Use of Dashboards for Winter Operations

Final Report

CLEAR ROADS

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Project CR22-05
December 2024

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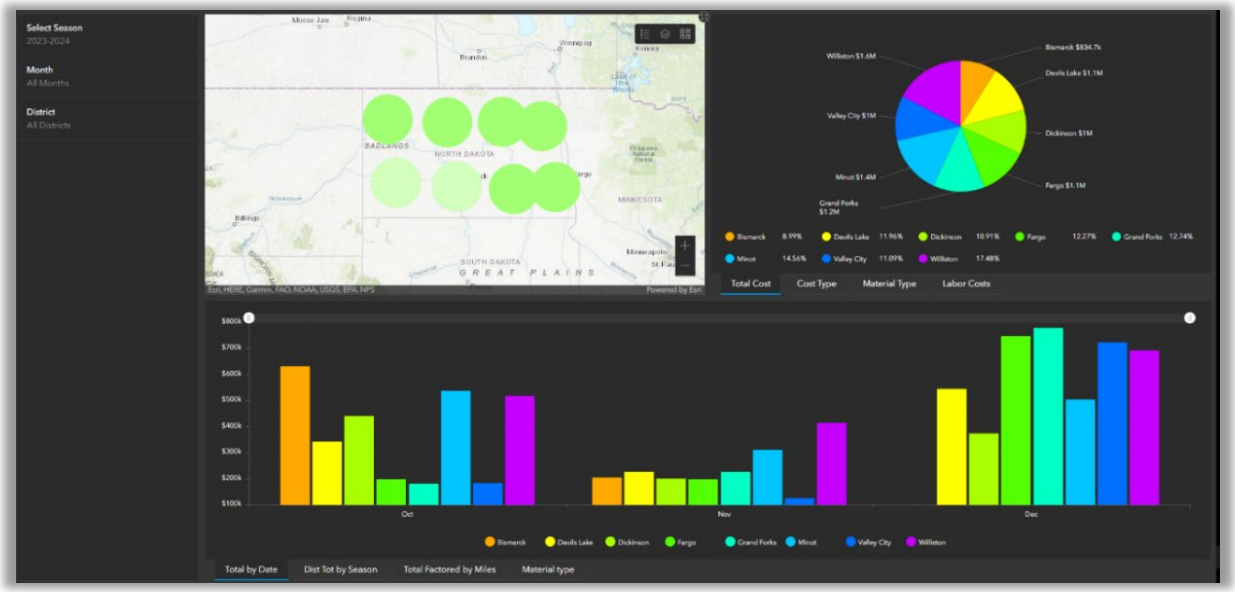

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16. Abstract

Public works agencies at state and municipal levels have invested a large amount of personnel and funding resources in dashboards to improve winter maintenance operations. The types and amounts of data gathered and performance measures used to track and monitor winter maintenance operations vary by agency. Due to these differences, there is a need to conduct a synthesis of agencies' practices in using dashboards for winter maintenance operations, which is the genesis of this research project.

This report will focus on all aspects of dashboarding to provide the most complete understanding for state winter maintenance managers to track and manage winter maintenance operations. This report summarizes a literature review, survey of practices and case studies of 5 agencies. This final report will serve as a reference guide for state department of transportations (DOTs) who are considering implementing or enhancing their winter maintenance operations dashboards.

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Executive Summary

The purpose of this research is gathering information on all aspects of dashboarding to provide a better understanding for state winter maintenance managers to track and manage winter maintenance operations. The purpose is to create a reference guide for state departments of transportation (DOTs) who are considering implementing or enhancing their winter maintenance operations dashboards.

This research started with an in-depth literature review which helped understand what the state of the practice is for winter dashboards and assist with the development of survey questions. The research team surveyed multiple state DOTs on the state of the practice for developing and using winter maintenance dashboards. The survey also gathered an understanding of which agencies or organizations have implemented one or more dashboards for winter maintenance operations; what data inventories and performance metrics are used; how the data are linked, cleaned, utilized, and stored; the frequency with which the dashboards are refreshed; and information about the platforms and databases that are utilized. The survey included information on agencies' planning, processes, steps, and results with their respective systems. Using the information gathered in the survey, a list of candidate agencies for interviews and case studies is recommended as part of this study. This survey includes facilitating the discussion and final selection of case study agencies with Clear Roads members. The research team developed detailed interview questions to help facilitate the conversation and worked with the selected agencies to arrange and conduct the interviews. The data gathered from the interviews allowed the research team to develop a case studies report for each agency.

Five agencies (Iowa DOT, Virginia DOT, North Dakota DOT, Kentucky DOT and Ohio DOT) were selected for in-depth interviews and case studies. Those case study reports collect and synthesize detailed information to document information, experience, and lessons learned regarding their goals, design, implementation, and uses of dashboards within winter maintenance operations.

This final report summarized this research project including literature review, survey assessment, and case study details. The final report will serve as a reference guide for state DOTs who are considering implementing or enhancing their winter maintenance operations dashboards.

1. Introduction

Transportation agencies constantly collect, store, query, analyze, and report data for decision-making. The enormous amount of data that flows into transportation agencies is only helpful if there are persons or systems set up to analyze the data to provide insights. Using persons to manually analyze data for insights can be time-consuming and unrealistic based on the amount of data and processing required. Additionally, it can be challenging for agencies, especially in this current climate, to hire and retain employees with the time to conduct manual analyses. An ideal method for data analytics is to invest in the development of automated systems for pulling various data sources to build useful insights, typically through a dashboard, for performance monitoring and decision-making in real-time or in planning for best practices at transportation agencies.

Dashboards are unique in all aspects, including how and what data are ingested into it, how are the data cleaned, stored, displayed and maintained, and the end users' goal of the dashboard. A dashboard should display performance measures clearly and concisely to allow for valuable insights. These insights will allow users to make decisions on best practices as well as fully understanding the needs of the end user will maximize the utilization of the dashboard allowing for the highest rate of return in the development and maintenance of the tool. Within transportation agencies, there are many opportunities to leverage dashboards for performance monitoring, decision-making and best practices.

In addition to data management, analytics and dashboarding, transportation agencies in cold regions undertake the massive task of winter maintenance operations, which consists of providing a high level of service (LOS) to the traveling public, even during snow and ice events. For many of these agencies, winter maintenance operations are a major component of their maintenance budgets. Due to the complexity of combating snow and ice events, agencies differ in the data they gather and use. Some agencies may be manually gathering data through operator notes and task forms, while others may have an automated system such as Automatic Vehicle Location (AVL) / Global Positioning System (GPS), onboard road surface temperature gauges, salt application data, and plow up/down data streaming in real-time to a central data server/hub or an online graphical user interface (GUI). Overall, winter maintenance operations generate abundant data, especially with the advancement in technology. Data generated and sources may include: equipment location and information, material application rates and usage, operational status (such as plow up/down, sprayer on/off), road weather conditions from Road Weather Information System (RWIS) stations, mobile RWIS, and mobile sensors on snow plows, and other weather sensor stations, driver behavior, visual images from the truck (such as a dash camera), Maintenance Decision Support System (MDSS), Connected Vehicles (CVs), Incident details/alerts, etc. CV data can be leveraged to alert agencies where tire traction is reduced, or hard braking occurs (whether due to less treated routes or impacts from incidents). Some CVs may be equipped with road condition and weather sensors that could be a useful tool to agencies. It is important to track data advances in the industry to plan for future applications that may lead to additional efficiencies.

The types and amounts of data gathered and performance measures used to track and monitor winter maintenance operations vary by agency. They have direct influence on agencies' ability to create dashboards and types of information to display. As such, agencies that currently use or in the process of developing dashboards for winter maintenance operations may have a wide variety of design and configurations for their dashboards. Due to these differences, there is a need to conduct a synthesis of

agencies' practices in using dashboards for winter maintenance operations, which is the genesis of this research project.

Understanding what internal and external data sources agencies use for best practices can help other agencies to leverage their available data and identify potential data gaps/limitations. In addition to what data are collected and analyzed, it is important to explore what insights or performance measures are used for identifying and tracking efficiencies on a winter maintenance operations dashboard. A synthesis of all the above factors can help agencies obtain insights for best practices and lessons learned in their effort to plan, design, implement and use dashboards for winter maintenance operations.

1.1 Background

This project focused on all aspects of dashboarding to provide a better understanding for state winter maintenance managers to track and manage winter maintenance operations. For increased efficiency, the research focused on ways to:

- Increase or track LOS,
- Reduce materials usage,
- Reduce labor, and
- Track and potentially reduce the overall cost of maintenance operations. These funds could be allocated to other maintenance areas or allow for investments in new technologies that could increase efficiencies.

Another goal is to determine how the information from these dashboards may be used to communicate with agency executives and legislators, and potentially the public.

The purpose of this report and its companion case study reports are to help other state DOTs make more informed decisions with all aspects of dashboarding for winter maintenance activities. Those reports are intended to summarize agencies' experiences and lessons learned. Those reports also highlight the types of issues other highway maintenance agencies should consider prior to implementing dashboards, provides guidance for successful implementation of the technology, and serves as a possible template for agencies to get the best value out of different levels their winter dashboard applications.

1.2 Methodology

The research team utilized the following methodology to complete the project as described below.

1.2.1 Literature Review

The research team first completed a review of relevant literature and project documents to gain a better understanding of transportation agencies' involvement with winter maintenance data collection, performance measures, and dashboards. This task helped gain an understanding of current practice and the state of the practice in data sources, data collection methods, data utilization and analysis, development of performance measures, dashboard design and layouts, and using dashboards to display performance measures for a variety of audiences. The literature review performed by the research team is summarized in Section 2 of this report.

1.2.2 Survey

This task focused on developing and conducting an online survey to gather information from Clear Roads member states and non-Clear Roads states, and municipalities. The purpose of the survey was to gather information on the state of the practice for winter maintenance dashboards. The survey also helped gain an understanding of:

- Which agencies or organizations have implemented one or more dashboards;
- What data are used (metrics);
- How the data are connect/linked, cleaned, and stored;
- The frequency of dashboard refreshes (real-time, semi-real-time, weekly, etc.); and
- What platforms and databases are utilized.

The survey also collected information on agencies' planning, processes, steps, and results with their respective systems. Using the information gathered in the survey, a list of candidate agencies for interviews and case studies was recommended. Five agencies were selected and interviewed in further depth to develop the case study reports. A summary of the survey results and the analysis performed by the research team is contained in Section 3 of this report.

1.2.3 Interviews and Case Studies

Virtual interviews were conducted with staff from each of the case study agencies to gain a detailed understanding on how they use their Winter dashboards. Interviews were conducted between November 2023 and January 2024 with the five agencies selected through the project survey. Interview summaries are contained in the Appendices B through F of this report.

With the information gathered from these interviews, the research team developed individual case study reports documenting how each agency implements and utilizes their winter dashboards. A summary of the case studies is contained in Section 4 of this report. Full versions of the case study reports are published separately on the Clear Roads Program website (http://clearroads.org/).

1.2.4 Best Practices and Recommendations

Recommendations were developed to summarize the key takeaways from the interviews and case studies. In addition, best practices were also identified and highlighted. The recommendations as well as best practices from the interviews and case studies are included in Section 5 of this report.

2. Literature Review

The literature review was designed to explore the use of dashboards for winter maintenance operations. The primary objective of this literature review was to analyze and assess the prevailing practices of transportation agencies, with a particular emphasis on identifying the most up-to-date, innovative, and effective approaches to winter maintenance operations. The review also examined the integration of CV, MDSS, and incident data with winter fleet and weather data to enhance winter operation dashboards. Relevant literature and experience with using dashboards for non-winter maintenance operations such as work zone operations, traffic operations, traffic safety, and asset management were investigated. This section of the report summarizes the literature review and synthesizes key findings, current practices,

trends, and issues related to the use of dashboards for winter maintenance operations. Additionally, this section establishes a definition of a dashboard to provide a basis for this research. By analyzing current practices and best practices, the literature review informed the design and implementation of effective dashboards for winter maintenance operations. The insights gained from this review also informed the development of recommendations for transportation agencies seeking to improve their winter maintenance operations through the implementation of dashboards.

2.1 Clear Roads Project 14-05 Snow Removal Performance Metrics (Xu, et al., 2017)

This report analyzes the use of dashboards in winter maintenance operations for all snow and ice states with a focus on performance metrics. Many agencies use dashboards in winter maintenance operations to help decisions making, such as the allocation of resources, and improve the efficiency and effectiveness of operations. However, performance measures were found to be non-standardized across the nation and vary by differing agency goals.

The research team in this report conducted a literature review, a survey for all snow and ice states, and international agencies, analyzed the differences between all agencies, and made recommendations based on their findings. The report identified several goals and useful performance metrics for winter maintenance dashboards across agencies:

1. Monitoring vehicle performance: Dashboards were used to monitor vehicle performance, including speed, fuel usage, and mechanical issues. This enabled managers to identify maintenance needs and ensure that vehicles were operating efficiently.

2. Optimizing resource allocation: Dashboards were used to track resource allocation, including the number of vehicles and personnel assigned to each task. This allowed managers to optimize resource allocation and improve the overall efficiency of operations.

3. Improving response times: Dashboards were used to measure response times for winter maintenance vehicles. By tracking response times, managers could identify opportunities for improvement and ensure that vehicles were responding to calls for service promptly.

4. Reducing material usage: Dashboards were used to track material usage, including salt, sand, and other materials. This enabled managers to optimize material usage and reduce costs.

5. Enhancing safety: Dashboards were used to monitor roadway conditions and track the effectiveness of winter maintenance operations in improving safety. This enabled managers to make data-driven decisions about when and where to deploy resources to enhance safety.

6. Real-time monitoring: Dashboards allow managers to monitor performance metrics in real time, enabling them to identify and address issues as they arise.

