DEPARTMENT OF TRANSPORTATION

# Development of a Mobile App for Reporting Work Zone Intrusions

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Work zone intrusions represent a significant safety risk to workers. To help better understand these situations, the Minnesota Department of Transportation partnered with the University of Minnesota to create a method to document intrusion events. This information provides a deeper understanding of the circumstances under which these events occur and enables data-driven decision making when considering ways to reduce or mitigate work zone intrusions. This work focuses on the development of a mobile smartphone app that allows workers to report intrusions from the field immediately after they occur, allowing for timely and accurate intrusion reporting. The work zone intrusion mobile app is developed using an iterative, user-centered design process that solicits feedback from work zone personnel, supervisors, and work zone safety stakeholders at every step in the process. The app uploads completed report data to the existing eSAFE system, allowing for a single repository of collected intrusion report data. To support deployment of the system, training workshops and supporting training and communications materials are created for distribution among users. Throughout the development and deployment of the app, user feedback shows that the app is easy to use and well liked.


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# Development of a Mobile App for Reporting Work Zone Intrusions

## FINAL REPORT

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# EXECUTIVE SUMMARY

In response to the critical safety risks that work zone intrusions have on maintenance workers in Minnesota, the University of Minnesota research team collaborated with MnDOT to design a smartphone-based work zone intrusion data entry tool. This smartphone application was developed to ensure it was easy to navigate, quick to use, and collected analyzable data from workers in the field. The intent of this data capture system was to allow MnDOT to track intrusion trends, risk factors, and develop countermeasures to reduce the likelihood of intrusions and improve worker safety

The Work Zone Intrusion Reporting App's user interface was developed through an iterative, worker-centered design process to allow workers to indicate basic information, report the presence of critical risk factors, and intelligently reveal a short- or long-form report according to the intrusion's reported risk. Multiple designs were evaluated through usability testing with MnDOT maintenance workers and supervisors who provided feedback after interacting with the different app prototypes. Goals of the user testing were to establish usability differences between different input methods and navigational styles, address process issues, resolve any confusing interface issues, reduce usage errors, and ensure high user acceptance. Following multiple rounds of user testing, MnDOT work crew end-users helped the research team determine optimal final design features, content, and aesthetics to meet worker expectations. These methods were extended to the creation of the intrusion report's alternate paper-based form.

The key features of the smartphone reporting application, which were then duplicated in the paper form, were an option to provide an abbreviated version of the report should an intrusion be reported as minor in severity, a display and selection mechanic that allowed for easy visual scanning of the questions and options with judicious use of screen space, an agreement on which questions were relevant for both MnDOT central office and work crews, and a common understanding of the terms used for the work zone characteristics so that comprehension was quick and intuitive. Afterward, a set of training materials, training sessions, and a preliminary test deployment of the application was conducted to determine any downstream issues that could occur in the product's lifecycle. The report analysis from the test deployment suggested significant potential in detailing useful and actionable information about work zone intrusions, including the distribution of intrusions throughout the week, the most common types of intrusions, and what safety equipment tended to be most effective in mitigating risk.

The research team created a communication plan to distribute work zone intrusion training and educational materials. The goal of the plan was to 1) raise awareness of the application and its purpose, 2) increase stakeholder buy-in for the importance of work zone intrusion reporting, and 3) educate users about the contents and functions of the application. Finally, long-term data management options and other backend issues were identified and detailed for use by relevant stakeholders and internal project champions. It was determined that the app would be developed for the Apple iPhone. This platform was targeted due to the preference within MnDOT IT to provide employees with iPhones. In addition to implementing the app's core functionality, work also included collaborating with MnDOT IT partners in the creation of an HTTP application programming interface (API) through which the app would authenticate users (i.e., verify their username and password) and upload completed intrusion reports.

# CHAPTER 1: INTRODUCTION

## 1.1 PROJECT MOTIVATION AND BACKGROUND

Work zones have become an increasingly important issue in terms of traffic safety for traffic engineers and safety analysis (Mokhtarimousavi et al., 2021). Work zones are needed to maintain the quality of roadways, in order to support economic activity, quality of life, and safety, but this comes at the cost of increased crash risk and crash occurrences (Sayed et al., 2021). According to the National Institute for Occupational Safety and Health (NIOSH, 2022), work zone deaths have been increasing since 2015, with an average of 794 deaths per year. Moreover, NIOSH reports that since 2003, an average of 123 workers have been fatally injured each year in road construction sites in the United States. The infrastructure of work zones, particularly their tendency to change the road geometries and introduce change to the roadway increases crash risk and crash severity (Garber & Zhao, 2002, Khattak et al., 2002). Some of these risks in work zones may be influenced by a combination of factors with some features providing a protective effect (e.g., flaggers present) and some increasing risk (e.g., two-lane roadways, Li & Bai, 2008).

The true frequency of work zone crashes may be underrepresented in crash data because they are too minor to meet internal or external reporting thresholds (Wang et al., 1996). This problem may be even more pronounced for documenting near-miss or intrusion events in work zones. A more recent transportation research synthesis surveyed work zone reporting practices across 19 states and found that few states employed a standardized method to document work zone intrusion data (MnDOT, 2015). Further, there may be confusion by reporting officers when documenting a crash on whether a crash is related to a work zone or how to properly denote its work zone association in the reporting document (Wang et al., 1996). This highlights the burdensome and often error-prone process of documenting actual work zone crashes. Such burdens would likely extend to work zone intrusion reporting. The previous research synthesis confirms that work zone intrusion reporting is perceived to be time consuming or burdening for safety managers or supervisors (MnDOT, 2015).

To address the serious safety concerns of work zone intrusions (FHWA, 2015), MnDOT worked with the University of Minnesota (Morris et al., 2018) to create a method to document the factors that may result in their occurrence since a national standard does not exist (MnDOT, 2015). This project resulted in a better understanding of the organizational and procedural considerations of how a novel data capture process could fit within the typical maintenance workflow and what data (i.e., elements and attributes) would be easy to document and result in greater insight into the contributing factors of work zone intrusions.

The research team employed an iterative, worker-centered design approach to create a simple web-based data entry tool that was easy to navigate, collected analyzable data, and was quick to use. The human-machine interface was built to allow workers to indicate basic information, report the presence of critical risk factors, and could intelligently reveal a short- or long-form report according to the

intrusions' risk. Figure 1.1 through Figure 1.3 show the prototype web interface developed as a part of this prior work.

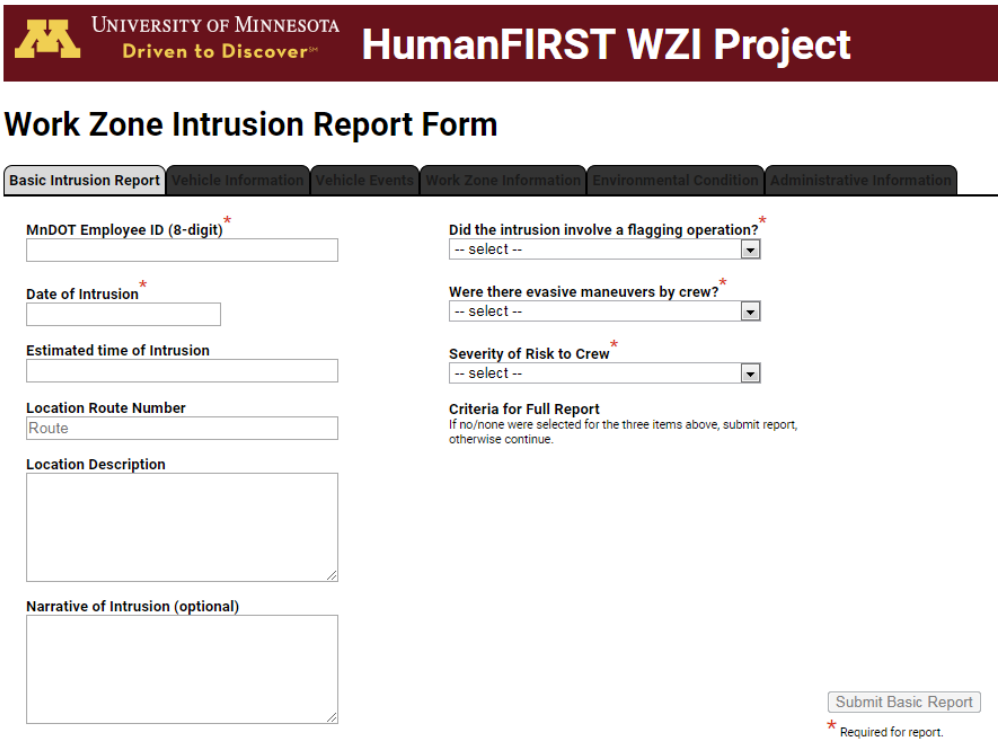



**Figure 1.1 Web Interface – Basic Report Screen (no data entered) (Morris et al., 2018)**

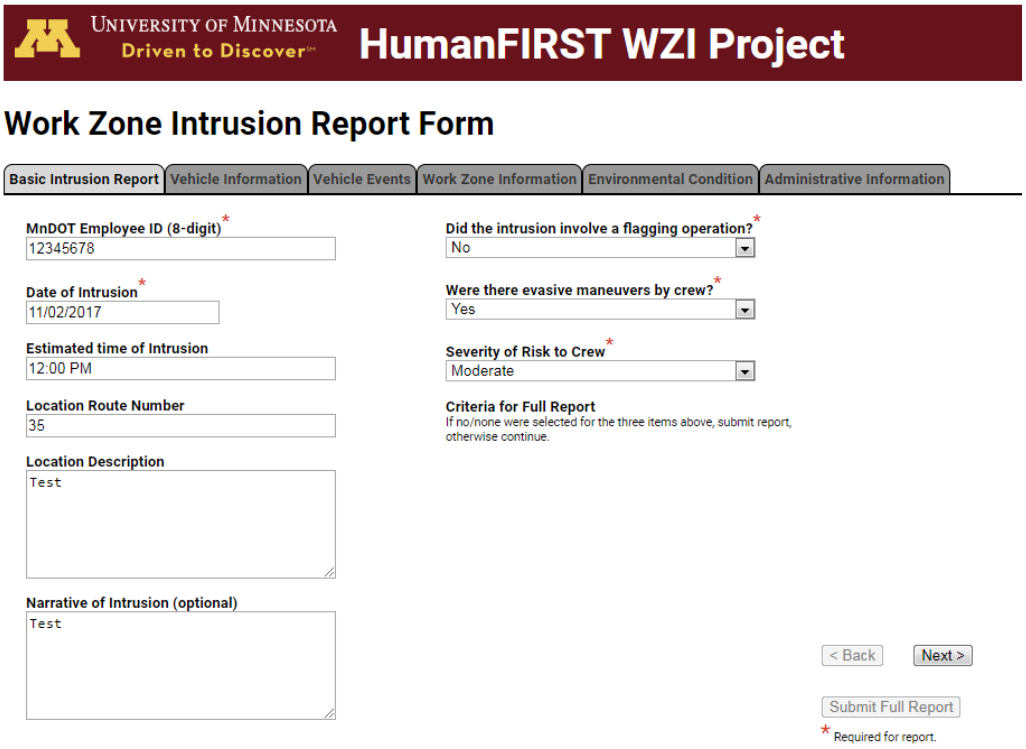



Figure 1.2 Web Interface - Basic Intrusion Report Screen (triggering full report) (Morris et al., 2018)

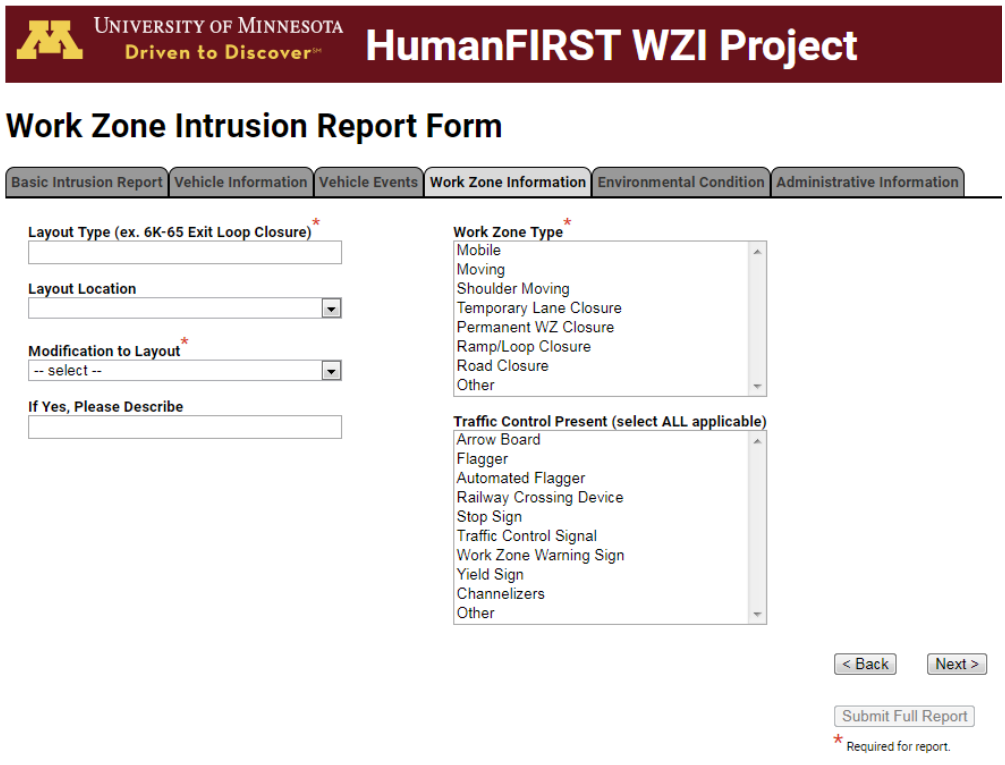
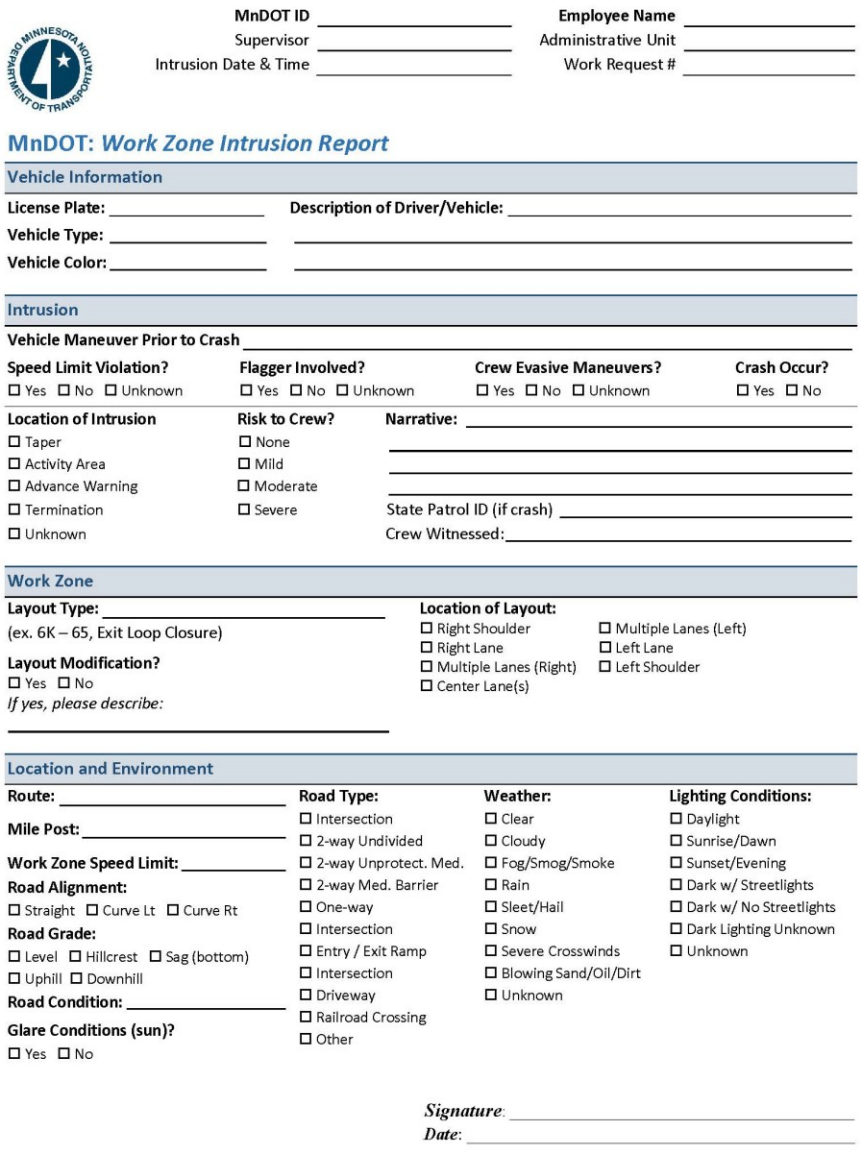



