the proposed model, the deviance goodness-of-fit test indicated that the model was a good fit to the observed data, with $X^2(7) = 9.862$, p = 0.197. However, the final model did not statistically significantly predict the dependent variable over and above the intercept-only model, $X^2(3) = 2.176$, p = 0.537. This result should be taken with caution, given the lack of combinations in the measure data.

Recommendation for Future Pilot Studies

Given the inconclusive results of the inferential tests, the research team has recommendations for future testing. First, we recommend that the drivers' comfort level in the pre- and post-training surveys be measured in a 0 to 100 scale. The larger spread of this scale will allow for less ties between pre- and post-training comfort level, making the use of a sign test acceptable. To improve the logistic regression results, we recommend a more balanced number of transfer and regular drivers, given that near 90% or participants in this pilot implementation were regular drivers.

APPENDIX G. PILOT TRAINING SURVEY QUESTIONS

Pre-intervention questions (to be completed before the training).

Demographics

Circle your age group: 18–24 | 25–29 | 30–34 | 35–39 | 40–44 | 45–49 | 50–54 | 55–59 | 60–64 | 65+ | Prefer not to say

Circle your gender: Male Female Prefer not to say

How many snow seasons have you been plowing snow for INDOT?
Note: Only count snow seasons that you have plowed snow for INDOT, which might be less than the number of years you have been working for INDOT.

Have you plowed snow before you started plowing snow for INDOT? Yes | No

What is your main work assignment at INDOT?
Maintenance department (snowplowing is main winter assignment)
Other department (transfer driver, meaning snowplowing is an occasional winter assignment)
Other (please describe):

Winter Operations

Based on your previous driving experience and your judgement, rate ***your comfort level** driving an INDOT snowplow truck (see example in figure above) to perform the tasks outlined in the next two pages.* Circle or mark with X over option that best matches your self-perception.

Overtaking other vehicles	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Changing traffic lanes	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Turning right	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Judging stopping distances	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Merging and exiting highway/interstates	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Driving at appropriate speed	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable

for different road conditions					
Reversing	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Parking	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Driving in tandem	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Plowing near ditches and edges	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Avoiding small objects (such as mailboxes and road signs) when plowing	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Avoiding large objects (such as stopped or parked cars and pedestrians) when plowing	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Plowing during whiteouts	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Multitasking to control equipment (salt deposition, blade, etc.,)	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Maintaining control of vehicle	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable

What is your current *confidence level* in your snowplow driving skills *utilizing an INDOT snowplow truck to perform winter maintenance operations, including snowplowing and treating roads during the snow season*?
Not confident at all
Slightly confident
Moderately confident
Very confident
Extremely confident

Perceptions of Simulator
Have you had previous experience in a driving simulator? Yes No

How interested would you be about training your snowplow skills using a driving simulator?

Not interested at all
Slightly interested
Moderately interested
Very interested
Extremely interested

Closing
Is there anything else you would like to add related to winter operations driver training or snowplow driver training using a simulator?

Post-intervention questions (to be completed after the training)

Winter Operations
Based on the training you have just received, your previous driving experience and your judgement, rate ***your comfort level*** *driving an INDOT snowplow truck (see example in figure above) to perform the tasks outlined in this and the next two pages.* Circle or mark with X over option that best matches your self-perception.

INDOT Snowplow

Overtaking other vehicles	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Changing traffic lanes	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Turning right	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Judging stopping distances	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Merging and exiting highway/interstates	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Driving at appropriate speed for different road conditions	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Reversing	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable

Parking	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Driving in tandem	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Plowing near ditches and edges	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Avoiding small objects (such as mailboxes and road signs) when plowing	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Avoiding large objects (such as stopped or parked cars and pedestrians) when plowing	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Plowing during whiteouts	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Multitasking to control equipment (salt deposition, blade, etc.,)	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable
Maintaining control of vehicle	Extremely Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Extremely comfortable

What is your current *confidence level* in your snowplow driving skills *utilizing an INDOT snowplow truck to perform winter maintenance operations, including snowplowing and treating roads during the snow season?*
Not confident at all
Slightly confident
Moderately confident
Very confident
Extremely confident

Perceptions of Simulator Training (interactions with hardware and software)
How involved were you in the virtual environment experience?
Not involved at all
Slightly involved
Moderately involved
Very involved
Extremely involved

Please rate your perceptions (from “terrible” to “excellent”) about specific hardware and software features in the simulator. Circle or mark with X over option that best matches your answer.

Equipment responsiveness (how quickly the simulated truck responded to your physical input)	Terrible	Poor	Average	Good	Excellent
Simulator fidelity to the controls of a INDOT snowplow truck	Terrible	Poor	Average	Good	Excellent
Visual input (graphical quality)	Terrible	Poor	Average	Good	Excellent
Audio input (sound)	Terrible	Poor	Average	Good	Excellent
Haptic input (vibration or other tactile sensation)	Terrible	Poor	Average	Good	Excellent
Believability of scenarios	Terrible	Poor	Average	Good	Excellent
Range of scenarios used in training	Terrible	Poor	Average	Good	Excellent

How accurately did the simulator equipment seem to replicate your real-world experiences?
Not accurately at all
Slightly accurately
Moderately accurately
Very accurately
Extremely accurately

Did you experience any physical discomfort (such as headache, nausea, dizziness) while driving the simulator?
Not at all
A little discomfort (did not impact driving)
A moderate amount (my driving was affected)
A lot (utilizing the simulator was difficult)
A great deal (I could not complete the training)

Perceptions of Simulator

Rate the usefulness of specific aspects of the simulator training, including the lecture portion. Circle or mark with X over option that best matches your answer.

Overall training	Not useful at all	Slightly useful	Moderately useful	Very useful	Extremely useful
Classroom / lecture portion	Not useful at all	Slightly useful	Moderately useful	Very useful	Extremely useful
Content on non-routine situations	Not useful at all	Slightly useful	Moderately useful	Very useful	Extremely useful
Content about speed management	Not useful at all	Slightly useful	Moderately useful	Very useful	Extremely useful
Content about space management	Not useful at all	Slightly useful	Moderately useful	Very useful	Extremely useful
Content about good communication	Not useful at all	Slightly useful	Moderately useful	Very useful	Extremely useful

Would you recommend this training for other snowplow drivers?

Novices snowplow drivers (0 to 3 years plowing snow)	Definitely not	Probably not	Undecided	Probably yes	Definitely yes
Transfer snowplow drivers with 4+ years plowing snow on occasion	Definitely not	Probably not	Undecided	Probably yes	Definitely yes
Experienced full-time snowplow drivers with 4+ years plowing snow full time)	Definitely not	Probably not	Undecided	Probably yes	Definitely yes

Was the time allocated for you to drive the simulator equipment adequate?
Definitely not
Probably not
Undecided
Probably yes
Definitely yes

Which part of the training do you think was most effective and why?

Any specific feedback you would like to share about the trainer?

Closing

Is there anything else you would like to add related to winter operations driver training or snowplow driver training using a simulator?

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

About This Report

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