These performance metrics were categorized into three groups: Inputs, Outputs, and Outcomes. Inputs include resources spent in operations such as labor, machinery, anti-icing materials, and fuel. Outputs include the physical achievements derived from the inputs quantified as lane miles per unit of time

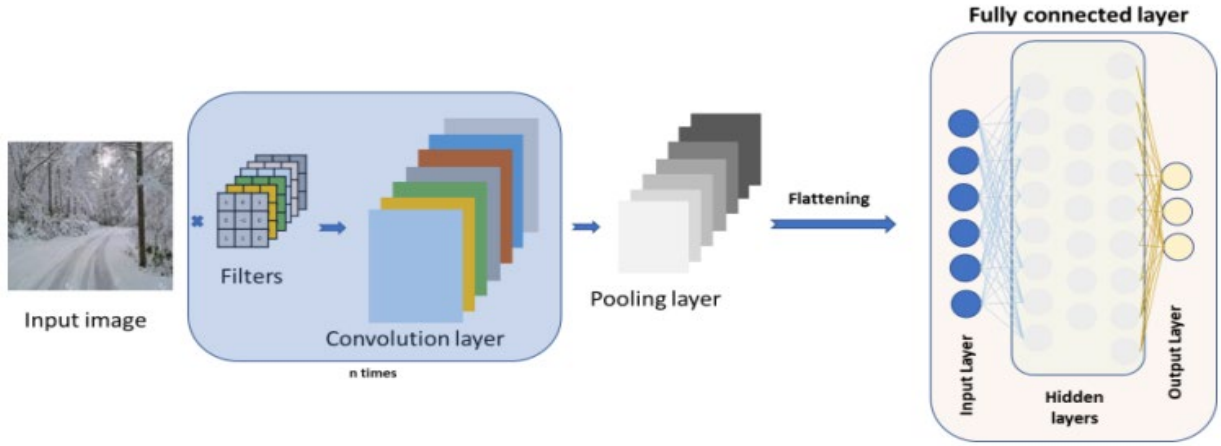
plowed, truck plowing speed, material application rates, and more. Outcomes include abstract concepts which usually could be measured by indicators such as user satisfaction. Other agency goals included infrastructure preservation, livable communities, safety, economy, environmental stewardship, and essential functions.

The report also discusses the platforms and data sources used to generate the dashboards, including AVL systems, weather sensors, and snowplow sensors. The use of Application Programming Interfaces (APIs) streamlines the collection of data from multiple sources. It should be noted that some of the challenges for DOTs' implementation of snow removal performance metrics are the expensive costs of software, hardware, and instrumentation to collect data. Other challenges include external influences such as media that may cause public feedback to be biased.

The use of dashboards supported by the implementation of comprehensive performance metrics was found to be essential in providing DOT's optimized operations, reduced costs, and enhanced safety. By leveraging the power of technology and data analytics, winter maintenance operations were able to operate more efficiently and effectively, ultimately providing safer and more reliable roadways for the traveling public at reduced costs.

2.2 Enhancing Winter Road Maintenance via Cloud Computing (Dastjerdi, Liu, Azmoon, & Yuan, 2023)

This journal article, sponsored by the Federal Highway Administration (FHWA) and Michigan DOT, highlights the use of an artificial intelligence (AI)-enhanced cloud computing framework to automate decision-making using SmartMDSS. A support and decision-making algorithm were developed utilizing an integrated Convolutional Neural Network (CNN) to identify snow coverage on road surfaces from road surveillance images. A CNN is a computational model (Figure 1) that can detect features in an image using filters to distinguish between features. CNNs have been successful in image recognition tasks, object detection, and semantic segmentation. They use a special kind of neural network architecture that is well-suited for processing spatial data, such as images. In the context of the SmartMDSS framework for winter road maintenance, CNNs can be used to analyze images captured by cameras installed on snowplows or road surveillance cameras. The images can provide information about road conditions, such as the presence of ice or snow, and can be used to inform maintenance decisions.

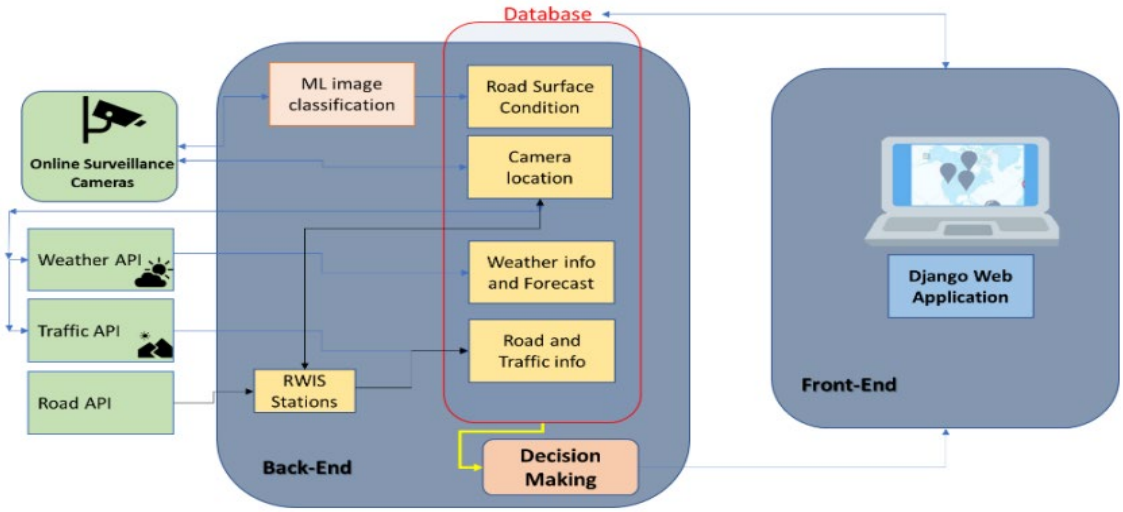


Source: **(Dastjerdi, Liu, Azmoon, & Yuan, 2023)**

Figure 1. CNN Structure

The CNN-based object detection algorithm can be trained on a large dataset of images that contain various road features, such as lane markings, traffic signs, and other objects that may be present on the road. Once the algorithm is trained, it can be used to detect and locate these features in real time, which can help snowplow drivers navigate more effectively and avoid obstacles. In this case, the model was trained using 2433 images, a fully connected layer's shape, the dataset's size, and the number of iterations.

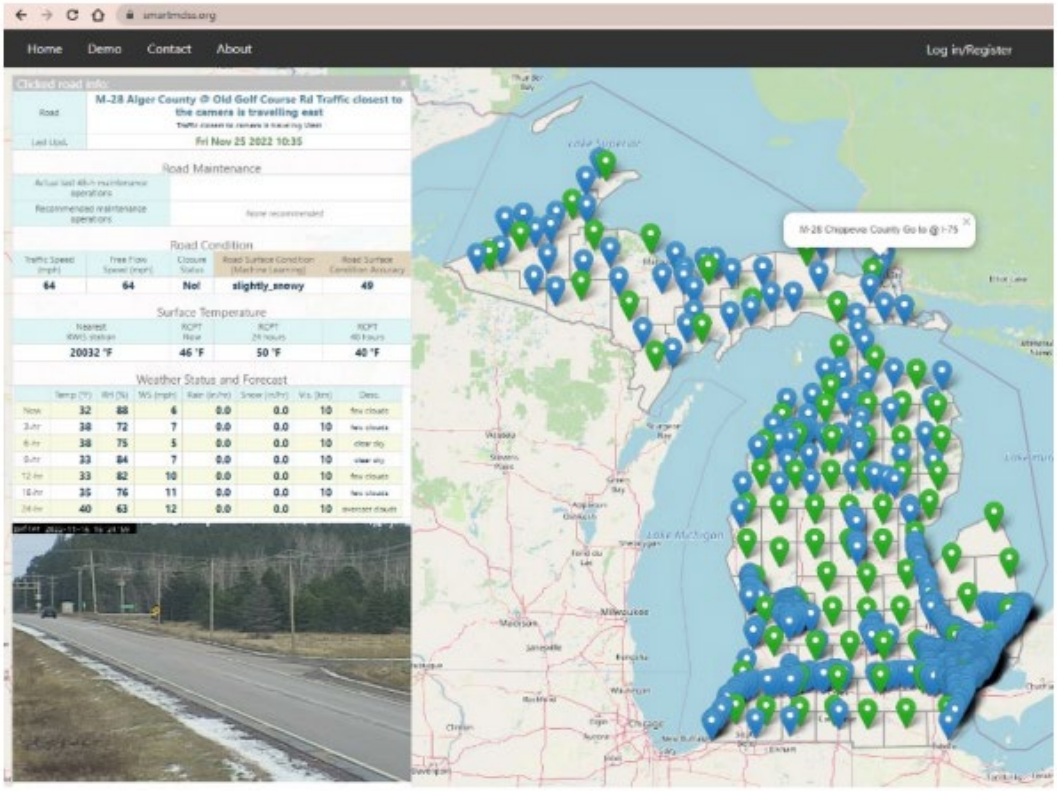
An Application Programming Interface (API) is a set of rules and protocols that allows different software applications to communicate and exchange data with each other. In the context of a Winter maintenance dashboard, an API can be used to fetch real-time weather data, road conditions, and other relevant information from external sources, enabling the dashboard to display up-to-date information for effective winter maintenance operations. Additional data sources included real-time traffic data from "TomTom API" like speed, incidents, and closures. Weather data from "Open Weather Map API" provided data for humidity, visibility, wind speed, temperature, and weather forecasts. Road Surface temperature data from RWIS API provided road surface temperature measured at active RWIS stations around Michigan. "MongoDB" NoSQL database was used for the large volumes of data to be sorted, modified, read, and searched by multi-users. This new framework can be seen in Figure 2 and can be applied to winter maintenance operations.



Source: **(Dastjerdi, Liu, Azmoon, & Yuan, 2023)**

Figure 2. Overview of the SmartMDSS Framework

The user interface of the SmartMDSS (Figure 3) includes an application with a map of the state, and points symbolized by red, yellow, and blue bubbles which represent road condition status. The bubbles are located at surveillance camera locations and once the user interacts with it, displays road condition information with the original road image used to derive data. This study identified three advantages of SmartMDSS: 1) the tool becomes more intelligent over time and as more data comes in, 2) needs for installing instrumentation devices on the roads decrease, and 3) the tool can be adjusted for local road agencies for instant budget savings in road maintenance.



Source: **(Dastjerdi, Liu, Azmoon, & Yuan, 2023)**

Figure 3. The SmartMDSS Web Interface for Michigan

Overall, the study highlights the potential benefits of integrating smart sensing technologies and innovative deep learning algorithms into winter road maintenance activities and suggests that the SmartMDSS framework can provide a more comprehensive and efficient approach to winter road maintenance.

2.3 ArcGIS Solutions for Winter Weather Released (Nosek, 2021)

This online article introduces a winter weather operations solution that maintains a comprehensive inventory of routes, vehicles, service area boundaries, and winter weather events. The article highlights some of the key features of the solution, such as the ability to automate snow route creation, view current and historical weather conditions, and integrate real-time data from sensors and plow trucks. The solution serves as a repository of winter maintenance data with the ability to connect to existing AVL providers and assess the current state of each vehicle with or without an AVL connection.

This winter weather operations solution uses a set of tools, dashboards, and applications designed to be easy to use and deploy and can be implemented quickly and efficiently. The Winter Operations Center, the software system of the solution, allows the user to input and define winter events and record performance metrics. Additionally, the Active Winter Event Dashboard (Figure 4) can manage roads by route priority, service areas, and previous service time for any given road. The article noted that the solution is configurable and can be customized for specific agency needs.

Source: (Nosek, 2021)

Figure 4. PC-Based Image from ArcGIS Webpage with Winter Operations Dashboard

The solution is built on ArcGIS, Esri's powerful mapping and analytics platform, which enables agencies to leverage a wide range of data sources, analysis tools, and technical support. Some of the benefits this solution provides are streamlining winter operations, transparency of winter response plans to the public, and the use of ArcGIS Velocity analytics to assess real-time spatial data and decision-making.

This article provides the research team with valuable insights for determining optimal metrics and strategies currently available and recommended for winter operations dashboards.

2.4 Dashboards for Real-time Monitoring of Winter Operations Activities and After-action Assessments (Desai, et al., 2020)

Developing and using dashboards to display various metrics for performance monitoring is a priority for agencies looking to operate from a unified data source. This study observed twenty heavy snow events in the state of Indiana and focused on Mobile Road Weather Information Sensors (MRWIS), traffic speeds, and North American Land Data Assimilation System (NLDAS) as inputs for developing winter maintenance dashboards. The goal of the study is to provide a comprehensive and unified look at snow and ice operations during winter storm events.

Traffic Tickers were used to monitor the statewide impact of precipitation and winter storms on traffic congestion and mobility. The traffic ticker uses the location of GPS-enabled devices, from fleet telematics to cellular phones, to measure speeds on a minute-by-minute basis. Outputs derived from this metric include total mile hours of congestion defined by roadways operating below a speed threshold of 45 mph.

The NLDAS database was used to derive weather data, particularly precipitation, for the chosen winter storm events. Additionally, Road condition and fleet location data such as latitude, longitude, altitude,

speeds, and heading for snowplow vehicles were collected through MRWIS sensors. The sensors also allow for estimates of road conditions from measures of dew point, surface temperature, water film height, ice percent, relative humidity, and friction. The capability of the sensors for measuring friction values allowed the authors to locate the exact beginning and end of winter weather events. Heatmaps were also produced for post-winter storm events to show road condition parameters and traffic speeds. These parameters jointly provide agencies with a localized depiction of winter storm impact on mobility.

The study identified future areas of expansion for dashboard performance measures, including safety and recovery from event metrics. Interest is shown in linking crash data to heat maps which would allow agencies to better plan and schedule resources during winter storm events.

Observations from this study help the research team evaluate current metrics used by DOTs, in this case, Indiana, and possible future metrics to include in dashboards. It should be noted that a comprehensive dashboard was not produced for this study.