Figure 1.3 Web Interface - Work Zone Information Screen (Morris et al., 2018)

In addition to the web-based data entry system, the team worked with maintenance personnel to create a worker-friendly, paper-based form that would support in-field intrusion reporting without a smartphone, allowing for later transcription of the intrusion details into the web interface (Figure 1.4).



MnDOT ID _____ Employee Name _____
Supervisor _____ Administrative Unit _____
Intrusion Date & Time _____ Work Request # _____

**MnDOT: *Work Zone Intrusion Report***

**Vehicle Information**

**License Plate:** _____ **Description of Driver/Vehicle:** _____
**Vehicle Type:** _____
**Vehicle Color:** _____

**Intrusion**

**Vehicle Maneuver Prior to Crash** _____

**Speed Limit Violation?** ☐ Yes ☐ No ☐ Unknown
**Flagger Involved?** ☐ Yes ☐ No ☐ Unknown
**Crew Evasive Maneuvers?** ☐ Yes ☐ No ☐ Unknown
**Crash Occur?** ☐ Yes ☐ No

**Location of Intrusion**
☐ Taper
☐ Activity Area
☐ Advance Warning
☐ Termination
☐ Unknown

**Risk to Crew?**
☐ None
☐ Mild
☐ Moderate
☐ Severe

**Narrative:** _____
State Patrol ID (if crash) _____
Crew Witnessed: _____

**Work Zone**

**Layout Type:** _____
(ex. 6K – 65, Exit Loop Closure)

**Layout Modification?**
☐ Yes ☐ No
*If yes, please describe:*
_____

**Location of Layout:**
☐ Right Shoulder
☐ Right Lane
☐ Multiple Lanes (Right)
☐ Center Lane(s)
☐ Multiple Lanes (Left)
☐ Left Lane
☐ Left Shoulder

**Location and Environment**

**Route:** _____
**Mile Post:** _____
**Work Zone Speed Limit:** _____
**Road Alignment:**
☐ Straight ☐ Curve Lt ☐ Curve Rt
**Road Grade:**
☐ Level ☐ Hillcrest ☐ Sag (bottom)
☐ Uphill ☐ Downhill
**Road Condition:** _____
**Glare Conditions (sun)?**
☐ Yes ☐ No

**Road Type:**
☐ Intersection
☐ 2-way Undivided
☐ 2-way Unprotect. Med.
☐ 2-way Med. Barrier
☐ One-way
☐ Intersection
☐ Entry / Exit Ramp
☐ Intersection
☐ Driveway
☐ Railroad Crossing
☐ Other

**Weather:**
☐ Clear
☐ Cloudy
☐ Fog/Smog/Smoke
☐ Rain
☐ Sleet/Hail
☐ Snow
☐ Severe Crosswinds
☐ Blowing Sand/Oil/Dirt
☐ Unknown

**Lighting Conditions:**
☐ Daylight
☐ Sunrise/Dawn
☐ Sunset/Evening
☐ Dark w/ Streetlights
☐ Dark w/ No Streetlights
☐ Dark Lighting Unknown
☐ Unknown

***Signature***: _____
***Date***: _____

**Figure 1.4 Paper version of intrusion report (Morris et al., 2018)**

Both data entry methods allowed workers to document a minor event with minimal information or a safety critical event with a more detailed account of what happened. The web version of the form required access to a tablet PC or computer and internet connectivity to access the intrusion reporting website. Based on interviews with MnDOT maintenance staff, supervisors would most likely complete intrusion reports after returning to the truck station. The paper form allowed workers to easily enter

information while in the field and removed the requirement for a computer, tablet, or internet connectivity. However, transferring this data into the database required an additional step and the difficulty and reliability of this process created a limitation for the system.

Ultimately, the past work by Morris and colleagues (2018) created a first step in establishing a data collection process to capture the circumstances surrounding work zone intrusions but did not allow a greater number of workers to document and upload information about work zone intrusions from the scene of the event. While supplying tablet PCs with internet connectivity would represent a significant financial investment, creating such a reporting system for a smartphone (i.e., an app) would offer a better solution to meet the needs of a larger population of workers.

## 1.2 PROJECT OBJECTIVES

The goal of this project was to support maintenance personnel in work zones by providing a convenient method for capturing work zone intrusion details from on the jobsite. A smartphone app was developed using a worker-centered design process that was driven by user feedback from workers. The goal of this process was to match the core functionality of the web-based data entry form but to do so using an interface that was well-suited for a smartphone form factor.

Backend software was developed by MnIT to create an HTTP application programming interface (API) through which the app could communicate and transmit intrusion report data to the existing eSAFE database where intrusion data has been stored. Additionally, an additional HTTP API was created so that the app could authenticate users logging into the app with a MnDOT username and password.

Training and information communications materials were created to support the deployment of the system. This includes training presentations that were delivered through virtual workshops, printable flyers for posting in truck stations, and digital materials for including in emails.

Lastly, to ensure the continued success of the system after the conclusion of this project, a long-term management plan was developed that identifies options for maintaining the work zone intrusion app and ensuring that it remains available, suitable, and functioning for its users.

## 1.3 REPORT ORGANIZATION

This report documents work performed as a part of this project. Chapter 1 provides an overview of the project's motivation, prior work in this area, and the objectives of this work. Chapter 2 describes the design process used to create the app's user interface and the user testing that informed this process. Chapter 3 shows the app's user interface and describes its functionality. Chapter 4 discusses the training and communication materials developed under this project to support the deployment of the app. Chapter 5 provides an overview of the other components of the work zone intrusion reporting system including the backend with which the app communicates. Chapter 6 is a discussion of major project findings, a discussion of how to achieve system longevity, and recommendations for future work.

# CHAPTER 2: USER-CENTERED INTERFACE DESIGN

The work zone intrusion mobile app's user interface was developed through an iterative, user-centered process. Candidate designs were evaluated through usability testing with MnDOT maintenance workers who provided feedback after interacting with different app prototypes. This chapter describes the process employed to create the final interface design.

## 2.1 PARALLEL PROCESS APP BUILD AND USABILITY TESTING #1

### 2.1.1 Design

The goal of this work was to empirically test and iteratively design a user-friendly work zone intrusion report interface in a smartphone application for MnDOT maintenance workers and supervisors. The first goal was set to establish usability differences between drop-down and radio-button interfaces. The second goal was set to observe and address any usability or process issues with either interface or data query fields more generally.

The research team modified the previously created work zone intrusion data collection interface (Morris et al., 2018) to be presented on a smartphone. The research team selected a parallel process design in which two distinct prototypes were created by different members of the team using the same system requirements. The first design, called Drop-down Menu Style, was created to mimic the same interactive components and experience that was presented in the previous website-based intrusion report, see Figure 1.1. This included drop-down menus for a majority of the report queries. The second design, called Novel Radio Button Style, was created to mimic the paper-based intrusion report, see Figure 1.4. This design substituted the drop-down menus with radio and check style selections throughout, see Figure 2.1. Each design was modified using concepts, guidance, and design elements from the other prototype until each prototype was ready for user testing. The design visual elements (i.e., font and color palette) were based on the Minnesota State Brand Style Guide (2018).

The prototypes were built using Justinmind prototyping software. The software allowed each prototype to be duplicated and re-sized to fit a variety of iPhone screen sizes. Three screen sizes were selected for testing: iPhone 5 (small screen), iPhone 7 (medium screen), and iPhone X (large screen). In total, six prototypes were built and iteratively modified to allow user testing with target users who may have a wide range of iPhone screen sizes. The prototypes could be accessed via MnDOT workers' iPhone remotely given COVID-19 safety restrictions. Prototype access required the user to download the Justinmind application. Once downloaded, they were able to enter a six-digit alphanumeric code that in turn loaded the prototype and optimally presented it as designed.

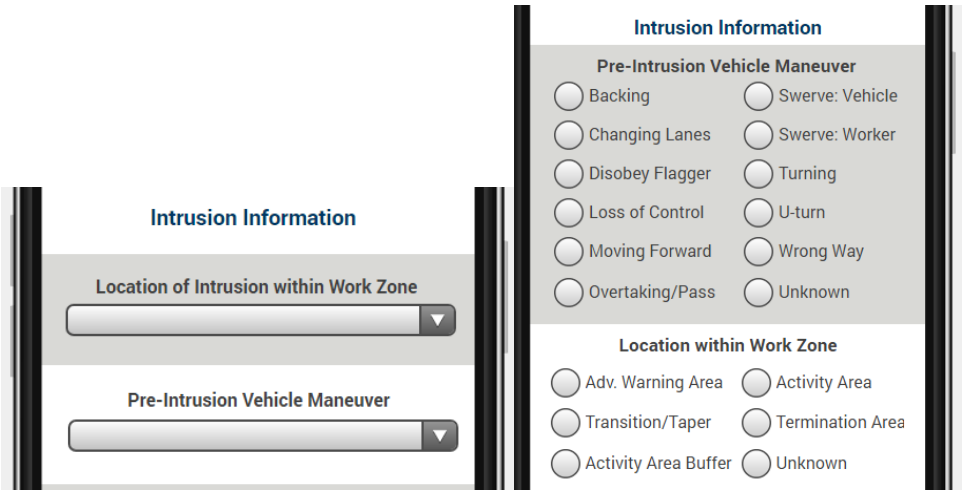



**Figure 2.1 Comparison of drop-down menu (left) and novel radio button (right) styles**

### 2.1.2 Methods

During the initial round of user testing, five end-users (i.e., subject matter experts in work zone intrusions) were tested. The participants included current and former truck station supervisors and crew members representing both metro and rural regions of the state. Due to COVID-19 constraints, usability testing was conducted via Zoom and each took approximately 1 hour to complete.

Participants were scheduled to meet with the research team via Zoom and were requested to have high-speed internet access, a webcam, and iPhone for testing. The research team requested the exact model of their iPhone (or preferred model if they had two models) to allow the correctly sized prototypes to be readied for testing. Additionally, the research team sent the participant an invitation to download the Justinmind application in advance of the testing session.

The research team virtually met with MnDOT employees and provided basic demographic information including work history. Final Justinmind download instructions were provided if not already completed. The research team used screen sharing features of Zoom to provide the prototype token of the first prototype selected for testing, counterbalanced in order so that half began with the Drop-down menu style and the other half with the Novel radio button style. This ensured there was no order related preference across participants.

Additionally, the screen presented a general intrusion scenario by which they were asked to enter the information into the prototype at their own pace. The first, brief scenario was designed such that it would not “trigger” the entire form, as it did not involve risk, evasive maneuver, or a flagger. The second intrusion scenario the participant was asked to document in the app involved greater risk to the crew and would “trigger” the full intrusion report. Participants were encouraged to “think aloud” as they navigated through the prototype, noting the features which might seem confusing, they liked, or disliked, etc., and were prompted by researchers to clarify any ambiguities. Researchers kept detailed notes while the participant interacted with the entry tool.