2.5 Data Dashboards at State DOTs: Case Studies of Select Transportation Agencies (Gillman & Cahill, 2021)

The FHWA released a report on best practices for dashboard development and their intended use among State DOTs. This report defines a dashboard as four category types: Tactical or Analytical Dashboards, Operational Dashboards, Strategic Dashboards, and Informational Dashboards. The report conveys that to create effective dashboards, it is important to identify the target audience and include stakeholders throughout the design and implementation process. The principle of simplicity and visual hierarchy should guide dashboard design, with important trends and data in larger, bolder elements, and more detailed information in smaller elements. The following paragraphs highlight key findings from each case study in the report.

The Arkansas Crash Analytics Tool (ACAT) (Figure 5) is an example dashboard maintained by the Geographic Information System (GIS) Division within the Transportation Planning and Policy Division. The traffic safety team developed this tool to identify, evaluate, and plan safety enhancement for hazardous roadway conditions, potential crash sites, and railway highway crossings. The tool uses crash data from State Police, after removing personally identifying information, including crash records and reports. After the creation of this tool, various safety projects such as the installation of cable barriers, rumble strips, and other safety measures have been implemented. Other benefits seen are improved crash reporting and increased public engagement as stakeholders identify missing data points and possible improvements to the tool.

Michigan DOT has over 100 different dashboards used regularly for operations. They created dashboards like the Bridge Conditions Dashboard (Figure 6) to track bridge conditions across the state, the Billboard Dashboard to track permits for billboards on Michigan DOT's property, and the Project Management Dashboard that monitors Michigan DOT dashboard usage.

Source: **(Gillman & Cahill, 2021)**

Figure 5. ARDOT's Arkansas Crash Analytics Tool (ACAT)

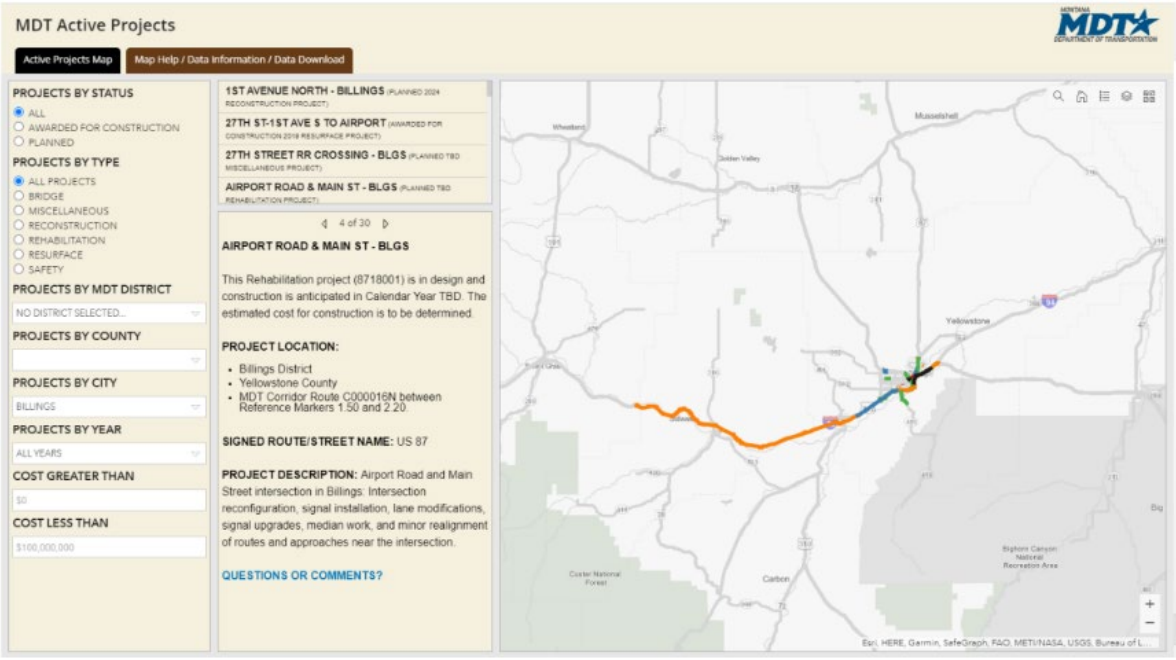
Source: **(Gillman & Cahill, 2021)**

Figure 6. MDOT's Bridge Conditions Dashboard

These dashboards fulfill agency goals and are created in collaboration with other departments. Michigan DOT primarily uses these dashboards to track project progress instead of creating maps and visualizations. The Performance Management Dashboard monitors the usage of all active dashboards to identify areas for improvement. To create dashboards, the GIS team relies on dashboard requests in the form of PowerPoint presentations that explain the dashboard's purpose and functions. Their dashboards have improved data and project tracking for the Agency and its partners, highlighting the critical role of the GIS

Unit. The GIS Unit aims to provide mobile device functionality for all dashboards and maps created by the department in 2020.

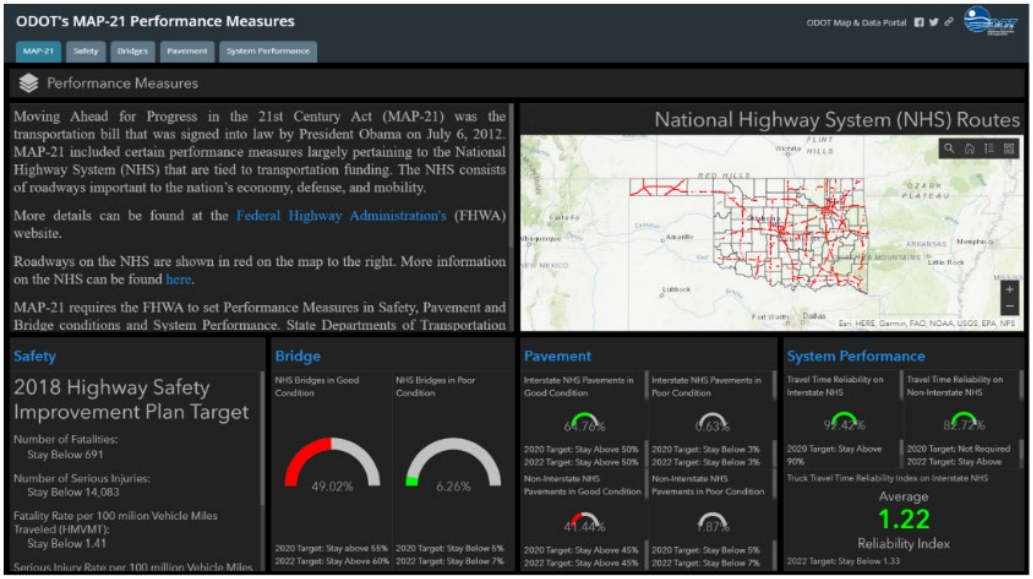
The Geospatial Information Section of Montana Department of Transportation (MDT) developed an interactive map dashboard (Figure 7**Error! Reference source not found.**) to display information on the state's construction and maintenance projects. The dashboard was created in response to the Transportation Commission's request for a report on upcoming transportation projects, which previously required significant time and resources to compile due to decentralized project information and inefficient data storage. The development team overcame challenges such as stakeholder involvement and compliance with Americans with Disabilities Act (ADA) standards for web design. They also learned important lessons, including the importance of managing stakeholder expectations and having a dedicated project manager. Since the launch of the dashboard, MDT has received positive feedback from stakeholders and fewer requests for project information, allowing them to save time on requests that the dashboard cannot address.



Source: **(Gillman & Cahill, 2021)**

Figure 7. MDT's Active Projects Dashboard

The Oklahoma DOT has implemented three public dashboard projects: the Asset Inventory Dashboard, the County Certification Mileage Dashboard, and the Performance Measures Dashboard (Figure 8). These dashboards provide access to information such as asset inventory, road mileage data, and performance metrics. The dashboards draw information primarily from databases that Oklahoma DOT already maintains. The team began creating these dashboards with limited skill sets, but with Esri tutorials and the analytics built into the software, the GIS team can now build multiple projects simultaneously. Oklahoma DOT's dashboards have improved transparency within the agency and with agency stakeholders, improved project management and operations, and increased collaboration among departments and agency partners. The department encourages other agencies to use data dashboards to improve their own internal and external performance.



Source: **(Gillman & Cahill, 2021)**

Figure 8. Oklahoma DOT's MAP-21 Performance Measures Dashboard

The Puerto Rico Department of Transportation and Public Works (DTOP) collaborated with Metric Engineering of Puerto Rico to develop two dashboards related to traffic operations and disaster recovery from Hurricane Maria. The Landslides Assessment Project dashboard displays the locations of landslides from Hurricane Maria, while the Traffic Data Collection dashboard (Figure 9) monitors traffic flow equipment. Both dashboards were developed using Esri's ArcGIS Online to collect more accurate location data. The dashboards have proven helpful for DTOP, allowing managers to track work and other performance metrics continuously. Metric Engineering offered the dashboards as an added value to their contract work with DTOP. DTOP has implemented several other dashboards within the agency to respond to questions about construction progress in the wake of Hurricane Maria.

Source: **(Gillman & Cahill, 2021)**

Figure 9. DTOP and Metric Engineering's Traffic Data Collection Dashboard

The report concludes that identifying and including stakeholders, creating prototypes, and managing development timelines and stakeholder expectations are important lessons learned. All the case studies reported streamlined existing reporting processes, improved data storage and validation, and increased engagement with the public. The overarching goal is for State DOTs to accomplish innovation and accountability by leading with innovative practices and technology and serving constituents with efficient and effective operations. The findings of this study inform the research team of best practices for dashboard making outside the bounds of Winter Maintenance applications.

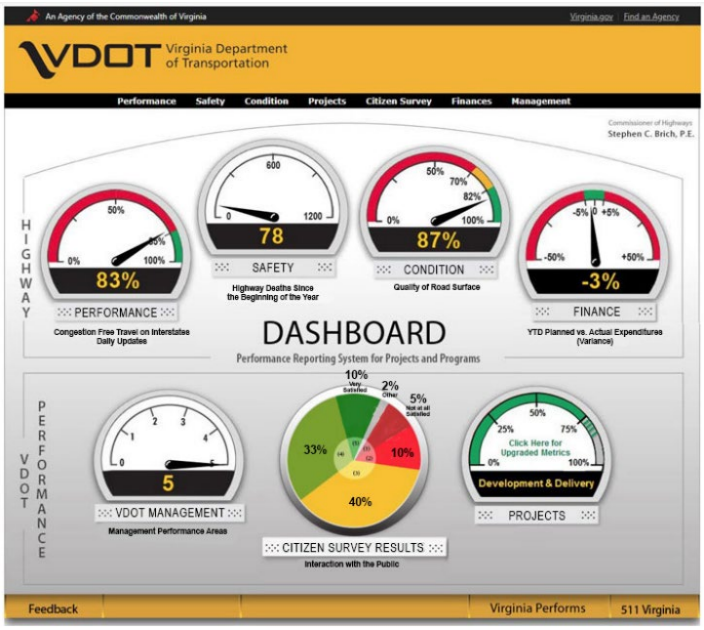
2.6 Transportation Management Center Performance Dashboards (Tantillo, Smith, Packard, Lomax, & Dhuri, 2021)

The "Transportation Performance Management Dashboard Implementation Guide" by the FHWA provides transportation agencies with guidance on using dashboards to enhance operations and improve performance measures. A dashboard aims to provide a user-friendly tool that can visualize, analyze, and communicate performance data effectively.

The report includes case studies of transportation agencies that have successfully implemented performance management dashboards. One such example is the Maryland DOT, which developed a dashboard to monitor progress toward its strategic goals, including reducing traffic fatalities and improving infrastructure conditions. Another case study is the Oregon DOT, which implemented a dashboard to track performance measures related to pavement conditions, bridge conditions, and congestion levels. Additionally, the Virginia DOT (VDOT) implemented a performance management dashboard (Figure 10) to track key performance indicators (KPIs) related to the state's transportation network. The dashboard allowed VDOT to monitor and analyze data related to traffic volume, travel time reliability, pavement condition, and other factors, and identify areas for improvement. These case studies demonstrate the potential benefits of using performance management dashboards to improve operations and achieve strategic goals.

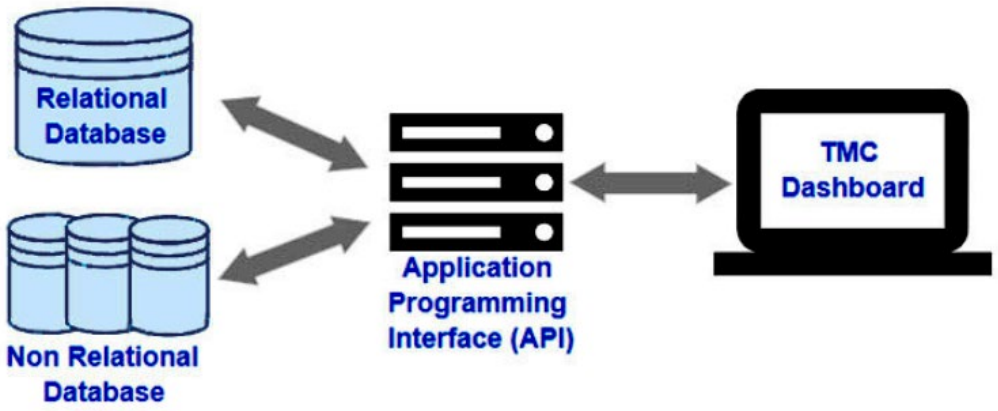
This report identifies several current trends in the planning and use of transportation dashboards. One trend is the integration of dashboards with strategic planning processes, aligning performance measures with strategic goals to ensure relevance and usefulness for decision-making. Another trend is a greater emphasis on data quality and accuracy, which enhances the effectiveness of dashboards and builds trust among stakeholders. Data format and storage can vary from agency to agency but are fundamentally built on two types of data management: a Relational database stores highly structured data and Structured Querying language (SQL) may be used to query the data; and a Non-relational database stores information in Key-value pairs or JSON documents for data in unstructured formats (Figure 11). Transportation agencies are also using real-time data to support real-time decision-making and optimize operations.