### 2.1.3 Results

The user testing revealed a wide range of useful recommendations to optimize the intrusion reporting system and improve the design of each prototype. The recommended improvements tended to fall into four categories: feedback, data variables/attributes to reduce or remove, variables/attributes to auto-fill based on other data entry, and variable or options to add. Recommendations included:

1) Providing a progress bar to each prototype to provide feedback regarding their progress within the form (see Figure 2.2)
2) Modify the "Back" and "Continue" button sizing to accommodate the smallest iPhone screens
3) "Severity of risk to crew" (previously as "Mild", "Moderate", and "Severe") to be reduced to a simple "Yes" or "No" question

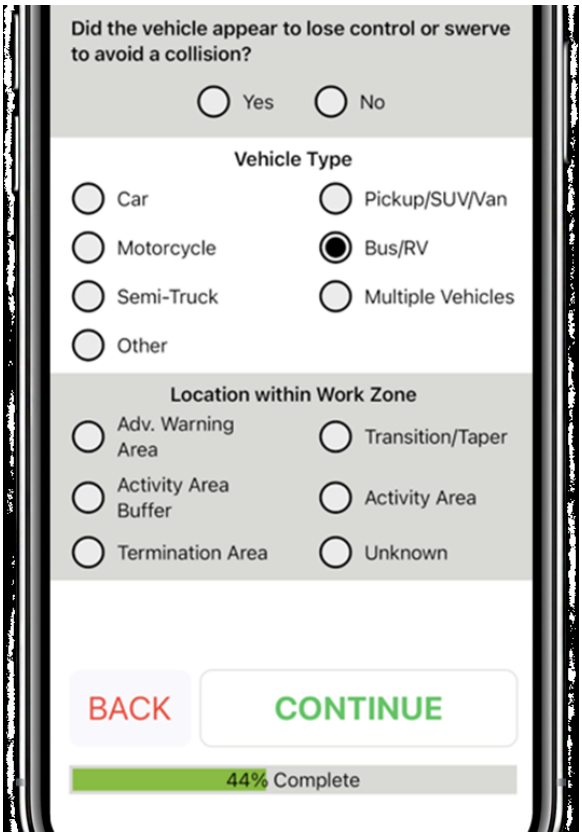



**Figure 2.2 Revised button-based design and addition of progress bar**

Overall, participants preferred the Novel radio button style prototype to the Drop-down menu style in a 4 to 1 vote. The rationale of the Novel radio button preference was based on a perception of it being faster and easier to "see all options" than what was viewable at any single moment in the drop-down style widget.

## 2.2 PARALLEL PROCESS APP BUILD AND USABILITY TESTING #2

### 2.2.1 Design

The goal of this work was to conduct usability field-testing of the final-stage versions of the work zone intrusion mobile app with MnDOT work crew end-users to determine if the features, content, and aesthetics met worker expectations. An additional end goal was to ensure that the intrusion report's mobile app was designed to support quick and efficient documentation of on-site work zone intrusions. This work also included a heuristic evaluation and usability testing of the intrusion report's alternate paper-based form.

This prototype testing round included the creation and usability testing of three iterations of the interface. The first iteration used the Novel radio button style interface created in the previous round of design and testing. The second and third explored standard layout, features, and widgets used in Apple-owned iOS applications, see Figure 2.3. This investigation was done to ensure that custom layout and widgets (i.e., radio buttons) were merited to achieve satisfactory usability over more standard, non-custom features. Additionally, these new prototypes allowed the team to explore an alternative organizational layout structure which employed a hierarchical or hub-and-spoke structure (i.e., instead of the original linear organizational structure of the first prototype).

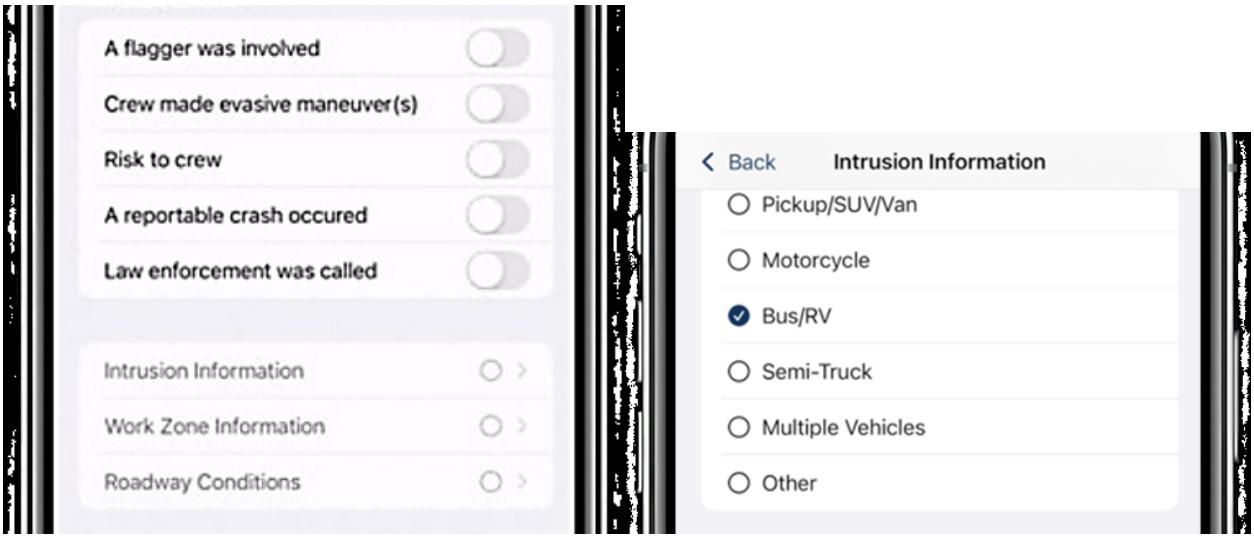



**Figure 2.3 Comparison of toggle switch (left) and radio button (right) styles**

### 2.2.2 Methods

Ten MnDOT maintenance employees participated in the field testing of the mobile intrusion reporting app, nine of which were supervisors and transportation general specialists (TGS), the app's target end-users. Testing included one non-targeted end-user maintenance worker.

Due to continued COVID-19 safety precaution needs, participants were scheduled to meet with the research team via Zoom. Participants were given access to download a test flight version of the app which provided access to each prototype's interface.

The research team virtually met with MnDOT employees and provided basic demographic information including work history. Participants were asked to recall a previous motorist intrusion they had experienced and requested to use this intrusion to complete the report. Any details they could not recall were requested to be substituted with general work experiences (e.g., layout type, traffic control). They were presented with an interface style in counterbalanced order to ensure no order-based preferences influenced results. Again, participants were encouraged to "think aloud" as they navigated through the prototype, noting the features which might seem confusing, they liked, or disliked, etc., and were prompted by researchers to clarify any ambiguities. Researchers kept detailed notes while the participant interacted with the entry tool. The participants were presented with the previous prototype with custom layout and radio buttons or with one of two standard iOS layout/widget versions.

### 2.2.3 Results

The field testing reinforced the superior performance and preference for the Novel radio button style over the alternative interfaces which used the standard iOS layout and widgets. Key findings included:

1) Participants did not prefer the hierarchical/hub and spoke organizational model and had fewer data entry errors with the standard, linear flow model
2) The standard iOS back button (i.e., on the top left corner, see Figure 2.3) was less likely to be found than the button placement at the bottom left of the Novel radio button style interface (Figure 2.2).
3) The column layout and style of the Novel radio buttons (Figure 2.2) was preferred to the vertical layout and style of the radio buttons in the standard iOS interfaces (Figure 2.3)
4) Separate radio buttons for "yes/no" data entry (Figure 2.2) of the Novel radio button style was preferred over the toggle switch widgets in the iOS style interfaces (Figure 2.3, left)
5) The paper-based form was found to have good usability and high user satisfaction
6) Participants periodically failed to notice text boxes and thus, periodically failed to answer typed-response questions in all interface versions.
7) Some work zone details (e.g., layout type) were often unknown and would be problematic to be made mandatory and would need to be updated later by supervisors or once the worker returned to the truck station to retrieve paperwork.

Participants reported the Novel radio button style interface to be both substantially more visually appealing and easier to use than either of the alternative prototypes using standard iOS features. Specific qualities of the Novel radio button prototype often emphasized during interviews as preferable over the alternatives included its:

- User-friendliness/ease of use
- Back-button placement location
- Progress bar
- Readability

Participants' preference for Novel radio button style prototype was so strong that none of the participants reported preferring any of the alternative prototypes' unique design or functionality aspects. Some selected quotes regarding the strong preference for the novel radio button prototype included:

> *"What you have right here, I will tell you compared to all of the stuff that we're used to, that we have been given over the last few years in technology, this is 100 times easier, it's easier, it's simpler."*
>
> *"I thought it was going to be hard, but it seemed pretty easy; like I said, it wasn't bad at all, yep, it wasn't bad at all."*
>
> *"I like this, it's just easy, yes, no, boom, boom, boom boom…I think it works really good."*
>
> *"It was pretty simple, pretty easy to understand."*

# CHAPTER 3: APP INTERFACE AND FUNCTIONALITY

The final user interface for the work zone intrusion app was created through the user-centered design process described above. The app, at its core, presents a series of screens each containing one or more prompts to which the user either provides text input or selects among provided options. The screens together collect the necessary information to generate a work zone intrusion report.

## 3.1 SHORT AND FULL REPORTS

There are two versions of the report contained within the app: the short report and the full report. The short report is intended for less severe intrusions where it is only necessary to capture minimal details about the intrusion, focusing only on its location, time, and any additional narrative information the worker chooses to provide. The full report is intended for safety-critical intrusions as determined by the presence of prespecified risk and severity indicators. This version of the report seeks to fully document the intrusion with a level of detail sufficient for later analysis.

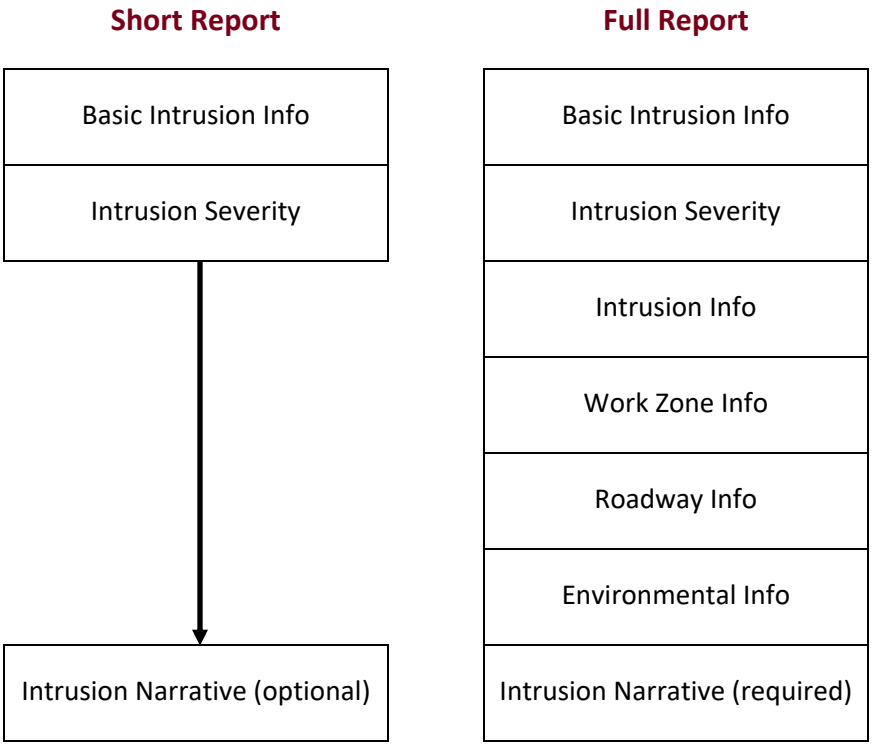



**Figure 3.1 Flow chart comparing short report and full report**

## 3.2 USER INTERFACE SCREENS

### 3.2.1 Login Screen

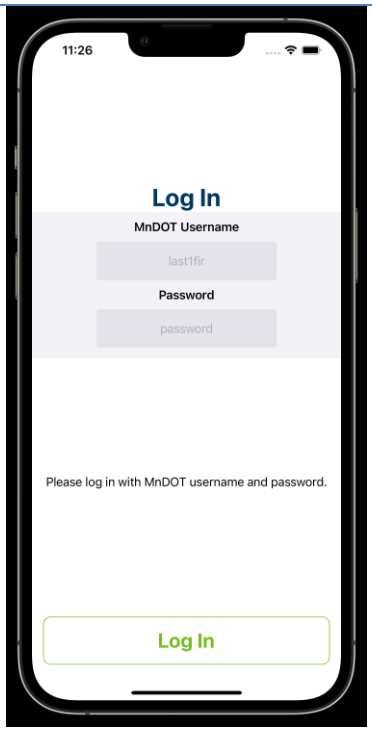



Figure 3.2 Login Screen

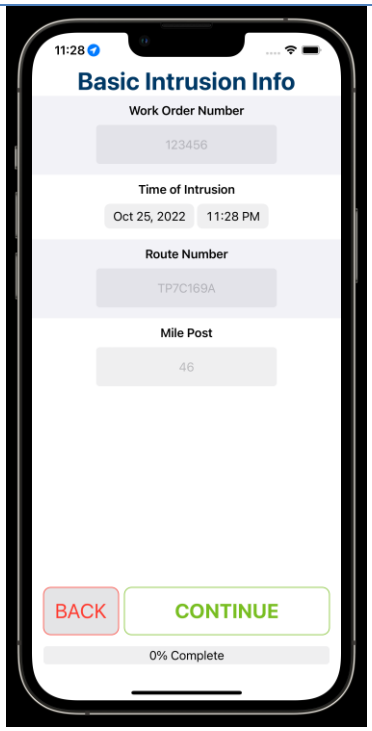
The login screen is displayed to the user the first time the app is launched, if they manually log out, or if their credentials expire. Users without an authorized MnDOT username and password will not be able to progress past this screen.

### 3.2.2 Main Screen

This is the main home screen of the app. From here, users can either begin an intrusion report or log out.

Figure 3.3 Main Screen

### 3.2.3 Basic intrusion info Screen

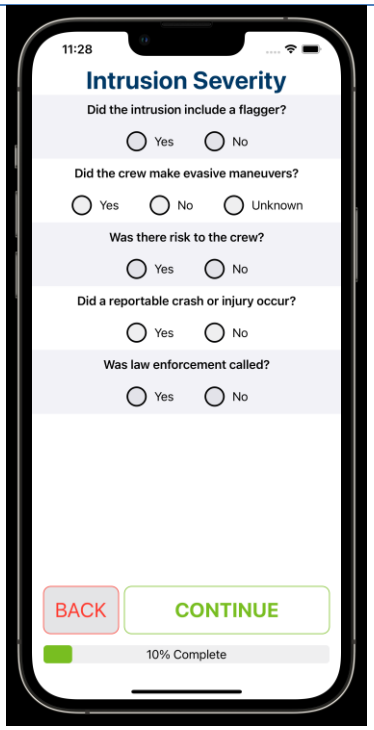



This is the first screen of the report which collects basic information about where the intrusion occurred, when it occurred, and the work order number for the worksite. This screen appears for both the snort report and the full report.

Based on user feedback, the work order number field is optional. This allows for the report to be completed even when the worker filling it out doesn't have access to the work order number.