In addition, there is a focus on accessibility and user-friendliness in the design of dashboards. By creating intuitive and easy-to-use dashboards, transportation agencies can increase engagement and adoption among stakeholders. Collaboration and stakeholder engagement is also a trend, as transportation agencies recognize the importance of involving stakeholders in the design and implementation process to ensure that dashboards meet the needs of all users. The report stresses the need for continuous improvement and monitoring of the dashboard to ensure that it remains relevant and aligned with the agency's goals and objectives.



Source: **(Tantillo, Smith, Packard, Lomax, & Dhuri, 2021)**

Figure 10. Virginia DOT Performance Reporting System for Projects and Programs



Note: TMC = Transportation Management Center.

Source: **(Tantillo, Smith, Packard, Lomax, & Dhuri, 2021)**

Figure 11. Illustration. Data workflow for relational and non-relational databases connected via an application programming interface to a dashboard.

The report highlights the importance of selecting the most useful performance measures and data sources to monitor progress and make data-driven decisions. However, transportation agencies may face several challenges during the implementation process, such as the availability and quality of data, lack of technical expertise, and limited financial resources. The report provides practical recommendations to address these challenges, such as developing a data management plan, seeking external technical assistance, and leveraging existing resources.

The use of big data also arises as a challenge to transportation agencies as they are collecting and analyzing larger and more complex data sets than ever before. To process and analyze these data sets, the guide emphasizes the importance of using advanced analytics tools and techniques. Another trend is predictive analytics, which involves using statistical models and machine learning algorithms to make predictions about future performance. The guide suggests that transportation agencies can use predictive analytics to identify potential problems before they occur and take proactive steps to mitigate them.

AI is also a current trend in transportation performance management. AI can be used to process and analyze large amounts of data and identify hidden patterns and trends. The guide recommends the use of AI to help transportation agencies make more informed decisions and predict future trends. Additionally, machine learning (ML), which involves the use of algorithms to analyze data and learn from it, can be used to identify patterns and trends in transportation performance data and make more accurate predictions about future performance.

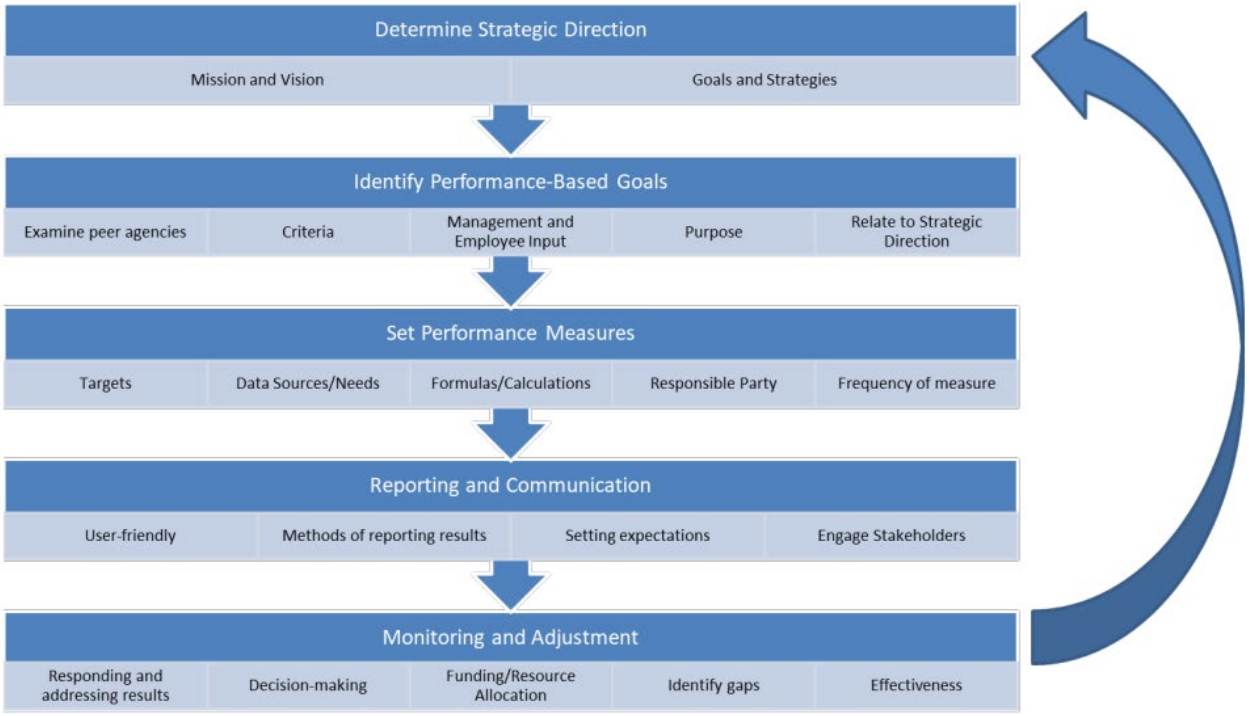
In summary, the report provides a valuable resource for transportation agencies to design and implement performance management dashboards. The report is useful to the research team to analyze performance measures, data sources, challenges, recommendations, case studies, and efforts for continuous improvement in dashboard development.

2.7 Best Practices for Performance Measurement in Transportation Operations and Maintenance (Gibson, Catchings, Dyke, Waddle, & Kreis, 2021)

The report provides a thorough overview of the current state of the practice in Transportation Systems Management and Operations (TSMO) performance measures. The report emphasizes the importance of developing effective performance measures for TSMO programs and highlights the need for standardization and consistency in performance measure development and reporting across different agencies and jurisdictions.

The report identifies several key elements of a TSMO dashboard, including the selection of appropriate performance measures, the use of data visualization techniques, and the inclusion of relevant contextual information. It provides practical strategies for developing TSMO dashboards, such as leveraging existing data sources and technologies, and ensuring that dashboards are user-friendly and accessible to a wide range of stakeholders.

The report discusses current data collection practices and potential performance measures that can be used to evaluate TSMO programs. These may include measures related to traffic flow and congestion, incident management, traveler information, and sustainability. Based on the FHWA's framework, the Performance Measures Roadmap (Figure 12) was produced as a strategic framework designed to guide agencies in developing and implementing performance measures for their TSMO programs. The roadmap consists of six steps.



Source: **(Gibson, Catchings, Dyke, Waddle, & Kreis, 2021)**

Figure 12. Performance Measures Roadmap

The first step is to define the goals and objectives of the TSMO program. The second step is to identify relevant performance measures that can be reliably measured. The third step is to establish specific and measurable targets for each performance measure that reflect the desired outcomes of the TSMO program. The fourth step is to develop data collection and analysis strategies, including identifying data sources and developing procedures for analyzing and reporting the data. The fifth step is to implement the performance measures and ensure accurate data collection. The final step is to monitor and evaluate the performance of the TSMO program on an ongoing basis, regularly reviewing performance measures and targets, analyzing data, and adjusting the program as needed. The Performance Measures Roadmap emphasizes the importance of a structured approach to developing and implementing performance measures for TSMO programs to ensure effective evaluation of the program's success.

The report provides case studies that illustrate how these measures can be used in practice. One such case study is the Colorado DOT's TSMO dashboard, which uses a variety of performance measures related to traffic operations, incident management, and traveler information to evaluate the effectiveness of its programs. The dashboard leverages data from multiple sources, including real-time traffic data and incident data, and uses data visualization techniques to make the data more accessible and understandable to stakeholders.

Another example is the Smart Columbus program in Ohio, which uses a variety of performance measures related to travel time reliability and sustainability to evaluate the effectiveness of its initiatives. The program uses data from a range of sources, including connected vehicles and sensors, to collect and analyze performance data.

Overall, the report provides valuable insights into the development and use of TSMO dashboards and performance measures. It emphasizes the importance of leveraging data and technology to improve transportation system management and operations and provides practical guidance on how to do so effectively.

2.8 Additional Studies:

2.8.1 Leveraging Telematics for Winter Operations Performance Measures and Tactical Adjustment (Desai, et al., 2021)

The study aims to develop real-time dashboards for systematic monitoring and allocation of resources during winter maintenance operations at the Indiana DOT. The study uses data from emerging technology, such as real-time truck telematics, hi-resolution National Oceanic and Atmospheric Administration (NOAA) data, dash camera imagery, and crowdsourced traffic speeds, to develop dashboards.

The study collects nearly 13 million location records and 11 million dash camera images from telematics onboard 1,105 trucks during the 2020-2021 winter season. The dashboards developed from these data were used for systematic monitoring and allocation of resources during critical weather events. The dashboards allowed for tactical adjustments of resources during storms and system-wide collection of resources, enabling agencies to monitor multiple seasons and make long-term strategic asset allocation decisions.

The study also highlights the usefulness of the dashboards from a public information perspective, as they provided real-time visual updates on conditions throughout the state during large storms, which was useful for agencies that interface with the media and social media.

2.8.2 Leveraging Road Weather Data for Performance Management Dashboards and Reports (U.S. Department of Transportation Federal Highway Administration, 2020)

This fact sheet describes how data management tools that use road weather data from mobile and connected vehicles can improve the performance of road weather operations and maintenance activities. Performance management principles can help agencies direct investments, measure progress, and make adjustments to improve operational performance. Agencies can use performance metrics to evaluate the benefits of new practices or processes, justify funding, and improve public understanding. The fact sheet also provides examples of performance dashboards and annual reports used by state transportation agencies to monitor their winter maintenance activities. Road weather performance metrics developed from data collected from mobile and connected vehicle sources can be published for internal or public use to compare year-over-year agency costs and performance.

2.8.3 A Real-Time Framework for Winter Weather Operations Using ArcGIS Velocity (Foss, Nosek, & Suresh, 2022)

This online article discusses the use of ESRI's ArcGIS Winter Weather Operation solution as a tool for government entities to manage snow and ice events. This article delves deeper into the capacities of ArcGIS Velocity analytics for hosting Big Data real-time streams from multiple IoT sources. The tool leverages historical vehicle data to show the length and percentage of serviced roadways, distance

traveled, and amount of material deployed as well as service status merged in the feed. Operation managers can track and manage progress through big data analytics which analyzes patterns and summary analyses of large amounts of stored data. The queries are displayed in the Active Events dashboard, which allows for stakeholder transparency in operations. Additionally, public safety is kept in mind as the Current Road Status application provides the public and safety officials with a real-time serviced route status Lastly, the Winter Season dashboard summarizes key metrics during multiple events which allow for review of each season and better budget allocation.

2.8.4 Performance Dashboard Snow and Ice Removal (Minnesota Department of Transportation, 2023)

This web page is part of a series of dashboard and maintenance decision support tools for the Minnesota DOT. The contents of the web page summarize snow and ice removal metrics such as Road Salt Chloride use, Bare Lane targets, and Winter Severity Index. The web page discusses the use of innovative strategies by districts during winter weather events including anti-icing, pre-wetting, and de-icing strategies. Minnesota DOT is currently looking to reduce the use of dry chlorides and increase liquid chlorides to minimize the impact of pollutants. Minnesota DOT defines a winter weather event as a "weather occurrence that consumes resources necessary to prevent, minimize or regain the loss of bare lanes". Minnesota DOT measures the percentage frequency of meeting bare lane targets based on predetermined levels of service for roadways for each season. The Winter Severity Index (WSI) is a single relative value that draws from: dew point/ relative humidity, wind speed gusts and direction, frost/ black ice, precipitation type and duration amounts, air temperature, road temperature, cloud cover, blowing snow, and surface pressure measures. These metrics are compiled for each season to get an understanding of variability among each winter event.

2.9 References

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3. Survey Summary

This section provides a summary of the responses received from the survey by public agencies for this project. The survey was designed to gather basic, high-level information regarding each agency's use of dashboards with dynamic or interactive performance measures for winter operations, as well as detailed information on data sources, dashboard development, and platforms used.

This section also presents recommendations on which agencies were selected for further in-depth interviews to gather more information on current dashboarding options and functional use cases supporting winter maintenance operations. The detailed information from each agency will be included within a case study report that will serve as a reference guide for state DOTs who are considering implementing or enhancing their winter maintenance operations dashboards.

3.1 Introduction

This task focused on developing and conducting an online survey to gather information from Clear Roads member states and non-Clear Roads states, and municipalities. The purpose of the survey was to gather information on the state of the practice for winter maintenance dashboards. The survey helped gain an understanding of which agencies or organizations have implemented one or more dashboards; what data are used (metrics); how the data are connected/linked, cleaned, and stored; the frequency with which the dashboards are refreshed (real-time, semi-real-time, weekly, etc.); and what platforms and databases are utilized. The survey also collected information on agencies' planning, processes, steps, and results with their respective systems. The surveys were distributed through the following methods:

- Snow and Ice listserv maintained by the University of Iowa,
- Clear Roads member state DOTs, and
- International agencies through the Norwegian Public Roads Administration and other Nordic countries through the Nordic Road Association (NVF).

A total of 25 surveys were received from 23 agencies and have been summarized in this section. Table 1 presents a listing of the agencies that responded to the survey. Table 1 also delineates the agencies that utilize Winter Maintenance Dashboards and the agencies that currently do not use them. Section 3.2 of

this report contains a question-by-question summary of the responses received from the responding agencies. Section 3.3 presents the evaluation of the survey results. Section 3.4 is the recommendations for Case Studies and next steps. Appendix A to this report contains each agency's response to the survey for further reference.

Table 1. Transportation Agency Survey Respondents

Survey Respondents with Dashboard for Winter Operations			
Arizona DOT	Kevin Duby	North Dakota DOT	Miles Nelson
California DOT (Caltrans)	John Oliva	Nebraska DOT	Michael Mattison
City of Columbus, Ohio	Scott Tourville	NPRA (Norwegian Public Roads Administration)	Bård Nonstad
Idaho Transportation Department	Steve Spoor	Ohio DOT	Dean Alatsis
Iowa DOT	Craig Bargfrede	Oregon DOT	Charles Van Genderen
Kansas DOT	Dale Kirmer	Rhode Island DOT	Matthew Ouellette
Kentucky Transportation Cabinet	Randi Feltner	Vermont Agency of Transportation	Todd C Law
Maine DOT	Brian Burne	Virginia DOT	A.J. Younes & Bryan Wade
Massachusetts DOT	Mark Goldstein	Montana DOT	Doug McBroom
Survey Respondents without Dashboard for Winter Operations			
City of Dubuque, Iowa	John Klosterman	Michigan DOT	Justin Droste
Illinois DOT	Laura Shanley	Oklahoma DOT	Alex Calvillo
Wyoming DOT	Clifford Spoonemore		

3.2 Summary of Survey Responses

The survey for transportation agencies consisted of 26 questions.

Question 1. Do you have any dashboards (with interactive performance measures) using data of winter maintenance operations? If yes, how many?

Yes			NA
18			
How Many Dashboards?	One	5	5
	Two	3	
	Three	2	
	Four	3	
	Five	1	
	Six	2	
	Seven	1	
	approx. 12	1	

If yes – please indicate how each one is used?

Agency	Response
Arizona DOT	We have three dashboards- 1- For performance measure and material reduction. 2- Equipment cleaning. 3- budgetary dashboard.
California DOT	AVL-RWIS-material usage-
City of Columbus, Ohio	Public Facing-shows mapping of how long ago a street was serviced, along with some other general info/links to snow plan Internal-shows exact location of each truck, if they are servicing, and collects data on how many miles serviced, percent complete by outpost or priority, etc.
Idaho Transportation Department	We have one that is a gauge type displaying the Mobility Score for each District and Statewide.
Iowa DOT	1. Salt Dashboard- calculates an anticipated salt usage rate and then compares anticipated usage versus actual usage. 2. Salt Ledger- Keeps a running total of salt on hand by garage. Shows daily usage as reported in the garage daily logs plus it shows when they receive salt and when they sell or transfer salt. 3. Material Usage and Storm Reporting Dashboard. This dashboard shows all material usage by garage for the current season plus it displays weather data as reported by the garages through their daily logs. 4. Winter Severity Index. This dashboard shows a graph of winter severity based on the winter weather data entered by the garage staff into their daily logs. 5. Salt usage chart. This dashboard shows salt usage for the past five years. 6. Snow Accumulation. This dashboard shows the amount of snowfall per year for the last five years. 7. Salt Budget Dashboard. This Dashboard is used to track the status of our $15millon salt budget.
Kansas DOT	We have a dashboard for the end of season performance measure.
Kentucky Transportation Cabinet	GoKY - public facing dashboard (511 type of setup); used by public and leadership; real time DSS - used by district and central office staff; more of an in-depth look; real time ITS Data Studio - visualization of short term trends and summarize 6-hour worth of data; more of a 'near time' Trimble OMS - material usage dashboard

Agency	Response
Maine DOT	2 cover cost graphs from different systems, one covers accomplishment graphs (pass-miles), one provides cost/accomplishment tables, and one covers salt stockpile balances.
Massachusetts DOT	We track expenditures for 3 key facets of our Snow & Ice program: Materials, Hired Equipment, Salaries
Michigan DOT	no interactive dashboards, just dashboards for material reporting every month.
Montana DOT	We have a dashboard that is linked to our Maintenance Management system, which delineates targets for material use in each of our sections, it also includes miles plowed and percent of year
North Dakota DOT	One dashboard is in development that shows status of highways. Dashboard displays how many roads are closed, snow covered, ice. Dashboard displays for each district. The second dashboard is a performance measure dashboard that tracks how long a snowstorm takes to return to normal travel speed. The third dashboard displays how much inventory of material districts have on hand such as salt and aggregate stockpiles.
Nebraska DOT	1. AVL functional - displays summary with drill down to individual trucks. 2. MDSS Recommendation vs Actual Action - displays operator accept or decline and actual action compared with recommendation. 3. Plow truck material spreader mode of operation - displays a history of spreader mode, summary with drill down to individual trucks. 4. AVL Road and Weather condition reports - Displays a list of trucks with conditions reported and date/time of report. 5. Cost of Storm - Displays the cost of equipment, personnel, and materials. Still in Beta testing. 6. GIS Display of MDSS route parameters. All of the reports except number 6 have selectable date range and multiple filters including location.
NPRA	This dashboard is used by NPRA for documentation of the winter production carried out by contractors.
Ohio DOT	GPS / AVL - Vehicle tracking, usage OHGO - Incidents, Construction, Cameras, Travel Delays Weather Hazards RWIS TTRI - Traffic Time Reliability Index RTSI - Real Time Snow and Ice - collects processes and reports data related to snow events & SNIPE - SNow and Ice Performance Evaluator - identifies and locates snow events and determines where ODOT was able to meet recovery goals. TMC - Traffic Management Center - Monitors and responds to events and incidents/accidents.
Oregon DOT	We use Geotab as our AVL Vendor. Their platform has a Dashboard for all registered users. We are developing and improving this dashboard to be of use in real time so we can see daily material logs, possible collisions, etc.
Rhode Island DOT	We have a vendor software program (website) for our winter vendors. We're starting to pilot dashboards through our VUEWorks maintenance management program. Our State plow trucks have Samsara AVL/GPS and the Samsara website has dashboard features. Dashboards for RWIS info.
Vermont Agency of Transportation	We can compare our materials usage, labor and overall costs that can be set for a storm or the entire season.

Agency	Response
Virginia DOT	They are used to visualize mobilization, weather, financial, materials, and contracting data/progress. We have our winter weather dashboard using ArcGIS and a maintenance dashboard using PowerBI. The winter weather dashboard looks at impactful winter weather affecting the commonwealth of Virginia. The maintenance dashboard reflects equipment readiness and supply information for winter weather treatments. There are also ArcGIS dashboards that capture recovery information form damage assessments.

Question 2. Do you find these dashboards useful during an event in real-time?

Yes	No	Not Applicable/Blank
10	7	6

Question 3. Do you find these dashboards useful after an event, such as after-action reports?

Yes	No	Not Applicable/Blank
17	0	6

Question 4. Do you use the dashboards to inform beneficial / best practices?

Yes	No	Not Applicable/Blank
11	6	6

Question 5. What data are you using in your dashboard(s)? (Select all that apply)

Agency	Automatic Vehicle Location/Global Positioning System (AVL/GPS)	Material Usage total	Material Usage Rates	Weather Data (For example: Road Weather Information System (RWIS))	Cycle Time	Plow Position	Traffic Data (Speed and/or Volumes)	Connected Vehicle (CV) data	Incident Data	Finance data	Other (please specify)
Arizona DOT	X	X	X							X	Equipment tracking and cleaning
California DOT	X	X	X	X							
City of Columbus, Ohio	X					X	X				mileage/mile serviced
Idaho Transportation Department											Mobility Score is defined as % of time moisture is present on a roadway that has a temperature less than 32 degrees F without ice forming.
Iowa DOT	X	X	X	X						X	
Kansas DOT							X				
Kentucky Transportation Cabinet	X	X	X	X			X		X		
Maine DOT		X								X	
Massachusetts DOT										X	
Michigan DOT		X									
Montana DOT		X	X								
North Dakota DOT		X	X	X		X	X		X		
Nebraska DOT	X	X	X	X						X	
NPRA	X	X	X	X	X	X					Static cameras for road condition
Ohio DOT	X	X	X	X	X		X		X	X	
Oklahoma DOT		X									

Agency	Automatic Vehicle Location/Global Positioning System (AVL/GPS)	Material Usage total	Material Usage Rates	Weather Data (For example: Road Weather Information System (RWIS))	Cycle Time	Plow Position	Traffic Data (Speed and/or Volumes)	Connected Vehicle (CV) data	Incident Data	Finance data	Other (please specify)
Oregon DOT		X	X						X		
Rhode Island DOT	X		X	X				X	X		
Vermont Agency of Transportation		X									labor and overall costs.
Virginia DOT	X	X		X		X	X		X	X	

Question 6. What are the sources of the data in the dashboards? (Select all that apply)

Agency	Automatic Vehicle Location/Global Positioning System (AVL/GPS)	Spreader/Sprayer Controller	Plow Position Sensor	Mobile Weather Sensors, etc.	Maintenance Decision Support Systems (MDSS)	RWIS Stations	Advance Traffic Management System (ATMS)	Maintenance Management System	Probe Traffic Data	Connected Vehicles (CVs)	Crowd Sourced data (e.g., Waze)	Other (please specify)
Arizona DOT	X	X						X				
California DOT	X			X		X	X					
City of Columbus, Ohio	X	X	X									
Idaho Transportation Department						X						
Iowa DOT	X	X		X		X						Our internal Resource Management System (RMS)
Kansas DOT						X			X			

Agency	Automatic Vehicle Location/Global Positioning System (AVL/GPS)	Spreader/Sprayer Controller	Plow Position Sensor	Mobile Weather Sensors, etc.	Maintenance Decision Support Systems (MDSS)	RWIS Stations	Advance Traffic Management System (ATMS)	Maintenance Management System	Probe Traffic Data	Connected Vehicles (CVs)	Crowd Sourced data (e.g., Waze)	Other (please specify)
Kentucky Transportation Cabinet	X	X	X		X	X	X	X	X		X	
Maine DOT								X				
Massachusetts DOT								X				
Montana DOT								X				
North Dakota DOT	X			X	X	X	X					
Nebraska DOT	X	X			X							AVL Functional uses Equipment Asst Management System and AVL, Storm cost uses data from the financial system
NPRA	X	X	X			X						
Ohio DOT	X	X		X		X	X	X	X		X	
Oklahoma DOT								X				
Oregon DOT	X	X	X									
Rhode Island DOT	X	X		X		X		X			X	
Vermont Agency of Transportation												activity tracking software.
Virginia DOT	X			X	X	X	X	X			X	

Question 7. How are the data ingested into the dashboard? (Select all that apply)

Agency	Application Programming Interface (API) from data source	SQL database updated	Excel spreadsheets	CSV/Text File	Access Database	Other (please specify)
Arizona DOT	X					
California DOT		X	X		X	
City of Columbus, Ohio	X					
Idaho Transportation Department			X			
Iowa DOT						Power Bi
Kansas DOT			X	X		
Kentucky Transportation Cabinet	X	X				
Maine DOT						Nightly updates from Oracle tables
Massachusetts DOT	X					
Montana DOT	X					
North Dakota DOT	X				X	
Nebraska DOT	X	X		X		
NPRA	X					
Ohio DOT	X	X	X	X		
Oklahoma DOT		X				
Oregon DOT	X					
Rhode Island DOT						I do not know this answer.
Vermont Agency of Transportation						BI Dashboard (graphs, figures, etc.)
Virginia DOT	X	X	X	X		CSV files to SharePoint Online, automated with Blue Prism or Power Automate. ArcGIS

Question 8. What is the frequency of the data refresh? (Select all that apply)

Frequency	Total Agencies Reporting Data
Minutes / Close to real-time	13
Hourly	2
Daily	9
Weekly	2
Monthly	1
Other (please specify) -Except the data is input after the fact for time, materials, and equipment.	1
No Response	4

Question 9. How are data stored? (Select all that apply)

Types of Data Storage	Total Agencies Reporting Data
Cloud-based	8
Client-Owned Server	11
Third-Party Server	6
Enterprise Content Management System (For example: SharePoint)	3
Other (please specify)	0
No Response	5

Question 10. What dashboarding platforms are used? (Select all that apply)

Types of Dashboarding Platforms	Total Agencies Reporting Data
PowerBi	6
Tableau	1
ArcGIS	9

Types of Dashboarding Platforms	Total Agencies Reporting Data
Internally custom created or other platform (please describe) • Geotab • VUEWorks (internal system), Samsara, Storm Manager • Looker Studio; Google Maps (GoKY); Trimble OMS • Gauge type dashboard • Atlas • Oracle Analytics Cloud • Internal program • 3rd party vendor custom solution	10
No Response	5

Question 11. What metrics/performance measures presented on the dashboard(s) do you find most helpful for operations? And describe why they are the most helpful.

Agency	Response
Arizona DOT	We have several measures- For AVL, we measure speeds, material amounts, liquid amounts, spinner speeds, ambient and road temps
California DOT	Location, material usage, weather
City of Columbus, Ohio	percent complete, exact truck location/total number trucks out, streets serviced map
Iowa DOT	1. Salt usage information- You cannot manage your operation properly if you cannot measure your usage properly. 2. Winter Severity - This has helped us paint the picture with DOT Leadership, the Governor's office and our Legislature on the overall winter severity. We have used this dashboard twice in the last 8 years to go to the legislature and ask for additional funding for salt due to the severity of the winter. Both times we were successful in our request.
Kentucky Transportation Cabinet	Performance Metrics are currently being developed using some of the same data/sources used for dashboards. KYTC does have a SSI developed.
Maine DOT	Expenditures per accomplishment are helpful in comparisons between crews and regions, but they don't tell the whole story. We need to build out a few more models to incorporate assets and lane mile responsibilities to make the systems more useful. We also need to implement AVL. The salt stockpile balances are very useful for ordering and establishing salt delivery priorities.
Massachusetts DOT	We need to know how much cost our program has incurred at any point in the season
Montana DOT	Material use and plow miles
North Dakota DOT	Currently working on new dashboards will have to test them out this winter to understand what performance measures work well.