Figure 3.4 Basic Intrusion Info Screen

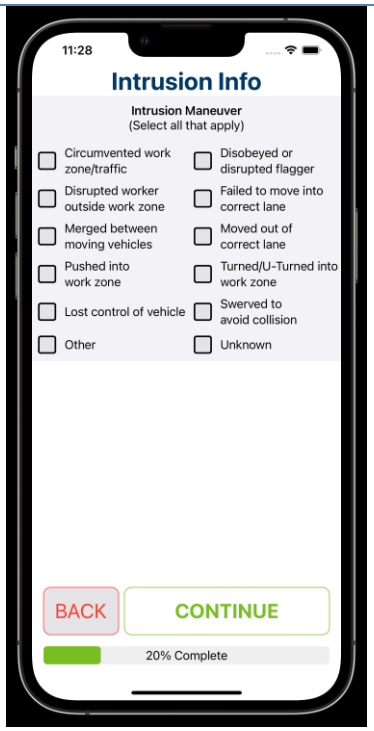
### 3.2.4 Intrusion Severity Screen




To determine the severity of the intrusion, users are presented with five yes/no questions. If the user selects “yes” for any of the questions, the app will present the full report. Otherwise, they will proceed to the Intrusion Narrative Screen.

**Figure 3.5 Intrusion Severity Screen**

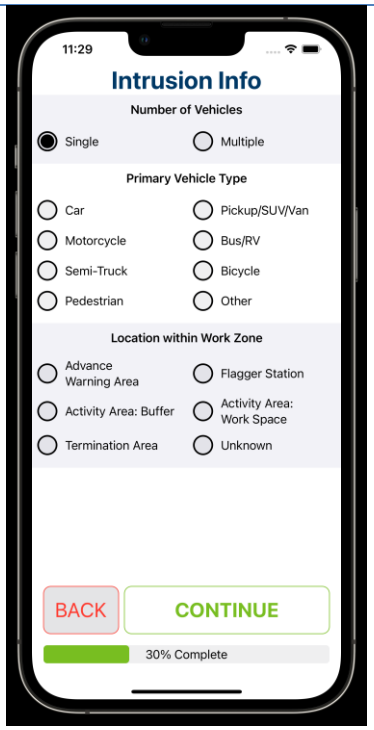
### 3.2.5 Intrusion Information: Intrusion Maneuver Screen




This screen collects any observed driver behavior about actions the intruding vehicle took before or during the intrusion. This question allows for multiple selections.

**Figure 3.6 Intrusion Information: Intrusion Maneuver Screen**

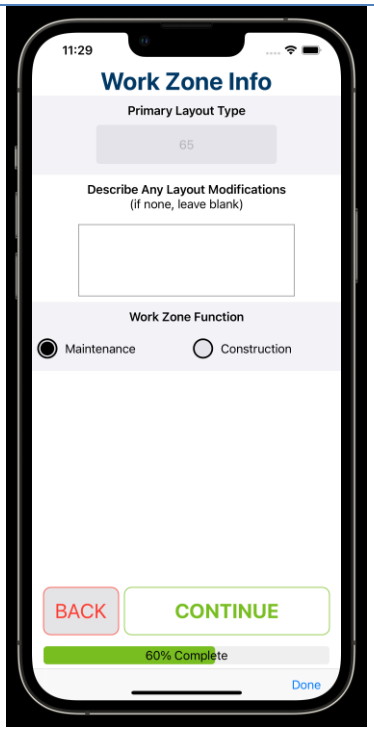
### 3.2.6 Intrusion Info: Additional Info Screen




This screen collects additional information about the intrusion including how many intruding vehicles there were, the type of vehicle that intruded, and the section of the work zone in which the intrusion occurred.

Figure 3.7 Intrusion Info: Additional Info Screen

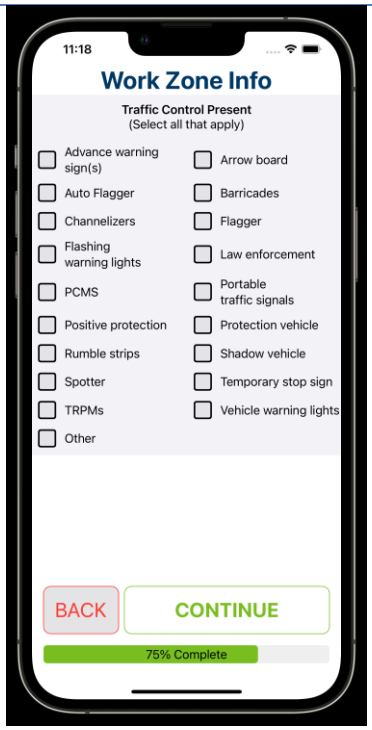
### 3.2.7 Work Zone Info: Layout Info Screen




This screen collects information about the work zone where the intrusion occurred including the layout type or number, a description of any modifications made to the layout, and whether the work zone was for maintenance or construction operations.

Figure 3.8 Work Zone Info: Layout Info Screen

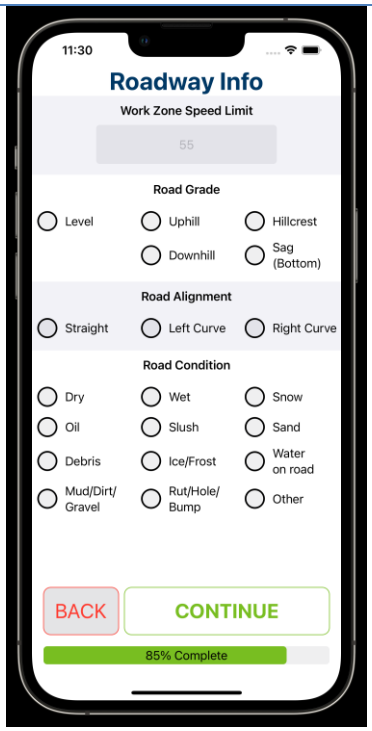
### 3.2.8 Work Zone Info: Traffic Control Screen




This screen collects information about the traffic control devices that were present in the work zone. This question allows for multiple selections.

Figure 3.9 Work Zone Info: Traffic Control Screen

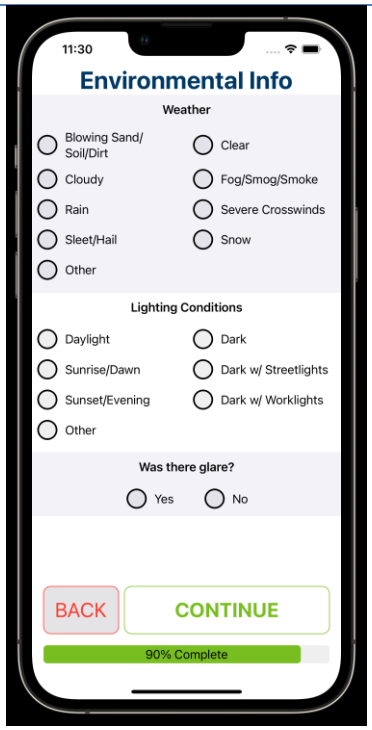
### 3.2.9 Roadway Info Screen




This screen collects information about the roadway where the intrusion occurred including the presence of horizontal or vertical curves, the speed limit, and the condition of the road surface.

Figure 3.10 Roadway Info Screen

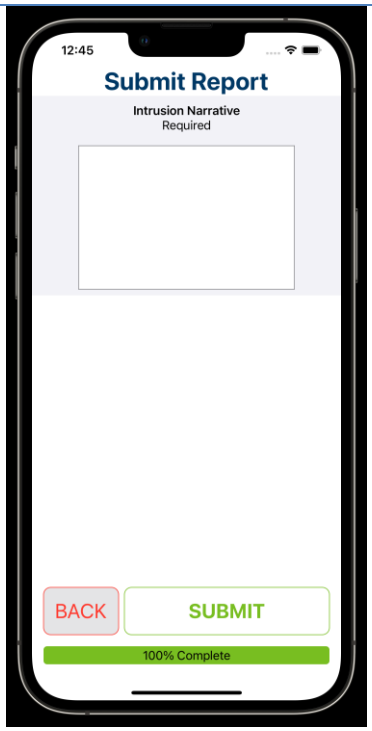
### 3.2.10 Environmental Info Screen




This screen collects information about weather and lighting conditions at the time of the intrusion.

Figure 3.11 Environmental Info Screen

### 3.2.11 Intrusion Narrative Screen




The final screen of the report contains a text entry box for users to provide a narrative description of the intrusion event. This screen is present on both the short report and the full report although this field is optional on the short report.

After entering the intrusion narrative, the user taps the “SUBMIT” button to upload the report.

Figure 3.12 Intrusion Narrative Screen

## 3.3 AUTOMATIC REPORT ELEMENTS

In addition to the intrusion report elements collected in the screens shown above, there is a small amount of additional information collected automatically by the phone. This includes the user's latitude and longitude which is collected when the "Begin New Form" button is tapped. This position data is only collected with the permission of the user. The first time the app is run, the operating system will display a prompt asking for permission to use the phone's position information. The other automatically collected information is the times at which the form is started and submitted. This provides time information about when the form was completed separate from the time when the intrusion occurred.

## 3.4 APP NAVIGATION

Users navigate between the screens of the app using the "CONTINUE" and "BACK" buttons. Additionally, users can track their progress with the progress bar at the bottom of each screen. These elements are shown in Figure 3.13.

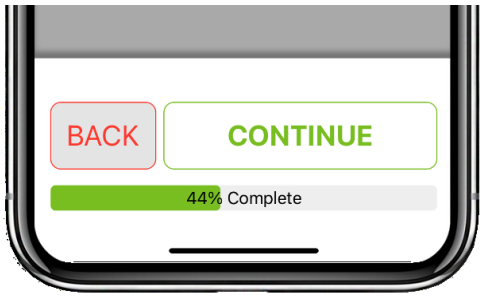



**Figure 3.13 Navigation controls and progress bar**

Except where otherwise noted, every question in the report is required. The app will not let the user progress to the next screen unless every question has a response. If the user taps the "CONTINUE" button on a screen that has not yet been completed, a red border will be drawn around any questions without a response. Once the user provides a response, the red border disappears. An example of this is shown in Figure 3.14.

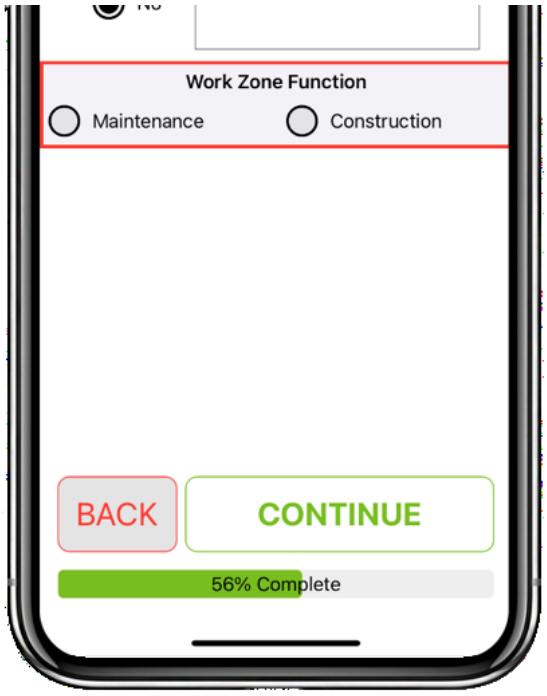



**Figure 3.14 Example of red border around incomplete question**

# CHAPTER 4: COMMUNICATIONS PLAN

A communications plan was created to organize the training, outreach, and other communications necessary to support the deployment of the system to workers. The key goals of the plan were to 1) raise awareness of the app and its purpose, 2) increase stakeholder buy-in for the importance of work zone intrusion reporting, and 3) educate users about the contents and functions of the application. Table 4.1 provides an overview of the individual products included in the communications plan.

**Table 4.1 Communications Plan Overview**

| Stakeholder Group | Objectives | Message Content | Delivery Methods/Venue |
|---|---|---|---|
| **Infographic** | | | |
| **Supervisors** | Raise awareness and buy-in for app | App Release Announcement | Email |
| **Flyer** | | | |
| **Supervisors, Asst. Supervisors, TGS, All** | Raise awareness and buy-in for app | Brief App Info/Buy-in Content | Bulletin board, break room |
| **Table Tent** | | | |
| **Supervisors, Asst. Supervisors, TGS, All** | Raise awareness and buy-in for app | Brief App Info/Buy-in Content | Break room tables |
| **Training Workshops** | | | |
| **Supervisors, Asst. Supervisors, TGS** | Buy-in for app, train users of content and functions of app | Audiovisual demonstration of app importance, and walkthrough of app | Microsoft teams training sessions (day and night crews) and online hosting of recording |
| **Training Video** | | | |
| **Supervisors, Asst. Supervisors, TGS** | Buy-in for app, train users of content and functions of app | Audiovisual demonstration of app importance, and walkthrough of app | Email, training hosting site |
| **Data Analysis Reports** | | | |
| **Supervisors, Asst. Supervisors, TGS** | Provide data feedback and buy-in for app | Preliminary/ Ongoing/ Completed Data Analyses | Email, Safety Meetings/ Conferences |

## 4.1 OUTREACH MATERIALS

### 4.1.1 Infographic

An infographic was designed as an announcement to be emailed to truck station supervisors. The goal of this was to raise awareness of the system and increase stakeholder buy-in for its importance. It was created with the intention that it be emailed and as such, provides an easy to digest and visually pleasing format in which to share its information. The infographic is shown in Figure 4.1.

**Figure 4.1 Infographic**

### 4.1.2 Flyer

An announcement flyer was designed to be distributed among a wider audience than the infographic. The target audience for this item included truck station supervisors, assistant supervisors, transportation generalist seniors (TGS), and others with the goal of raising awareness of the system and increasing stakeholder buy-in for its importance. The flyer was created so that it could be emailed or physically printed and posted in truck stations. The flyer is shown in Figure 4.2.