Agency	Response
Nebraska DOT	AVL Function Report: Helps District Management find problems with AVL in their trucks and get them fixed. MDSS Recommended vs Actual: Provides insight into operator perceptions, identifies possible issues with MDSS recommendations GIS Display of MDSS Route Parameters: Helps identify inconsistencies in maintenance practices and errors in route setup
NPRA	Winter production data and cycle time presented in a map solution, together with weather data/forecast and pictures of the road conditions.
Ohio DOT	All are helpful, based on the user needs.
Oregon DOT	Many of our responses are aspirational because this program is under development. To date, Material by truck has been most useful for maint mgrs post event.
Rhode Island DOT	AVL/GPS beneficial to see where assets are and the history of the asset's routes. Number of assets working a winter storm at any one time.
Vermont Agency of Transportation	Salt use, compared to winter severity (but not in the dashboard at this time).
Virginia DOT	Virginia contracts a significant portion of snow removal services. Dashboards that visualize the contracting process offer a lot of insight into the amount of contractors we have vs the amount we need, the types of equipment we are signing up, the progress of the applications and more.

Question 12. Are you able to generate static reports / outputs from the dashboard?

Yes	No	Not Applicable/Blank
13	4	6

Question 13. Who has access to view the dashboards? (Select all that apply)

Access	Total Agencies Reporting Data
Internal agency	18
Partner Agencies	3
Contractors	1
Public	4
Other (please specify)	0
No Response	4

Question 14. Who developed the dashboard(s)? (Select all that apply)

Developer	Total Agencies Reporting Data
Internal agency	16
Consultant	8
AVL/GPS Vendor	5
Other Third-Party vendor	4
University	1
Other (please specify) Dashboard is standard but reports are a combo of custom and standard	1
No Response	3

Question 15. If an external entity developed any of your dashboards, were you a part of the design process?

Yes	No	No Response
9	3	11

15.A) Is your dashboard customizable to fit your needs?

Yes	No	No Response
14	3	5

Question 16. Who maintains the dashboard and data used?

Agency	Response
California DOT	Don't know
City of Columbus, Ohio	Consultant and internal data team
Idaho Transportation Department	District users
Kansas DOT	Performance Measures Section
Kentucky Transportation Cabinet	Internal for 3 out of 4; Trimble maintains material dashboard. All data is maintained internally.
Maine DOT	The data is the responsibility of the data owners. The Dashboard system, models and reports are maintained by our Results and Information Office (RIO).

Agency	Response
Massachusetts DOT	Our Operations and Maintenance leadership
Michigan DOT	Material usage dashboards done in house.
Montana DOT	Our ITS group
North Dakota DOT	Future small budget dashboard created with powerBI would be maintained by the division requesting the dashboard. Larger budget dashboards are maintained by information technology. Medium budget dashboard created with Arcmap would be maintained by a vendor.
Nebraska DOT	Nebraska DOT maintains the dashboard and the data collected from APIs and csv files.
NPRA	Consultants
Ohio DOT	ODOT / Consultant / Third Party Vendor
Oklahoma DOT	DOT staff
Oregon DOT	We work with the Geotab Licensed reseller to maintain the dashboard and make changes.
Rhode Island DOT	Internal agency, AVL/GPS vendor, third-party vendor
Vermont Agency of Transportation	Our performance section. Need to update and see about doing a better job of helping to establish performance measure dashboard that auto-populates.
Virginia DOT	My team does. Other working groups maintain dashboards as well. Data ownership maybe shared depending on type of data. Office of Safety, Security, and Emergency Management, VDOT Maintenance Division, AVL Provider

Question 17. How are the data checked for accuracy and who is responsible for checking?

Agency	Response
Arizona DOT	The data is big, so we have created some safeguards in the data and filtering out bad data
California DOT	Don't know
City of Columbus, Ohio	Verified by driver reports within internal staff
Idaho Transportation Department	Our Winter Maintenance Data SME
Iowa DOT	We provide our own QA/QC.
Kentucky Transportation Cabinet	It is not readily checked for accuracy. Errors are noticed after the fact. There has been some data quality issues noticed by KYTC staff.
Maine DOT	Data owners are responsible for the quality of their own data.
Massachusetts DOT	versus reports generated from our Snow & Ice Management System (SIMS) software

Agency	Response
Montana DOT	I am (Doug McBroom)
North Dakota DOT	Individuals using the dashboard would check for accuracy. Accuracy is checked when the numbers do not make sense.
Nebraska DOT	Most of the data is not readily error checked by an automated process (at least not yet). Personnel who are familiar with the data find accuracy concerns when viewing the dashboards. We do automatically filter some known bad data (spreader mode) in the MDSS Recommended vs Actual dashboard.
NPRA	Automatic program control, and the contractor is responsible for the data quality.
Ohio DOT	Spot checks are done based on abnormal results.
Oklahoma DOT	Internal checks, some QA
Oregon DOT	Customer is responsible for verify data accuracy.
Vermont Agency of Transportation	By all users. No one in responsible at this time. It used to be me in my previous capacity. We are working to get the new employee up to speed on review and checking.
Virginia DOT	Each dashboard owner is responsible for accuracy. Recovery data is verified and reviewed by district and central office staff, Maintenance division reviews district inputted data

Question 18. What data do you wish you had within a dashboard? And why?

Agency	Response
Arizona DOT	Better QA checks for the most accurate data
City of Columbus, Ohio	Custom solution means we have about everything we need
Iowa DOT	We are happy with the data we currently have right now.
Kentucky Transportation Cabinet	More data of the same sources. For example, more weather information (RWIS); more cameras.
Maine DOT	Crew assignments on the network and other assets. It would allow the creation of more meaningful reports.
Massachusetts DOT	We have a Snow & Ice Operations dashboard that is on hold as we become familiar with a new GPS platform. We will integrate GPS feeds with Snow & Ice dashboard in the future.
Montana DOT	N/A
North Dakota DOT	Information that would help the traveling public. The reason being most of the dashboards currently being created are for internal use.
Nebraska DOT	A good solid comparison of MDSS Recommended vs Actual and LOS achieved for all routes and trucks without operator input. This would provide greater insight into how MDSS is used and its value to the DOT.
NPRA	Traffic speed and volume under different conditions. Road conditions including friction measurements.

Agency	Response
Ohio DOT	More reliable weather data
Oregon Department of Transportation	N/A
Vermont Agency of Transportation	More AVL and RWIS data to report better/ additional performance metrics along with Winter/ Storm Severity Index for material use versus storm severity metrics.
Virginia DOT	Real time inventory management data (for salt, etc.). Our current IMS system isn't real time, resulting in manual entry to keep material data updated during weather events. Data from our 511 system. To be able to show road closure information, traffic incidents, and other traffic related dated

Question 19. What are the limitations of your current dashboard(s)?

Agency	Response
Arizona DOT	Since these are internal dashboards, we are limited by the bandwidths and personnel at our agency
City of Columbus, Ohio	Relying on consultant if something goes wrong; since the AVL system is on EVERY vehicle, including some outside ours, making sure we only track our trucks and activating trucks into/out of an event.
Iowa DOT	Unsure
Kansas DOT	It only looks at return to level of service.
Kentucky Transportation Cabinet	Limited scale of views/queries on ArcGIS online and Looker concurrently. Dependency on data source/providers maintenance or changes to the feed, API, fields, etc.
Maine DOT	Only partially built out. Needs exceed the resources available.
Massachusetts DOT	Only cost information is reflected
Montana DOT	None
North Dakota DOT	Connecting to the data source is the biggest limitation. The next limitation would be policy about budget amounts to create dashboards.
Nebraska DOT	Level of Service (LOS) achieved is not currently available.
Oregon DOT	Unknown
Vermont Agency of Transportation	Provide good information, but not a lot in the performance measures, which is more of a manual review now.
Virginia DOT	Data availability. The potential for human error during the data collection process. Fear of putting in data that reflects poorly on a district or user

Question 20. Do you have any enhancements to current dashboards, or new dashboards, you want to develop or are in the process of developing?

Yes	No	No Response
12	5	6

If yes, please describe:

Agency	Response
Arizona DOT	We are currently developing a salt storage dashboard
California DOT	Combine location and material usage to integrate with time keeping system
City of Columbus, Ohio	Newest version/display changes with vendor
Kentucky Transportation Cabinet	Mobile version of GoKY; development of performance management dashboards
Maine DOT	Salt usage, equipment costs and labor costs per lane mile or centerline mile, by storm and accumulative to date.
Montana DOT	Developing for equipment
North Dakota DOT	Currently working on a dashboard that will display maintenance costs including labor and materials. Another dashboard that is being worked on will display stockpile inventories and will help with reordering salt.
Nebraska DOT	Refining the storm start/end/location criteria for the cost of storm dashboard
Ohio DOT	Always looking for ways to help function better.
Vermont Agency of Transportation	Want to incorporate other information for better measure reviews.
Virginia DOT	New situational awareness site and integration of new capabilities within the DOT

Question 21. Has your agency deployed or planned to deploy connected vehicle technology that may assist with winter operations?

Yes, we have deployed	We plan to deploy	No	No Response
2	6	12	3

Question 22. Has your agency used or planned to use connected vehicle data for winter maintenance dashboards?

Yes, we have deployed	We plan to deploy	No	No Response
1	7	12	3

Question 23. What issues has your agency experienced with developing the dashboard(s)?

Agency	Response
Arizona DOT	We have challenges with filtering out bad data and the quality of the incoming data, especially from our third party
California DOT	Time and money
City of Columbus, Ohio	Small local vendor who is creating custom solution means sometimes we struggle with support or getting exactly what we want.
City of Dubuque	None
Idaho Transportation Department	Data quality issues (uniformity), not enough staff and or lack of expertise
Iowa DOT	Typical issues that one has when working with big data. It is always a concern that the data quality is a good as possible.
Kansas DOT	We are not using MDSS. So our resources are limited.
Kentucky Transportation Cabinet	Staffing; changes in staffing which then leads to changes in opinions of views.
Maine DOT	Limited knowledgeable resources to build out the necessary models.
Massachusetts DOT	Fairly simple for one of our tech-savvy leaders to develop
Montana DOT	N/A
North Dakota DOT	Cost to develop dashboard. Finding a programmer who has the time to create the dashboard. Connecting to traditional data sources and where to store the data.
Nebraska DOT	Accuracy and completeness of data.
NPRA	When visualizing the data, we have seen that the quality is not always good.
Oregon DOT	Complexity of systems and logic to get proper answers.
Rhode Island DOT	Time to further develop and integrate (limited staff resources, normal workload, etc.).
Vermont Agency of Transportation	Lack of resources (personnel) for dashboards and developing the performance measures. We have experienced a great deal of turnover in these areas.
Virginia DOT	Automating data that wasn't previously maintained in a fashion that easily allows for automation. Cost and technical abilities of staff

Question 24. What issues has your agency experienced with using the dashboard(s)?

Agency	Response
Arizona DOT	Sometimes the technology and data points are very large and do not always upload

Agency	Response
California DOT	Sometimes the information isn't accurate
City of Columbus, Ohio	Making sure staff use it correctly/assign trucks to event.
City of Dubuque	N/A
Iowa DOT	Educating those who are using the dashboards- Making sure that they understand what the dashboard is telling them....
Kentucky Transportation Cabinet	Reaching technical limits (concurrent views); data quality issues with a vendor source.
Maine DOT	Data quality issues are a constant battle.
Massachusetts DOT	None
Montana DOT	Compliance
North Dakota DOT	Most of the dashboards are currently being developed. Dashboards that have been developed would need to be viewable on a mobile device.
Nebraska DOT	It is challenging to get field personnel to engage with the data. We are going to be pushing static (pdf) dashboards to district personnel on a regular basis. We think this will generate more interest.
NPRA	Too early to say that because this a new dashboard.
Oregon DOT	The marriage of mechanical, electrical and technological systems has its own complexity. Capturing accurate data and applying it to mgt decisions is just beginning in Oregon DOT and the process takes time to build out in an accurate reliable manner
Vermont Agency of Transportation	Previous iterations of the dashboard needed to be updated manually which was problematic. And the turnover for improvements to the existing dashboard have inhibited the development of measures in the dashboards.
Virginia DOT	Adjusting to the different functionality of the dashboard platform (exporting, manipulating, filtering, etc.). Licenses for some products expire because of use limits set by the State IT Agency

Question 25. What practical advice and/or lessons learned can be offered to others interested in developing and implementing dashboards to support winter maintenance operations?

Agency	Response
Arizona DOT	Get information before hand and know your limitations. Involve the stakeholders early and often to understand their limitations and challenges they may have
City of Columbus, Ohio	Suggest talking to partner agencies that have one to see how it works, how its used and make sure you know what you want/how you will use it.
City of Dubuque	N/A

Agency	Response
Iowa DOT	Dashboards are an effective way to display big data. They are very useful in painting a picture or telling the story of what happened during the winter season.
Kentucky Transportation Cabinet	Be specific with scoping; keep team small; need members on team to be knowledgeable of both operations and technology and use of data
Maine DOT	That which is measured improves. Make sure you're measuring the right stuff.
North Dakota DOT	Create different budget amounts to develop dashboards. Figure out how the agency wants to create dashboards with a small budget. Smaller budget dashboards require less programming time and less maintenance time. Figure out what dashboard program is easy to maintain and create, as that will help reduce the overall cost. Determine who will perform the work based on cost internal department, information technology, or a consultant.
Nebraska DOT	Data collection can be difficult. Presentation in a relatively simple to digest format is important. Data accuracy needs to be verified.
NPRA	The leaders for the users of the dashboard have been early involved in the process. That has
Ohio DOT	Having good reliable data, in-place in advance, before implementing.
Oregon DOT	Go slow. Be clear as to what your needs are. And verify accuracy.
Vermont Agency of Transportation	We are currently looking to work with our Transportation Research Center to see about developing some additional metrics for winter maintenance performance. It is still a while out for any implementation.
Virginia DOT	Develop dashboards that replace existing manual processes to build confidence and familiarity with dashboards. Most of our dashboards have been created with a needs-based design approach. Worth the time and effort

Question 26. May we contact you with follow-up questions?

Yes	No	No Response
19	2	2

3.3 Evaluation of Agencies

Per the project scope, four to six agencies would be considered for a candidate of a detailed case studies based on a set of criteria.

Given that the purpose of the study is to develop case study reports on agencies that use winter maintenance dashboards, the agencies that indicated they do not currently utilize dashboards for winter maintenance purposes were not considered for a case study review. This resulted in 5 of the 23 agencies were removed from further analysis.

Among the remaining 18 agencies, given this number of agencies that use winter maintenance dashboard, a numerical scoring method was designed to assess and rank each agency's level of dashboard activities within their winter maintenance operations. This method was applied to responses received to several survey questions as shown in Table 2.

The research team utilized a scoring method to assess and rank each agency's level of use of dashboard activities. The values that can be determined from the survey responses were multiplied by a weighted value that is assigned based on the importance of that criterion, with a higher weight indicating a greater importance of the criterion. Each survey response value is multiplied by the assigned weighted value, and these weighted values are added together for each agency. The highest weighted sum totals can indicate which agencies would be good candidates for case study interviews, as shown in Table 3 on the following page.

Table 2. Criteria for Evaluating Case Study Agencies

Evaluation Criteria	Survey Questions	Values	Weighted Values
How many dashboards do you have for winter maintenance operations?	1A	Number of Dashboards	2
Do you find these dashboards useful during an event in real-time?	2	1 for Yes; 0 for No	2
Do you find these dashboards useful after an event, such as after-action reports?	3	1 for Yes; 0 for No	2
Do you use the dashboards to inform beneficial / best practices?	4	1 for Yes; 0 for No	2
What data are you using in your dashboard(s)?	5	Number of Types of Data	1
What are the sources of the data in the dashboards?	6	Number of Data Sources	1
What is the frequency of the data refresh?	8	Scale 1-5; Real-time - 5; Monthly -1	2
Are you able to generate static reports / outputs from the dashboard?	12	1 for Yes; 0 for No	2
Who has access to view the dashboards?	13	Quantity of those who have access	1
Has your agency used or planned to use connected vehicle data for winter maintenance dashboards?	22	2 for Deployed; 1 Plan to Deploy; 0 for No	2

Table 3. Summary of Agency Scoring and Ranking

Survey Question #	**1A**	**2**	**3**	**4**	**5**	**6**	**8**	**12**	**13**	**22**	**Score with Weight**
Weighted Value	*2*	*2*	*2*	*2*	*1*	*1*	*2*	*2*	*1*	*2*	
Agencies											
Virginia DOT	12	1	1	1	7	7	5	1	2	2	**62**
Ohio DOT	6	1	1	1	8	8	5	1	2	0	**48**
Kentucky Transportation Cabinet	4	1	1	1	6	9	5	1	4	0	**45**
Iowa DOT	7	0	1	1	5	5	5	0	3	0	**41**
California DOT	4	1	1	1	4	4	5	1	1	1	**37**
Rhode Island DOT	4	1	1	0	5	6	5	1	1	0	**36**
Nebraska DOT	6	0	1	1	5	4	3	1	1	0	**34**
North Dakota DOT	3	1	1	0	6	5	5	0	1	0	**32**
NPRA	1	1	1	0	7	4	5	1	1	1	**32**
Arizona DOT	3	1	1	1	5	3	3	1	1	1	**31**
City of Columbus, Ohio	2	1	1	1	4	3	5	1	1	0	**30**
Oregon DOT	1	0	1	1	3	3	5	1	1	1	**27**
Maine DOT	5	0	1	1	2	1	3	1	1	0	**26**
Montana DOT	2	1	1	1	2	1	5	1	1	0	**26**
Vermont Agency of Transportation	2	0	1	0	2	1	3	1	1	1	**20**
Massachusetts DOT	1	0	1	0	1	1	5	0	1	1	**19**
Kansas DOT	1	0	1	0	1	2	1	0	1	0	**10**
Idaho Transportation Department	1	0	0	0	1	1	2	0	1	0	**9**

*Survey Questions/Evaluation Criteria:
1A: How many dashboards do you have for winter maintenance operations?
2: Do you find these dashboards useful during an event in real-time?
3: Do you find these dashboards useful after an event, such as after-action reports?
4: Do you use the dashboards to inform beneficial / best practices?
5: What data are you using in your dashboard(s)?
6: What are the sources of the data in the dashboards?
8: What is the frequency of the data refresh?
12: Are you able to generate static reports / outputs from the dashboard?
13: Who has access to view the dashboards?
22: Has your agency used or planned to use connected vehicle data for winter maintenance dashboards?

3.4 Recommendations and Next Steps

Based on the survey responses gathered and reviewed, the research team offers the following recommendations presented in Table 4.

Table 4. Recommended Case Study Agencies

Primary Agencies	Backup Agencies
1. Virginia DOT 2. Ohio DOT 3. Kentucky Transportation Cabinet 4. Iowa DOT 5. North Dakota DOT	1. California DOT 2. Rhode Island DOT 3. Nebraska DOT 4. NPRA

The Primary Agencies include the top scoring agencies and additionally, North Dakota DOT since it has a majority rural landscape. In the event that one or more primary agencies could not be interviewed for a case study, four additional agencies were recommended as backup agencies, as illustrated in Table 4. The Clear Roads Project Committee approved of the final recommendations.

A set of interview questions was drafted for multiple levels of agency staff involved in the development, deployment, operations, and maintenance of the winter maintenance dashboards. The interview questions were drafted to gather information from agency staff for developing Case Study reports. After interview questions were drafted and approved by the Clear Roads Project Committee, interviews were conducted virtually with each agency. The recommended agencies and their characteristics are summarized in Table 5.

Table 5. Characteristics of Agency Candidates for Case Studies

Agency	Virginia DOT	Ohio DOT	Kentucky Transportation Cabinet	Iowa DOT	North Dakota DOT	California DOT	Rhode Island DOT	Nebraska DOT	NPRA
Do you have any dashboards (with interactive performance measures) using data of winter maintenance operations?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If yes, how many?	approx. 12	6+	4	7	3	4 or more	4	6	1
Do you find these dashboards useful during an event in real-time?	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Do you find these dashboards useful after an event, such as after-action reports?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Do you use the dashboards to inform beneficial / best practices?	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
What data are you using in your dashboard(s)? (Select all that apply)	7	8	6	5	6	4	5	5	7
Automatic Vehicle Location/Global Positioning System (AVL/GPS)	X	X	X	X		X	X	X	X
Material Usage total	X	X	X	X	X	X		X	X
Material Usage Rates		X	X	X	X	X	X	X	X
Weather Data (For example: Road Weather Information System (RWIS))	X	X	X	X	X	X	X	X	X
Cycle Time		X							X
Plow Position	X				X				X
Traffic Data (Speed and/or Volumes)	X	X	X		X				
Connected Vehicle (CV) data							X		
Incident Data	X	X	X		X		X		
Finance data	X	X		X				X	
Other (please specify)									Static cameras for road condition
What are the sources of the data in the dashboards? (Select all that apply)	7	8	9	5	5	4	6	4	4
Automatic Vehicle Location/Global Positioning System (AVL/GPS)	X	X	X	X	X	X	X	X	X
Spreader/Sprayer Controller		X	X	X			X	X	X
Plow Position Sensor			X						X
Mobile Weather Sensors, etc.	X	X		X	X	X	X		
Maintenance Decision Support Systems (MDSS)	X		X		X			X	

Agency	Virginia DOT	Ohio DOT	Kentucky Transportation Cabinet	Iowa DOT	North Dakota DOT	California DOT	Rhode Island DOT	Nebraska DOT	NPRA
RWIS Stations	X	X	X	X	X	X	X		X
Advance Traffic Management System (ATMS)	X	X	X		X	X			
Maintenance Management System	X	X	X				X		
Probe Traffic Data		X	X						
Connected Vehicles (CVs)									
Crowd Sourced data (e.g. Waze)	X	X	X				X		
Other (please specify)				our internal Resource Management System (RMS)				AVL Functional uses Equipment Asset Management System and AVL, Storm cost uses data from the financial system	
What is the frequency of the data refresh? (Select all that apply)	5	5	5	5	5	5	5	3	5
Minutes / Close to real-time (5)	X	X	X	X	X	X	X		X
Hourly (4)	X					X			
Daily (3)	X	X	X	X		X		X	
Weekly (2)		X							
Monthly (1)									
Other (please specify)									
Are you able to generate static reports / outputs from the dashboard?	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Who has access to view the dashboards? (Select all that apply)	2	2	4	3	1	1	1	1	1
Internal agency	X	X	X	X	X	X	X	X	X
Partner Agencies	X		X	X					
Contractors			X						
Public		X	X	X					
Other (please specify)									

Agency	Virginia DOT	Ohio DOT	Kentucky Transportation Cabinet	Iowa DOT	North Dakota DOT	California DOT	Rhode Island DOT	Nebraska DOT	NPRA
Has your agency deployed or planned to deploy connected vehicle technology that may assist with winter operations?	No		No	No	We plan to deploy	We plan to deploy	No	No	We plan to deploy
Has your agency used or planned to use connected vehicle data for winter maintenance dashboards?	Yes, we have used connected vehicle data		No	No	No	We plan to use connected vehicle data	No	No	We plan to use connected vehicle data

4. Case Study Summary

4.1 Introduction

Upon selection of the agencies for detailed case studies, the research team contacted key representatives from each agency to schedule virtual interviews and provided an overview of the subjects which would be discussed with each agency. To obtain the information needed for developing case study reports, virtual interviews were conducted with multiple levels of agency staff. Table 6 presents the interview dates with each agency and agency representatives participated in the interviews.

Table 6. Interviews for Case Studies

Agencies	Interview Dates	Representatives
Iowa DOT	Nov. 27, 2023	Tina Greenfield Huitt
Kentucky Transportation Cabinet	Dec. 21, 2023	Chris Lambert, Randi Feltner
North Dakota DOT	Dec. 24, 2023	Brandon Beise, Steeg Nelson, Brad Darr
Ohio DOT	Jan. 24, 2024	Dean Alatsis, Ryan Lowe, Tim Filla, Stephanie Marik, Joshua Thieman
Virginia DOT	Jan. 23, 2024	Bryan Wade, AJ Younes

A set of interview questions were prepared and shared with case study agencies prior to the interviews. The interviews covered questions in the following categories:

- General overview of the agency's objectives for implementing dashboards for winter maintenance programs,
- Descriptions of the dashboards, how they are used, and its limitations,
- Development of the dashboards,
- System operations and maintenance, and
- The costs and resources needed to develop, implement, maintain and enhance dashboards.

The focus of the interviews was designed to gather sufficient information for the case study reports. A summary of the information gathered from each of the virtual interviews is contained in the Appendices B through F of this report.

A total of five case study reports were developed. They are available on the Clear Roads website (http://clearroads.org/). A high-level summary of the case study results and findings are presented on the following pages.

4.2 Case Study 1: Iowa Department of Transportation

4.2.1 Agency Overview and Background

The Iowa DOT consists of six districts as shown in Figure 13. Each district contains a maintenance superintendent and a maintenance supervisor responsible for winter maintenance operations.

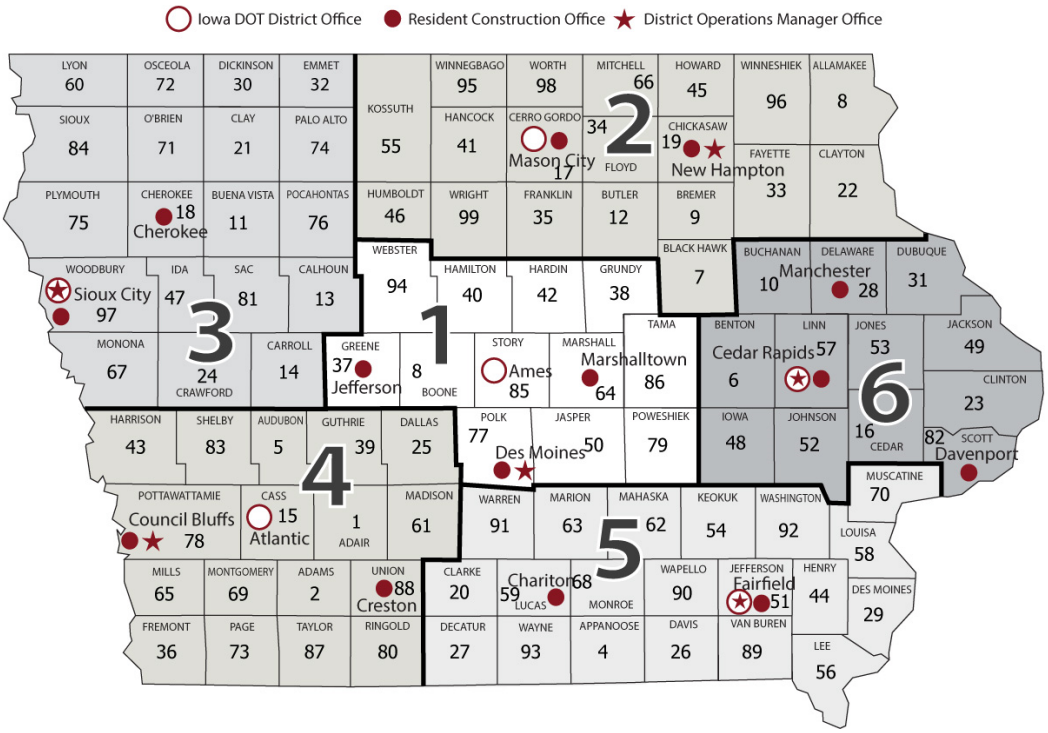


Figure 13. Iowa DOT Districts

Iowa DOT manages 24,592 total lane miles with 920 state-owned plow trucks with over 1,000 state employees and 425 seasonal workers. Iowa DOT maintains 99% of the state-owned roadways. In the 2022-2023 winter season, Iowa DOT applied approximately 129,000 tons of sodium chloride, 17,000 tons of abrasives, and 31,700,000 gallons of liquids (sodium chloride brine and calcium chloride brine). The cost of salt last season was $83.11 per ton resulting in $17.8 million dollars in material cost. The average accumulated winter season index was 653[1]. These data were reported to Clear Roads Winter Data Survey.