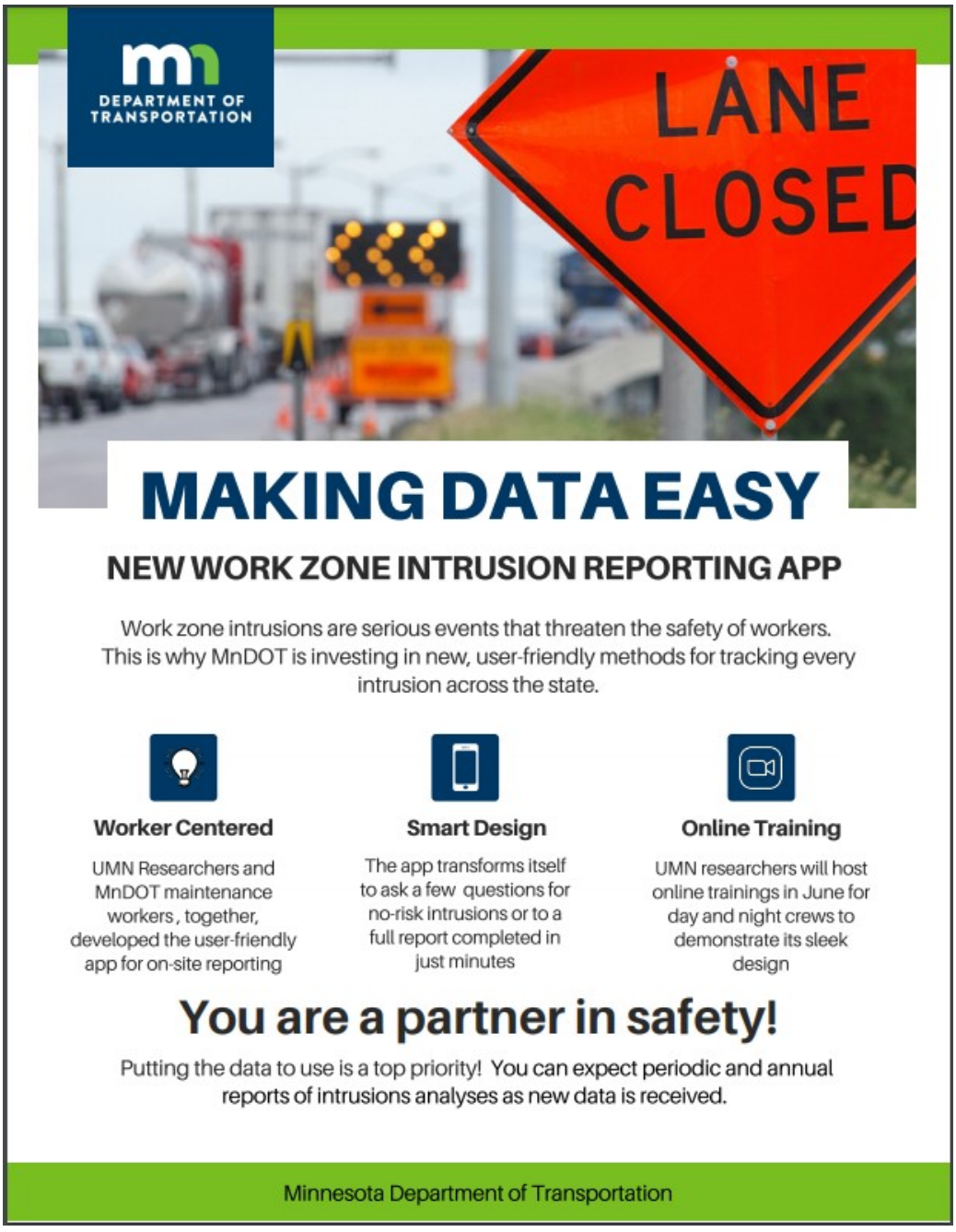



Figure 4.2 Flyer

### 4.1.3 Table Tent

A table tent was also designed that could be placed in truck station break rooms. The target audience was primarily the workers who would be using the app from the field. The goal was to raise awareness and increase stakeholder buy-in. The front and back of the table tent design is shown in Figure 4.3. Figure 4.4 shows the instructions for constructing the table tent from a single printed piece.

Figure 4.3 Table tent

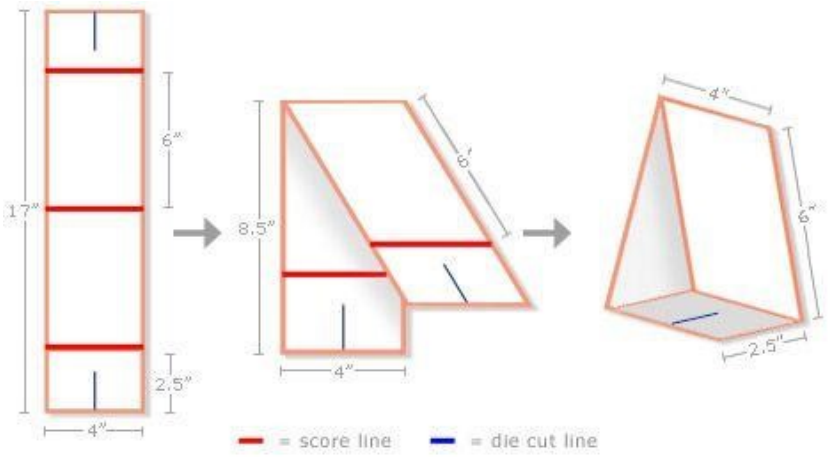



Figure 4.4 Table tent instructions

## 4.2 TRAINING MATERIALS

### 4.2.1 Training Workshops

Training materials were developed to support a live 60-minute training session conducted through Microsoft Teams video conference. The goal of these sessions was to make sure users were able to download the app, that they understood how to complete intrusion reports, and to provide information about why this information is important. The training sessions included the following components:

- Providing assistance for users downloading the app.
- A brief background on the importance of work zone intrusion reporting.
- Procedures for reporting intrusions.
- A guided walkthrough of the app.
- A practice trial run of the app.
- An open-ended question and feedback discussion section.

Four training sessions were hosted to accommodate the schedules of attendees. The schedule of the training sessions is shown in Table 4.2.

**Table 4.2 Training Session Information**

| Session Number | Date | Time | Number of Attendees | Notes |
|---|---|---|---|---|
| 1 | June 16th, 2021 | 8:30 am | 72 | |
| 2 | June 16th, 2021 | 8:00 pm | 1 | This training conflicted with a metro area supervisor's meeting. |
| 3 | June 23rd, 2021 | 8:30 am | 45 | |
| 4 | June 23rd, 2021 | 8:00 pm | 9 | |

### 4.2.2 Training Video

A training video was created to provide an additional format for reaching interested personnel. The content of the video was similar to the information presented in the training sessions but was adjusted so that it was appropriate for the video format. The content of the video included:

- Why intrusion reporting is important
- The power of data

- What users can expect from the data
- Encouraging partnership in safety-related data collection
- Preparation for reporting a work zone intrusion in the app
- A walkthrough of the app, its functionality, and its contents
- Closing summary

## 4.3 DATA ANALYSIS REPORTS

The goal of creating the preliminary analysis and report framework was to establish a foundation for supporting the consumers of the work zone intrusion data. Project stakeholders at MnDOT identified the State Work Zone Engineer in the Office of Traffic Engineering to be the responsible party for owning the data collected by the system as well as managing the generation and communication of system-wide analyses. This framework supports these goals by conducting an initial analysis of the available work zone intrusion data, creating an example infographic document for communicating results, as well as providing a framework for future analyses. The full preliminary report can be found in Appendix A.

The preliminary analysis categories presented here are based on the example report and how the values in the report were generally conducted from the raw data. For each category, the calculation method and important considerations for each category are presented.

### 4.3.1 District Percent Reported

This analysis takes the intrusion report count of each MnDOT district as a percentage of all reported intrusion locations (Figure 4.5).

*Considerations:* Higher percentage of reporting from a district can reflect either better reporting practices, higher intrusion rates because of higher traffic volume, or higher intrusion rates because of other factors.

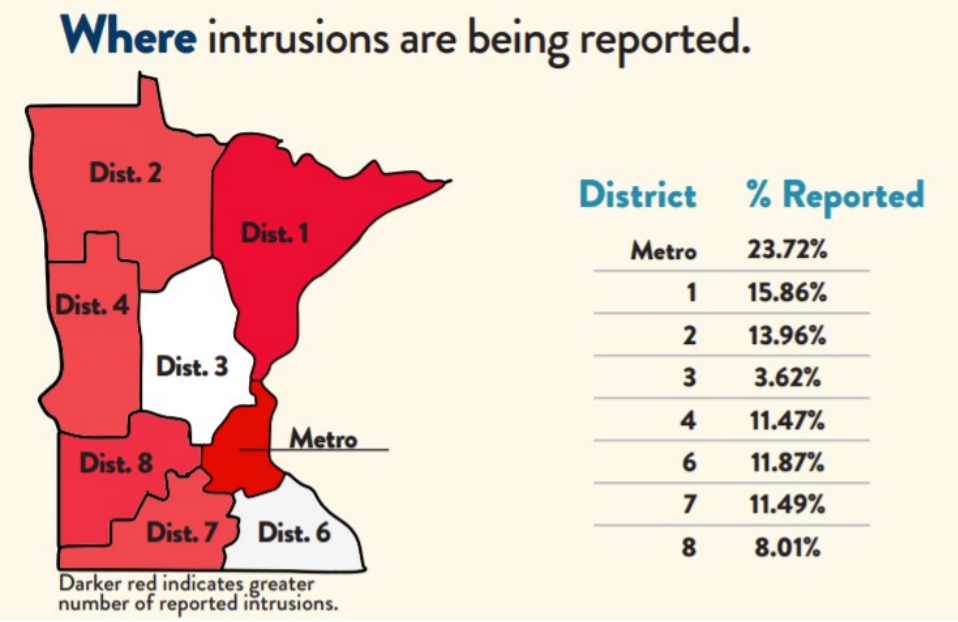



Figure 4.5 District percent reported

### 4.3.2 Roadway division

Of the two types of roadway divisions, what percentage of intrusions happen on one type compared to the other type (Figure 4.6).

*Considerations:* Higher percentage of intrusions on larger roadway types may correspond with density or other ADT factors. May not be informative without providing a count of all roadway division types present in work zones over a recent time period.

### 4.3.3 TTC Zone Area

This analysis takes the intrusion report count of each work zone area (Advance Warning Area, etc.) as a percentage of all reported intrusion reports for work zone areas (Figure 4.6).

*Considerations:* Higher percentage of intrusions in a particular zone area may be associated with higher intrusion risks for that zone area. The conclusions may not be reliable with uneven or poor reporting rates throughout the districts.

### 4.3.4 Primary Work Area

This analysis presents the three highest percentages of reported locations of the primary work area of the work zone. The numbers are a percentage of all reported intrusion locations (Figure 4.6).

*Considerations:* This measure may indicate sections of the work zone most at risk, particularly when examining across layout types. May not be reliable with uneven or poor reporting rates throughout the

districts. Work zones with long of activity areas (e.g., one mile or greater) will have greater physical exposure but may not capture the relative risk against other shorter work area segments.

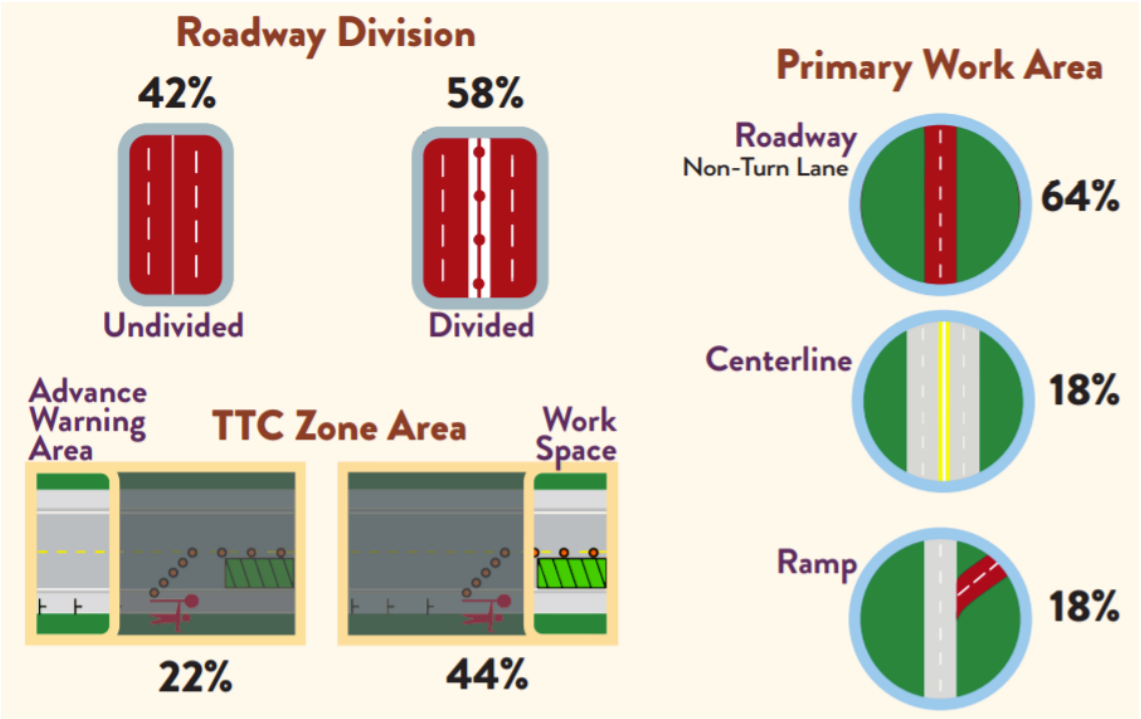



Figure 4.6 Figures for roadway division, TTC zone area, and primary work area

### 4.3.5 Layouts with most intrusions

The presented layouts have the highest count of intrusion reports (Figure 4.7).

*Considerations:* The counts are not completely reliable because we do not know the base rate of each layout type (i.e., how frequently each layout is used across the state). This measure may also be correlated with the under or over reporting from different regions of the state (e.g., Metro district has more ramps than other districts).

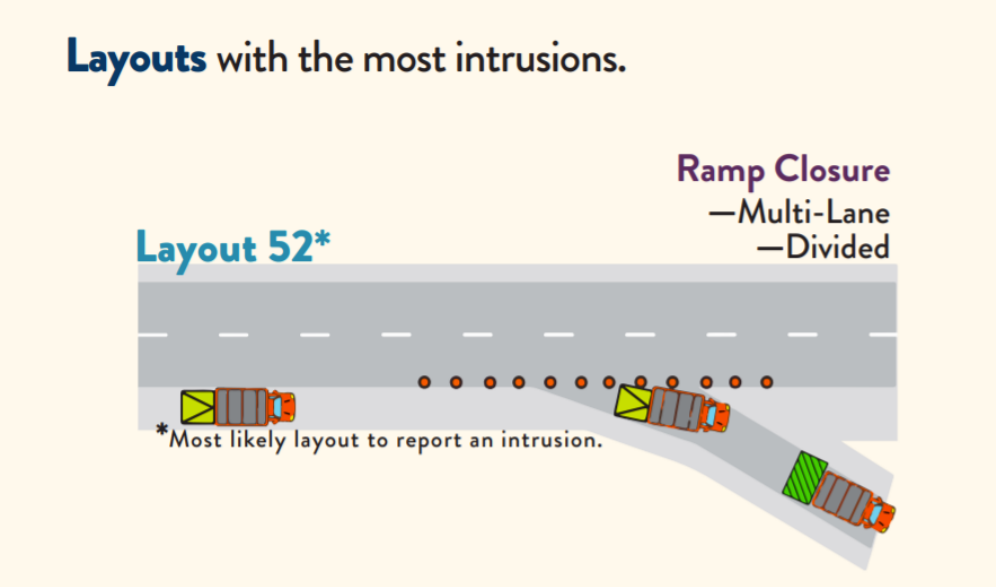



Figure 4.7 Layout with the most intrusions

### 4.3.6 Types of intrusions being reported

This analysis presents the three highest percentages of reported intrusion types. The numbers are a percentage of all reported intrusions (Figure 4.8).

*Considerations:* This analysis will help to guide mitigation solutions through engineering or enforcement efforts. May not be reliable with uneven or poor reporting rates throughout the districts.

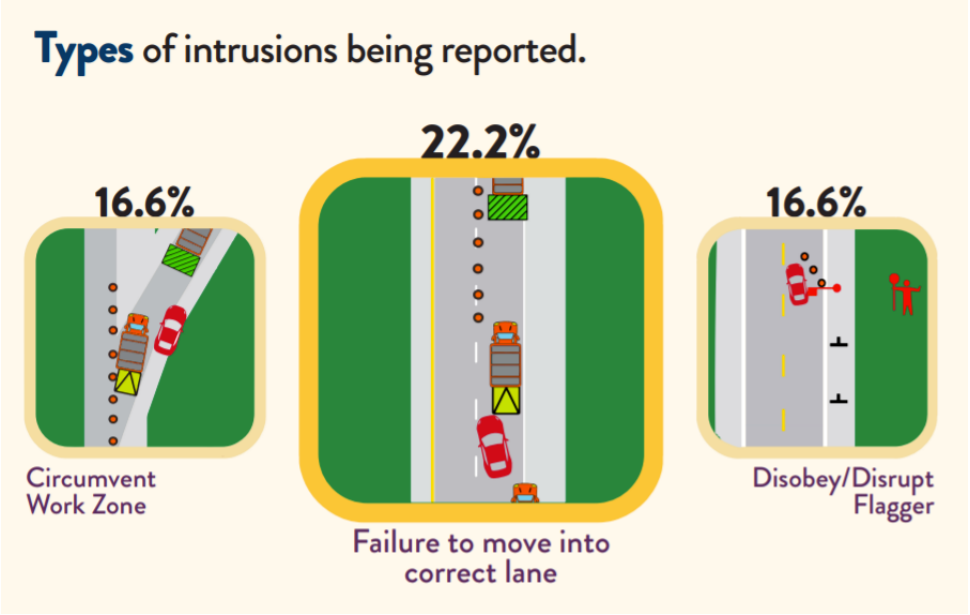



Figure 4.8 Types of intrusions being reported

### 4.3.7 Consequences of reported intrusions

This analysis reports the percentage of each consequence (severe intrusion, evasive maneuvers, etc.) as a function of all reported intrusions (Figure 4.9).

*Considerations:* This measure can present a general picture of the risk and consequences for work zones across the state. There can be multiple consequences reported, therefore the percentages do not have to add up to 100%.

**Figure 4.9 Consequences of reported intrusions**

### 4.3.8 Safety equipment

For relevant outcome measures such as “crew needing to take evasion maneuvers” or intrusions rated as “severe”, this analysis calculates the percentage of these outcomes that had a specific traffic control device or safety device, and what percentage did not have the device present (Figure 4.10).

*Considerations:* These relative risks can allow for an assessment of the protective factor of a safety or traffic control device, and indicate which devices are most reliable for improving safety margins. The measures may not consider the importance of combinations of devices or devices in concert with other factors (e.g., weather). May be premature to draw conclusions if based on small sample sizes.

Figure 4.10 Safety equipment found most protective

### 4.3.9 When intrusions are occurring

This analysis presents the percentage of intrusions reported for each day of the week, and the three highest percentages of types of weather and time of day (Figure 4.11).

*Considerations:* These values can provide engineers with an assessment of what times of the week and what weather patterns may be most prone to work zone intrusions and allow preparations for mitigation. However, these numbers may not be reliable with uneven or poor reporting rates throughout the districts.

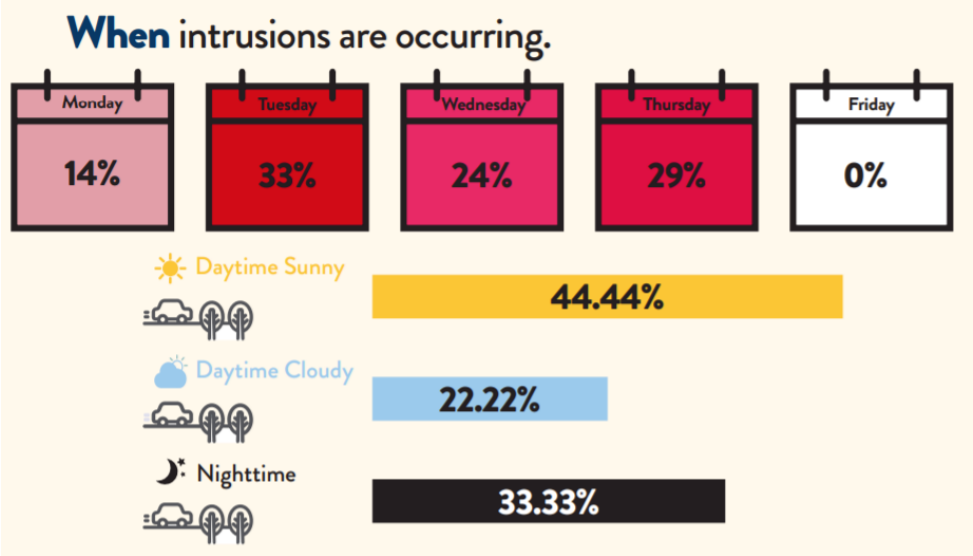
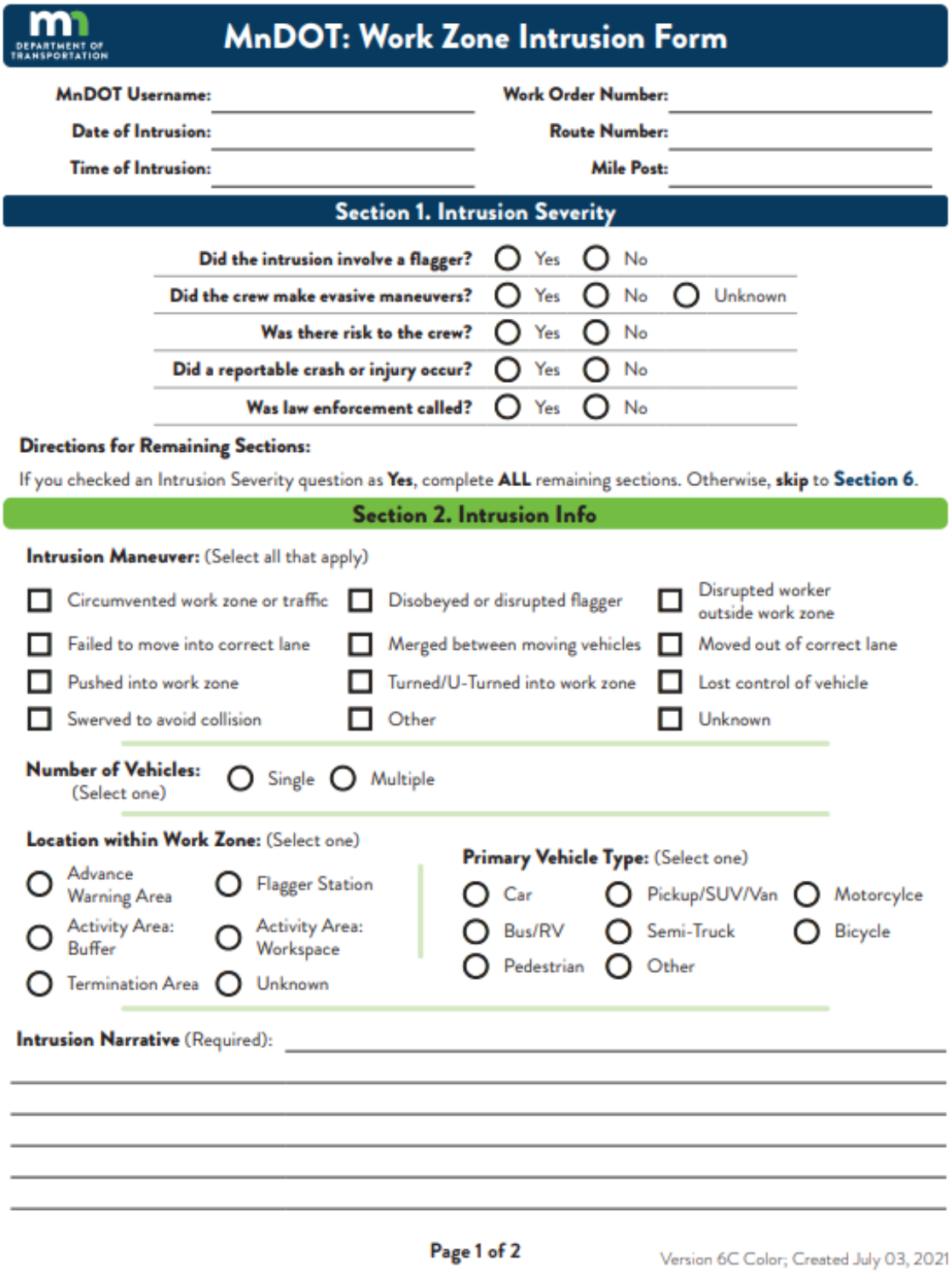



Figure 4.11 When intrusions are occurring

## 4.4 PAPER INTRUSION REPORT

A paper version of the form was also created alongside the app to provide an in-field reporting method for personnel who did not have or weren't allowed to use smartphones. The paper form was designed to be printed on the front and back of a single page and stored in work trucks. The full color version of the paper form is shown in Figure 4.12 and Figure 4.13.



# MnDOT: Work Zone Intrusion Form

**MnDOT Username:** _____ **Work Order Number:** _____

**Date of Intrusion:** _____ **Route Number:** _____

**Time of Intrusion:** _____ **Mile Post:** _____

## Section 1. Intrusion Severity

| | | | |
|---|---|---|---|
| **Did the intrusion involve a flagger?** | ○ Yes | ○ No | |
| **Did the crew make evasive maneuvers?** | ○ Yes | ○ No | ○ Unknown |
| **Was there risk to the crew?** | ○ Yes | ○ No | |
| **Did a reportable crash or injury occur?** | ○ Yes | ○ No | |
| **Was law enforcement called?** | ○ Yes | ○ No | |

**Directions for Remaining Sections:**

If you checked an Intrusion Severity question as **Yes**, complete **ALL** remaining sections. Otherwise, **skip** to **Section 6**.

## Section 2. Intrusion Info

**Intrusion Maneuver:** (Select all that apply)

- ☐ Circumvented work zone or traffic
- ☐ Disobeyed or disrupted flagger
- ☐ Disrupted worker outside work zone
- ☐ Failed to move into correct lane
- ☐ Merged between moving vehicles
- ☐ Moved out of correct lane
- ☐ Pushed into work zone
- ☐ Turned/U-Turned into work zone
- ☐ Lost control of vehicle
- ☐ Swerved to avoid collision
- ☐ Other
- ☐ Unknown

**Number of Vehicles:** (Select one) ○ Single ○ Multiple

**Location within Work Zone:** (Select one)

- ○ Advance Warning Area
- ○ Flagger Station
- ○ Activity Area: Buffer
- ○ Activity Area: Workspace
- ○ Termination Area
- ○ Unknown

**Primary Vehicle Type:** (Select one)

- ○ Car
- ○ Pickup/SUV/Van
- ○ Motorcycle
- ○ Bus/RV
- ○ Semi-Truck
- ○ Bicycle
- ○ Pedestrian
- ○ Other

**Intrusion Narrative** (Required): _____

**Page 1 of 2**

Version 6C Color; Created July 03, 2021

Figure 4.12 Paper Intrusion Report Form - Page 1 of 2

## Section 3. Work Zone Info

**Work Zone Function:** (Select one) ○ Maintenance ○ Construction

**Primary Layout Type:** _____ (Ex. 6K-65)

**Was the layout modified?** ○ Yes ○ No

(If so, please describe): _____

**Traffic Control Present:** (Select all that apply)

- ☐ Advance warning sign(s)
- ☐ Arrow board
- ☐ Auto flagger
- ☐ Barricades
- ☐ Channelizers
- ☐ Flashing warning lights
- ☐ Flagger
- ☐ Law enforcement
- ☐ Positive protection
- ☐ Portable traffic signals
- ☐ PCMS
- ☐ Protection vehicle
- ☐ Rumble strips
- ☐ Shadow vehicle
- ☐ Spotter
- ☐ Temporary stop sign
- ☐ TRPMs
- ☐ Vehicle warning lights
- ☐ Other

## Section 4. Roadway Info

**Work Zone Speed Limit:** _____

**Road Grade:** (Select one) ○ Level ○ Uphill ○ Downhill ○ Hillcrest ○ Sag (Bottom)

**Road Alignment:** (Select one)

- ○ Straight
- ○ Left Curve
- ○ Right Curve

**Road Condition:** (Select one)

- ○ Dry
- ○ Wet
- ○ Snow
- ○ Oil
- ○ Slush
- ○ Sand
- ○ Debris
- ○ Ice/Frost
- ○ Water on road
- ○ Mud/Dirt/Gravel
- ○ Rut/Hole/Bump
- ○ Other

## Section 5. Environment Info

**Weather:** (Select one)

- ○ Blowing Dirt/Sand/Soil
- ○ Clear
- ○ Cloudy
- ○ Fog/Smog/Smoke
- ○ Rain
- ○ Severe Crosswinds
- ○ Sleet/Hail
- ○ Snow
- ○ Other

**Lighting Conditions:** (Select one)

- ○ Daylight
- ○ Dark w/ Streetlights
- ○ Sunrise/Dawn
- ○ Sunset/Evening
- ○ Dark
- ○ Dark w/ Worklights
- ○ Other

**Was there glare?** ○ Yes ○ No

## Section 6. Additional Comments and Signature & Date

**Additional Coments** (Optional): _____

**Print Name:** _____ **Date:** _____

Page 2 of 2

Version 6C Color; Created July 03, 2021

Figure 4.13 Paper Intrusion Report Form - Page 2 of 2

# CHAPTER 5: WORK ZONE INTRUSION SYSTEM BACKEND

## 5.1 OVERVIEW OF SYSTEM COMPONENTS

The work zone intrusion app has connectivity or association with two external systems (illustrated in Figure 5.1). The first is MNIT which authenticate users to ensure they are authorized to upload data and, following authentication, uploads the data to the eSAFE database. The second system, managed by Vertigo Simulation Inc., has association with the app because it hosts the eSAFE web form for data collection of intrusions from desktop or tablet computers. eSafe is the primary method for capturing work zone intrusion report data is through a web form. Its interface was initially designed by the HumanFIRST Laboratory as a part of a previous project (Morris et al., 2018). The data collected in the form is uploaded to the eSAFE database for post-processing and reporting. eSAFE is a Microsoft SQL Server database that holds, among other data, the data from the intrusion reports. It is managed by Vertigo, Inc.

Following industry best practices and guidance from MNIT, it was determined that this would best be accomplished using a REST API that would expose endpoints capable of authenticating users and receiving data and inserting it into the eSAFE database. The interface design was an iterative process led by Rick Meyer, an IT Solutions Architect with MNIT, in consultation with the research team and the MNIT developers working to implement these designs.

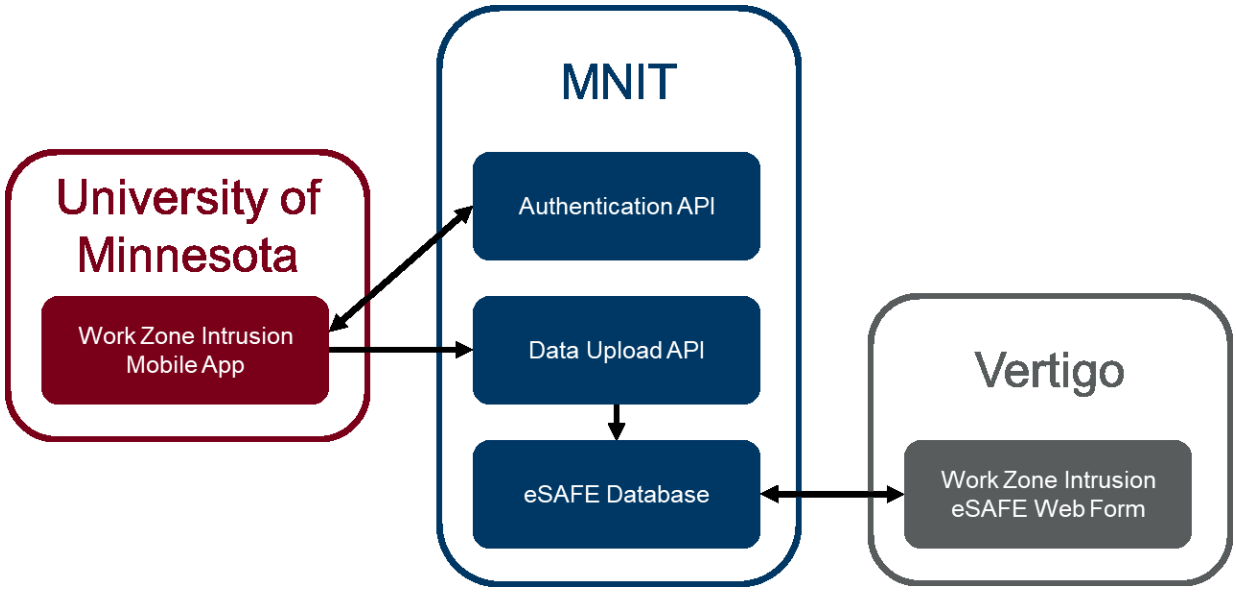



**Figure 5.1 Diagram of work zone intrusion system components**

## 5.2 USER AUTHENTICATION AND REPORT SUBMISSION

Once the user has completed the form, the app must first validate the user's username and password in order to confirm who is completing the form and that they are authorized to do so. After authenticating, the data must be submitted to the backend system that can insert it into the database where it is stored

and combined with the data created by the eSAFE web form. This is done in two HTTPS requests to MnDOT servers that host the API endpoint code.

### 5.2.1 User Authentication

Authentication is the process by which a user confirms their identity with the app by providing their username and password. The app verifies these credentials by comparing them with those stored in MnDOT's Microsoft Active Directory server, which can confirm whether the credentials are correct. This process is accomplished through a RESTful API endpoint with which the app can communicate to perform the verification. The user authentication data flow is illustrated in Figure 5.2 and described below.

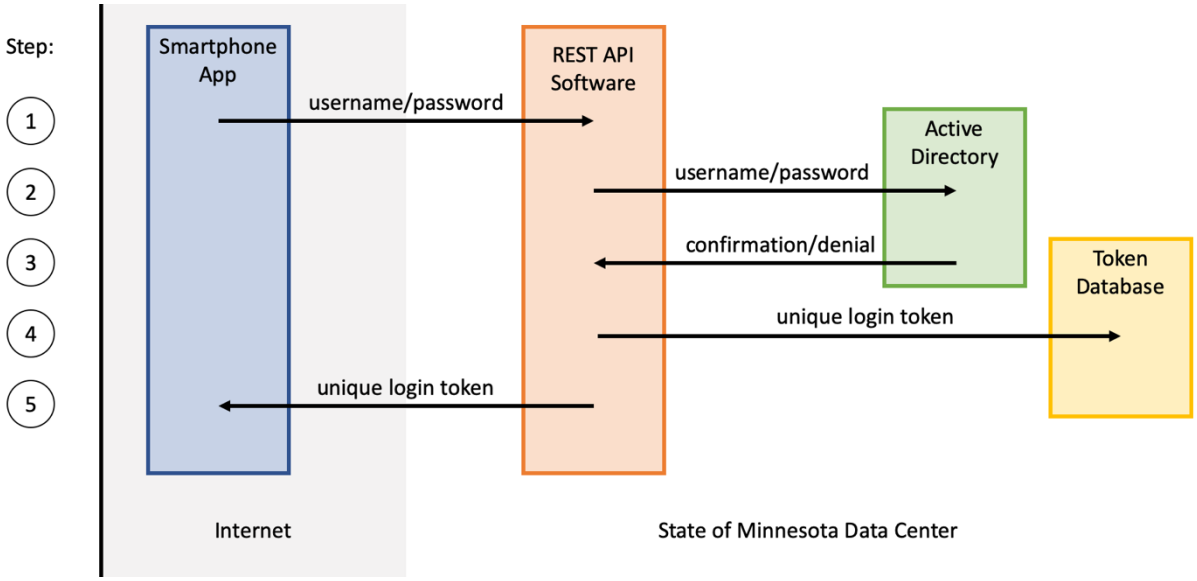



Figure 5.2 User authentication data flow

1. The app sends a request containing the user's username and password to the API endpoint.
2. The API software validates the provided username and password with the Active Directory.
3. The Active Directory responds either confirming or denying the authentication attempt.
4. If the authentication attempt is successful, the API software generates a unique token (a long, unique string of characters). The token is sent to the Token Database which holds all active tokens which corresponds to all users who are currently logged in.
5. The unique token is sent back to the app to be used later or a message is sent notifying the app that the authentication was unsuccessful.

## 5.3 REPORT SUBMISSION

The work zone intrusion report data is uploaded to the API endpoint. The data is sent using the JSON format, a widely used way to serialize data being sent over the internet. The unique token is sent along with the data so that the API software can verify who is sending the data. Once the data is inserted into

the eSAFE database, a confirmation is sent back to the app. The upload data flow is illustrated in Figure 5.3 and described below.

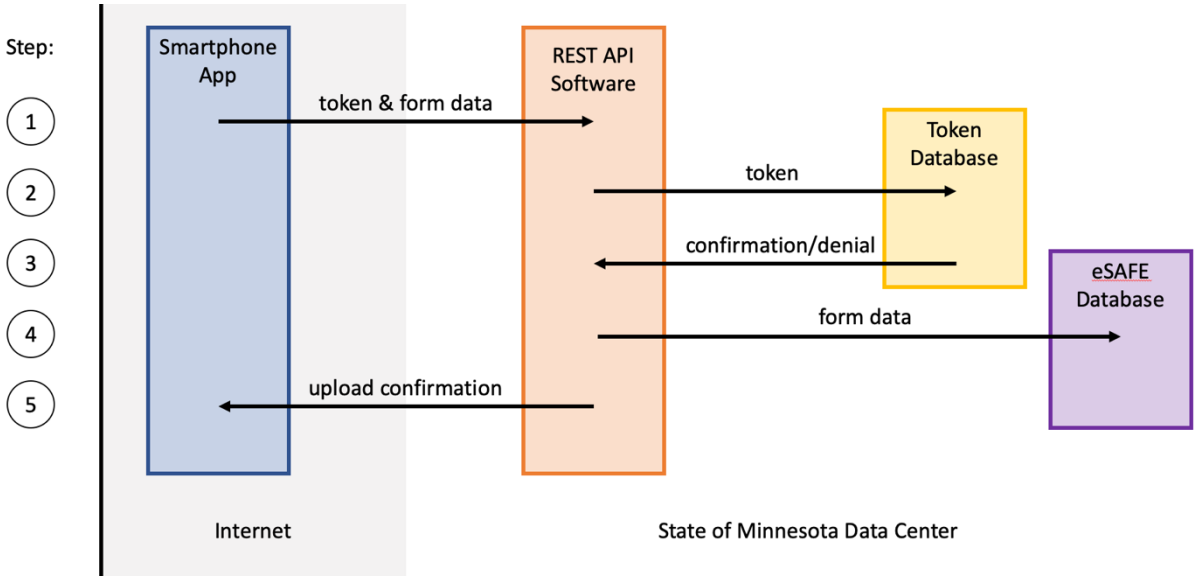



**Figure 5.3 Intrusion report submission data flow**

1. The app sends the unique token obtained in the authentication process along with the work zone intrusion report data to the API endpoint.
2. The API software sends the unique token to the Token Database to compare it against the list of currently valid tokens stored in the database.
3. The Token Database confirms whether the user submitting the data is currently logged in or denies the request.
4. If the upload request is authorized, the data is inserted into the eSAFE database.
5. The API confirms the successful receipt of the data or responds with a reason why the request was denied.

## 5.4 APP DISTRIBUTION

The work zone intrusion app, as beta software, was distributed to users through Apple's TestFlight. This allows for a controlled distribution to only those users who are granted access to the app. Additionally, the TestFlight system provides a high level of detail in usage statistics. These benefits aid in the beta testing process of providing the app to users, soliciting feedback, and making bug fixes and improvements. However, the cost of this method is that there are more steps required for a user to get access to the app. Namely, the user must download the TestFlight and redeem an invitation for the app. In practice, this was found to be overly complicated and burdensome on both the users and the research team members providing user support.

A number of different distribution methods exist that require varying levels of management. The method most users are familiar with is to make the app available in the Apple App Store. Then users can

either search for it in the App Store or be provided with a direct URL or QR code to find it. However, this also makes the app available to the general public which is not an intended use case for the work zone intrusion system as members of the general public wouldn't be able to log into the app. Other options include private or enterprise distribution schemes. However, this would require buy-in, support, and administrative oversight on the part of MNIT.

## 5.5 SYSTEM MAINTENANCE

It is anticipated that over the course of the app's deployment lifetime, additional app development or accommodations will be required. This may include changes to the report itself, such as the addition of new questions or response options, reordering questions, or other modifications.

The app currently targets and requires the Apple Operating System of iOS 15 or higher. As new operating systems are released, the SDK (software development kit) can change, in turn, causing changes to the behavior of the app when running on different operating systems. Additionally, as new hardware is released, new screen sizes and resolutions are introduced into the ecosystem, the app's performance may be altered from its current state. In order to ensure compatibility, it is important to test the app against new OS and hardware releases. Even in the absence of disruptive changes to the app's behavior, the expectation of users may shift over time based on current best practices or interface guidelines for the platform.

The work zone intrusion reporting system is comprised of different components maintained and operated by different entities. To ensure the continued functionality of the app, it is also necessary that these other pieces remain functioning as well and that the interface or contracts that define how they communicate is stable or changed in a careful way that allows for all entities to upgrade simultaneously. For example, additional app development would be required if there was a change in the HTTP API through which the app authenticates users and submits completed reports. Similarly, if the fields expected in the eSAFE database changed, the app would need to be updated to provide new data or to no longer send unneeded data.

# CHAPTER 6: CONCLUSIONS

## 6.1 RECOMMENDATIONS AND FUTURE WORK

### 6.1.1 Long-Term App Management

The focus of this project was the design, development, and initial deployment of the work zone intrusion mobile app. To ensure the continued success of the system and to make sure the app continues to be available, suitable, and functional for its users, it was important to identify a long-term app management plan. This included finding an administrative home for the work zone intrusion system as a whole and identifying long-term system champions representing and demonstrating value to maintenance workers using the system as well as safety stakeholders who will use the aggregated results of the intrusion reporting system to make improvements to work zone layouts or operations.

Long-term stability also requires identifying and implementing a technical management plan. This includes finding a technical home for or custodian of the app with personnel capable of keeping it up to date and functional on new operating systems and hardware, implementing new features and bug fixes, maintaining interoperability and feature parity with the eSAFE web interface, and providing end-user support.

### 6.1.2 Integration with Other Reporting and Informational Systems

The work zone intrusion report requires that all report information be entered by the user completing the report. However, it is possible that some of this information could be automatically fetched from other sources. For example, if information about a work zone has already been documented in other systems for managing inventory, personnel, or other resources, providing a work order number could allow for this information to be cross referenced in the intrusion report. This could provide additional information about work zone or reduce the amount of information the user needs to enter.

Other pertinent information could be automatically gathered as well such as weather data at the time and location of the intrusion. This could similarly provide additional pertinent information about the intrusion or reduce the number of questions the user is required to answer.

Lastly, there currently is no mechanism to link or analyze intrusions alongside data collected by other reporting methods for documenting occurrences of equipment damage, injuries, and crashes. System-wide analyses of intrusion data may benefit from the added context and insights provided by these other sources.

## 6.2 CONCLUSIONS

Work zone intrusions represent a significant safety risk to workers and represent a precursor to crashes, injuries, and fatalities. To reduce or mitigate these events, it is critical to first understand the circumstances under which they occur and then apply this understanding to develop countermeasures.

The work zone intrusion mobile app was developed to allow workers to provide this safety critical data from the field, immediately after these events occur, enabling timely and accurate intrusion reporting.

However, simply adding another form for workers and supervisors to complete runs the risk of high rates of non-compliance along with incomplete or incorrect data entry, due to frustration and time-costs of reporting, limitations in accessibility, and/or non-worker friendly design of the reporting interface. Simply mandating use of an unusable form or web-interface will not result in the capture or understanding of work zone intrusion events but should be expected to result in underuse and underestimation of the scope and scale of work zone intrusions across the state.

To develop a reporting form that was understandable, easy, quick to complete, and provided the information requirements needed by MnDOT, this research project thoughtfully employed usability testing and iterative, worker-centered design with volunteering MnDOT maintenance workers and supervisors across the state. This ensured that the system was designed with workers in mind from the very start of its creation. Once a design was relatively optimized for usability and a stable backend was developed, instructional materials were made, preliminary training sessions and a test deployment were conducted to determine any further issues in the upcoming stages of the product lifecycle. This led to an initial report analysis, along with development of a communications plan and long-term management recommendations.

The final conclusions based on the design and testing of the interface and its broader testing phases indicate high usability for the smartphone application and useful preliminary data, along with identified challenges for long-term management and implementation. Any changes to a well-established maintenance workflow, particularly when imposed by management on workers and supervisors, can be initially perceived as unnecessary and disruptive by those who would have to use the system, resulting in potential underutilization. Employing work-centered design practices is essential to combating these issues of system uptake; however, these practices are not sufficient to realize full acceptance and cultural changes to make the reporting system's use a part of typical processes. Long-term and broad adoption require sustained effort by an internal champion with sufficient resources and reach to overcome the initial skepticism and eventual adoption in the ordinary maintenance workflow. The research team encourages MnDOT to continue processing the data collected by the work zone intrusion reporting application and frequently sharing back this data, what it means, and how the agency intends to act on it to reach optimal use and acceptance of this necessary safety system in the future.

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# APPENDIX A

## PRELIMINARY WORK ZONE INTRUSION REPORT

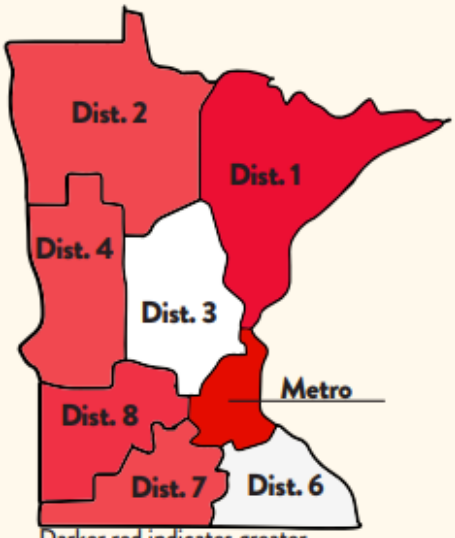
DEPARTMENT OF TRANSPORTATION

# PRELIMINARY WORK ZONE INTRUSION REPORT

Draft for Reveiw

DEPARTMENT OF TRANSPORTATION

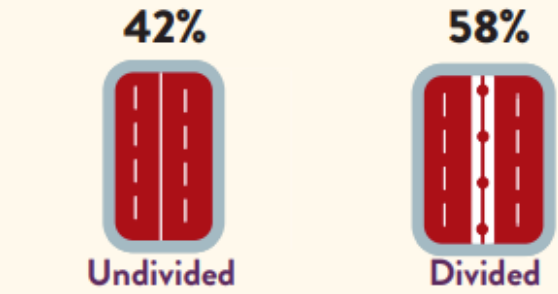
## Where intrusions are being reported.



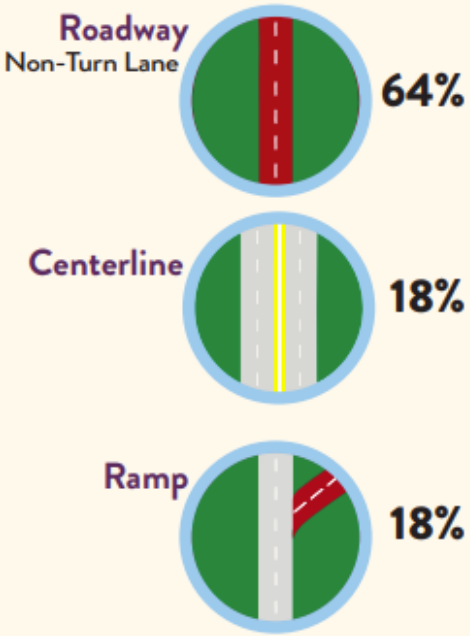

Darker red indicates greater number of reported intrusions.

| District | % Reported |
|---|---|
| Metro | 23.72% |
| 1 | 15.86% |
| 2 | 13.96% |
| 3 | 3.62% |
| 4 | 11.47% |
| 6 | 11.87% |
| 7 | 11.49% |
| 8 | 8.01% |

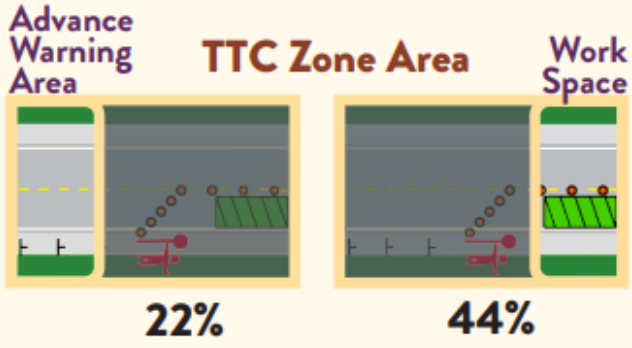
## Roadway Division




## Primary Work Area

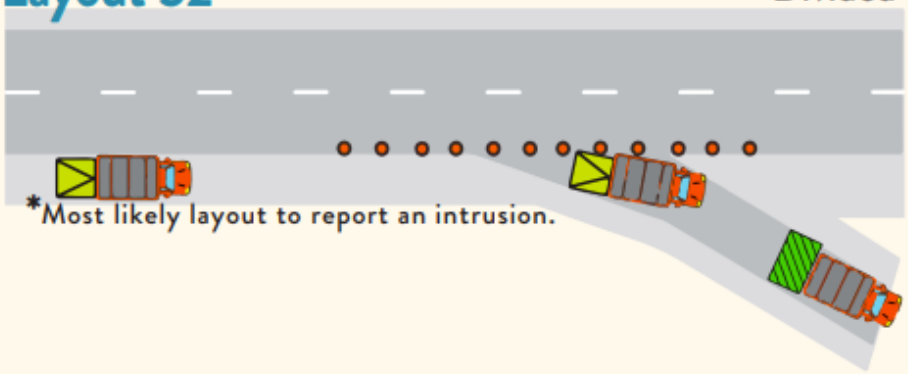



## TTC Zone Area



## **Layouts** with the most intrusions.

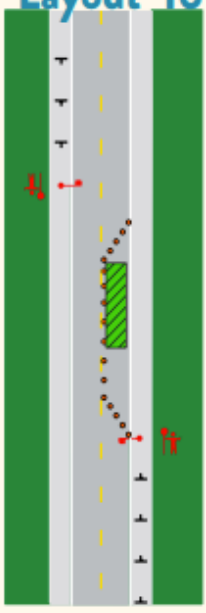
### Layout 52*



*Most likely layout to report an intrusion.

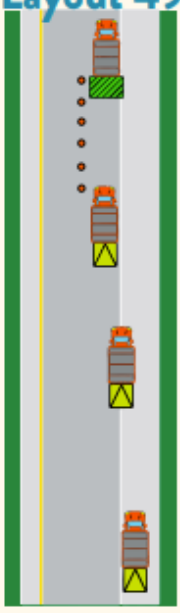
**Ramp Closure**
—Multi-Lane
—Divided

### Layout 16



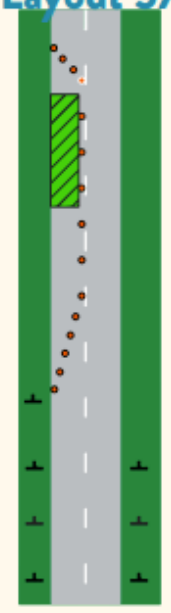
**Lane Closure**
**Two Flaggers**
—Two-Lane
—Two-Way

### Layout 49



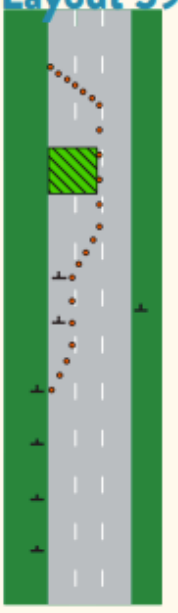
**Lane Closure**
—Multi-Lane
—Divided

### Layout 57



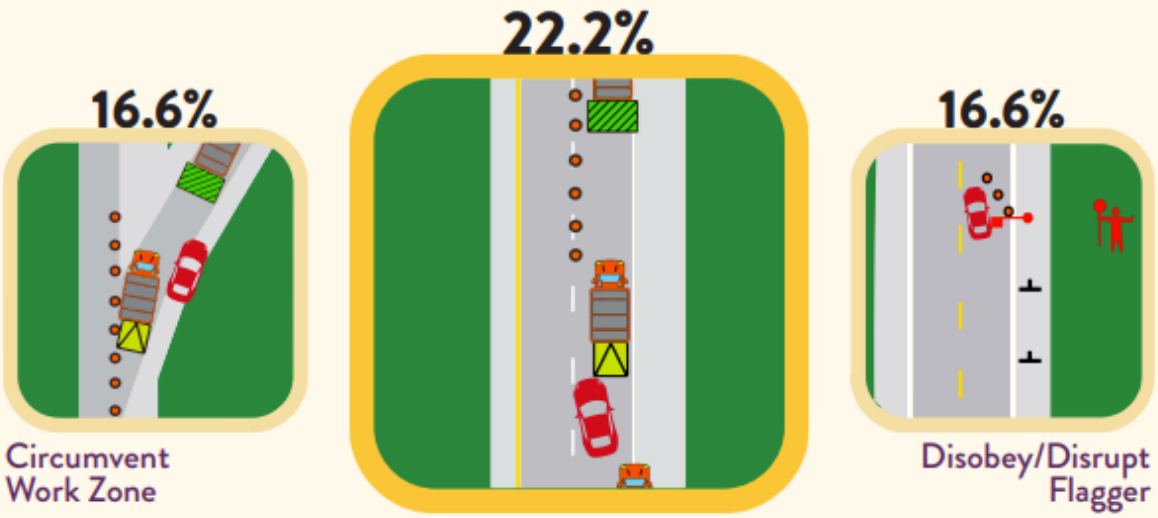
**Lane Closure**
—Multi-Lane
—Divided

### Layout 59



**Left Two**
**Lanes Closed**
—Multi-Lane
—Divided

## **Types** of intrusions being reported.




## **Consequences** of reported intrusions.

**62%** Reported as being severe.

**29%** Evasive safety maneuvers taken by crew.

**28%** Involved a reportable crash.

**28%** Ended with law enforcement being called.

## **Safety equipment** found most protective.

Reports with crew needing to take evasive safety maneuvers.

### Flashing Warning Lights

Without 50%

With 7%

### Arrow Board

Without 50%

With 23%

### Barricades

Without 43%

With 10%

### Channelizers

Without 43%

With 10%

Intrusions reported as severe.

### Barricades

Without 77%

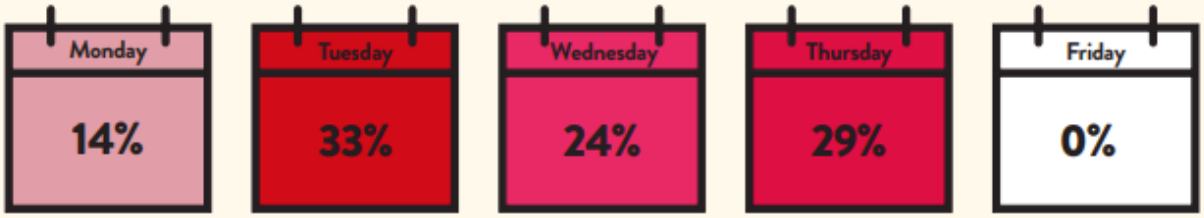
With 50%

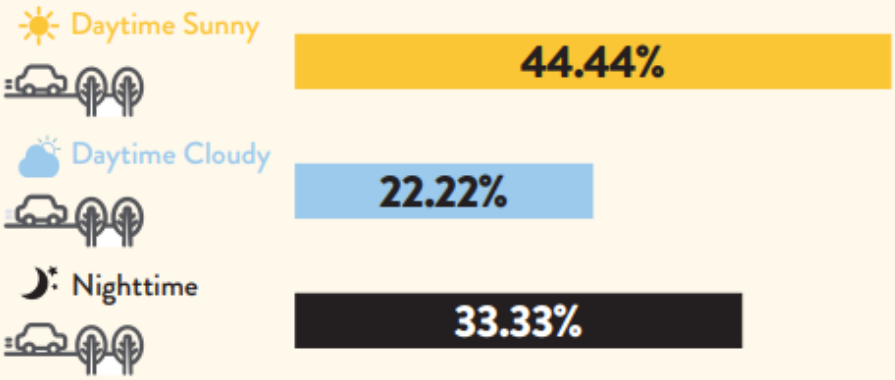
### Channelizers

Without 77%

With 50%

## **When** intrusions are occurring.




## **Last** messages to MnDOT Supervisors, TGS, & TGs.

- **This report aimed to provide you with clear and useful facts about intrusions into your work zone to aid your decisions and ability to stay safe while working.**
- All information contained within this report comes from work zone intrusion reports submitted before November 2nd, 2021.
- Please continue to document intrusions after experiencing them in your work zones when safe to do so using either the intrusion reporting app or its alternate paper form. Doing so enables us to learn more about intrusions and, ultimately, allows us to provide you with better, more accurate information about intrusions to aid your and your team members' safety.

iPhone app

Paper form

**Instructions:** Use your smartphone camera and scan the QR code to the right of the intrusion report you wish to download.