Most of the dashboards are centered around material and salt usage tracking. Iowa DOT has several winter dashboards, one is the Salt dashboard, the other is the salt ledger dashboard and the third is the material usage and storm reporting dashboard, fourth is a public dashboard that provides salt usage chart, salt accumulation and weather severity index and lastly the fifth dashboard is a salt budget dashboard overview.

4.2.2 The Salt Dashboard General Overview

The Salt Dashboard tracks and monitors salt usage, it is a tool for calculating and comparing anticipated versus actual salt usage rates. It operates by forecasting the expected salt usage and then cross-referencing it with real-time data. This comparison provides essential insights into the efficiency and accuracy of salt usage throughout operations. Its primary function is to offer a clear overview of anticipated versus actual usage, enabling more informed decisions based on these insights. Figure 14 shows the example of the salt dashboard. Table 7 provides details of the Salt Dashboard.

[1] https://mrcc.purdue.edu/research/awssi/indexAwssi.jsp

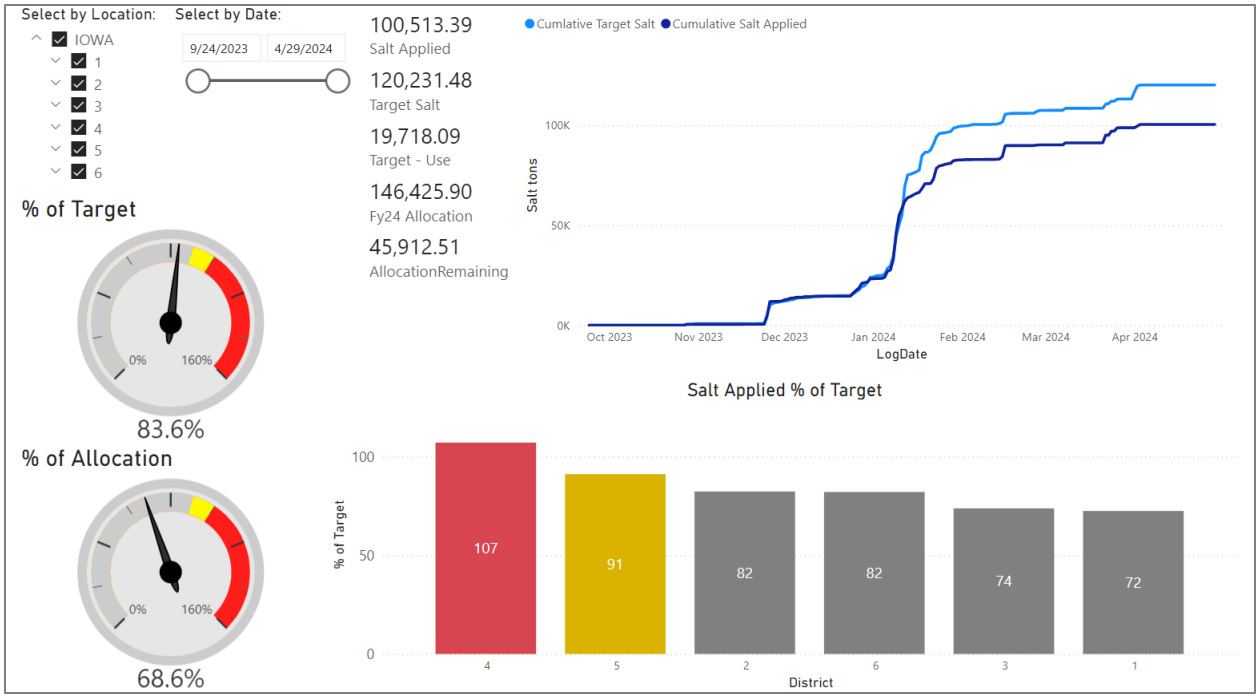


Figure 14. Salt Dashboard (Iowa DOT)

Table 7. Salt Dashboard Overview

Purpose	Track and monitor salt usage.
Performance Measures	Calculates an anticipated salt usage rate (predictive analytics) and then compares anticipated usage versus actual usage.
Data Sources	Field staff report salt usage manually. Garage managers and field staff then review salt usage gathered by the AVL and adjust as needed. Field staff report weather information manually as well. Weather data was gathered from RWIS. Weather is important since it is used to calculate target ideal salt usage. The salt target uses miles for garage responsibility routes (not miles driven), LOS priority, and weather. Data are entered and pulled from Iowa DOT's MMS and RMS.
Refresh Rate	Daily refresh
Users/Access	Garage supervisor, district managers, and field division manager utilize the dashboard. Data Management Analyst and Winter Operations Administrator use to assist with administration even though their roles are not included in Field Operations. Data Management Analyst and the Winter Operations Administrator use to review budget and monitor salt requests. Garages and district supervisors review for managing their resources. The Winter Operations Administrator procures the salt, so they use the dashboard to guide procurement needs.
Platform/Software	Microsoft PowerBI

As shown in Table 7, The purpose of the salt dashboard is to track and monitor salt usage and the performance measures includes calculation of anticipated salt usage rate (predictive analytics) and then comparing anticipated usage versus actual usage. This dashboard is refreshed daily. The software used for the dashboard is PowerBI. The field staff reports salt usage manually. Garage managers and field staff then review salt usage gathered by the AVL and adjust as needed. Field staff report weather information manually as well. Weather data was gathered from RWIS. Weather is important since it is used to calculate target ideal salt usage. The salt target uses miles for garage responsibility routes (not miles driven), LOS priority, and weather. Data are entered and pulled from Iowa DOT's Maintenance Management System (MMS) and Roadway Management System (RMS). The users of the data are mainly Garage supervisor, district managers, and field division manager utilize the dashboard. Data Management Analyst and Winter Operations Administrator use to assist with administration even though their roles are not included in Field Operations. Data Management Analyst and the Winter Operations Administrator use to review budget and monitor salt requests. Garages and district supervisors review for managing their resources. The Winter Operations Administrator procures the salt, so they use the dashboard to guide procurement needs.

It was noted that the prediction helps but is not always prefect. Fortunately, Iowa DOT has been using the Salt Dashboard for 11 years and the garage managers are used to the model. These insights facilitate conversations between managers on best practices to hit target salt usage. The dashboard is a tool to help education and start conversations with maintenance staff, which helps alleviate concerns regarding staff turnover, particularly at the supervisor level.

Iowa DOT is currently working on a storm or daily weather index instead of a monthly/seasonal index. Current mobility data are not added to prediction/targeted salt usage. Iowa DOT attempted to integrate speed but fell apart because of inaccurate speed data (note that was 10 years ago, so data might be better now). Iowa DOT is currently not using any road surface friction sensor data within their storm index calculations or within their dashboard.

Future enhancements are to explore filling data gaps with crowdsource data. Also, Iowa DOT has already calculated time to bare pavement but has not integrated into the dashboard yet.

4.2.3 The Salt Ledger Dashboard General Overview

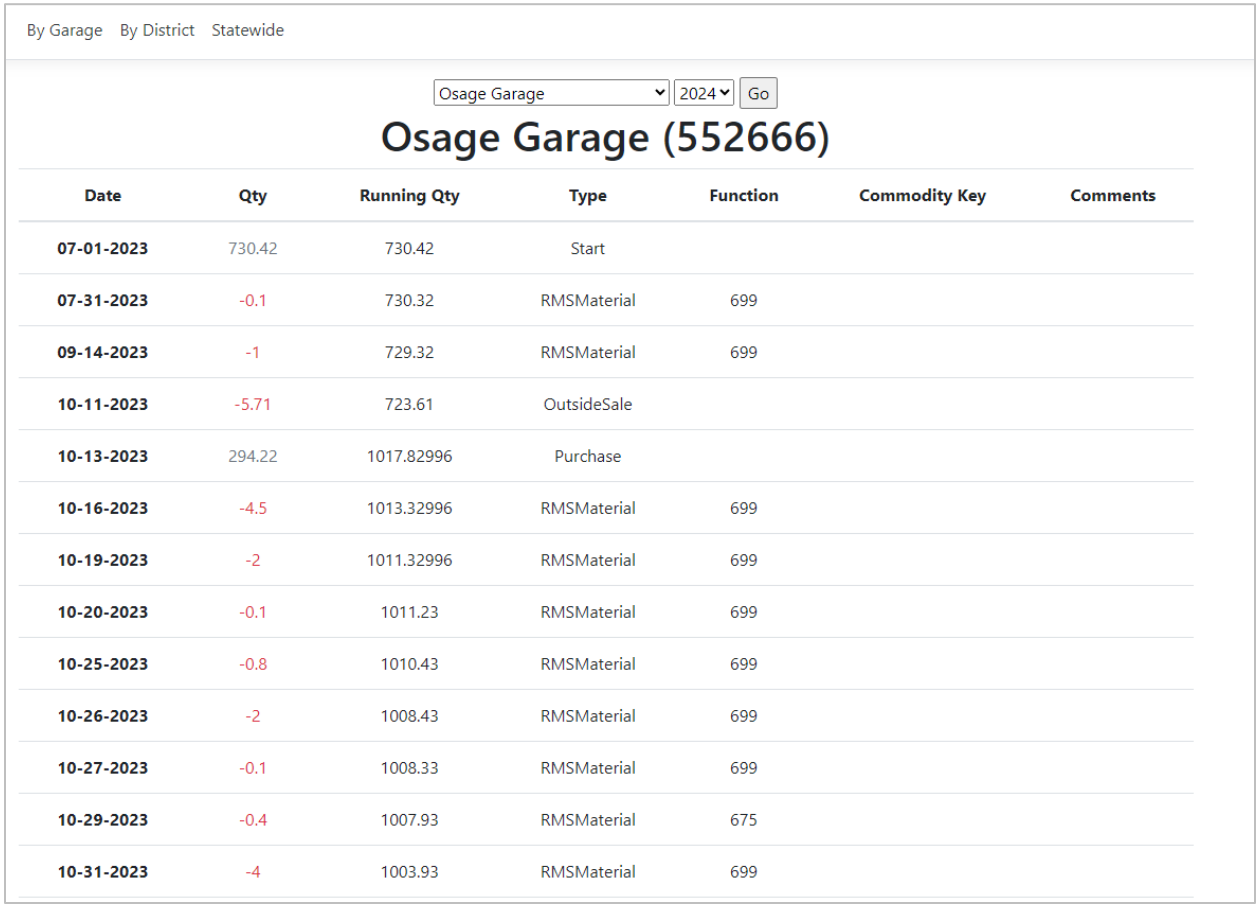
The Salt Ledger dashboard serves as a comprehensive record-keeping system for salt-related transactions. It keeps a running total of salt on hand by garage and salt usages. This dashboard provides opportunities to manage in a more real-time for better tracking. It tracks salt quantities across garages, documenting daily usage, receipts, sales, transfers, and contracts with the city. This ledger ensures a real-time assessment of salt quantities, allowing garages to manage their inventories more effectively. This information is given to the dashboards. The users started with a few offices and IT, but then continued to grow into other bureaus and districts. Table 8 provides details of the Salt ledger Dashboard.

As shown in Table 8, the purpose of the salt ledger dashboard is keeping a running total of salt on hand by garage and salt usages. The performance measures show daily usage as reported in the garage daily logs, plus it shows when they receive salt and when they sell or transfer salt. The data sources include Field staff report salt usage manually and review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Data are added and pulled from Iowa DOT's MMS, RMS. This dashboard is also refreshed daily, and the system software is Power BI. The users

for the dashboard are generally garage/district managers for the purpose of actively manage resources. Figure 15 shows the Salt Ledger Dashboard.

Table 8. Salt Ledger Dashboard Overview

Purpose	Keeps a running total of salt on hand by garage and salt usages. Opportunities to manage in a more real-time, better tracking. Helps with garage tracking when making brine. Not used for ordering future salt.
Performance Measures	Shows daily usage as reported in the garage daily logs, plus it shows when they receive salt and when they sell or transfer salt.
Data Sources	Field staff report salt usage manually and review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Data are added and pulled from Iowa DOT's MMS, RMS.
Refresh Rate	Daily refresh
Users/Access	Garage/district managers use to actively manage resources
Platform/Software	Microsoft PowerBI



Date	Qty	Running Qty	Type	Function	Commodity Key	Comments
07-01-2023	730.42	730.42	Start			
07-31-2023	-0.1	730.32	RMSMaterial	699		
09-14-2023	-1	729.32	RMSMaterial	699		
10-11-2023	-5.71	723.61	OutsideSale			
10-13-2023	294.22	1017.82996	Purchase			
10-16-2023	-4.5	1013.32996	RMSMaterial	699		
10-19-2023	-2	1011.32996	RMSMaterial	699		
10-20-2023	-0.1	1011.23	RMSMaterial	699		
10-25-2023	-0.8	1010.43	RMSMaterial	699		
10-26-2023	-2	1008.43	RMSMaterial	699		
10-27-2023	-0.1	1008.33	RMSMaterial	699		
10-29-2023	-0.4	1007.93	RMSMaterial	675		
10-31-2023	-4	1003.93	RMSMaterial	699		

Figure 15. Salt Ledger Dashboard (Iowa DOT)

4.2.4 The Material Usage and Storm Reporting Dashboard General Overview

The Material Usage and Storm Reporting dashboard provides a detailed breakdown of material usage across different garages throughout the current season. It correlates these data with weather information sourced from daily logs, offering a comprehensive overview of how materials are utilized in varying weather conditions. Acting as a complementary tool to the Salt Dashboard, it uses the same data reports to enable comparative analysis and aid in decision-making processes. Figure 16 shows the example of the material usage dashboard.

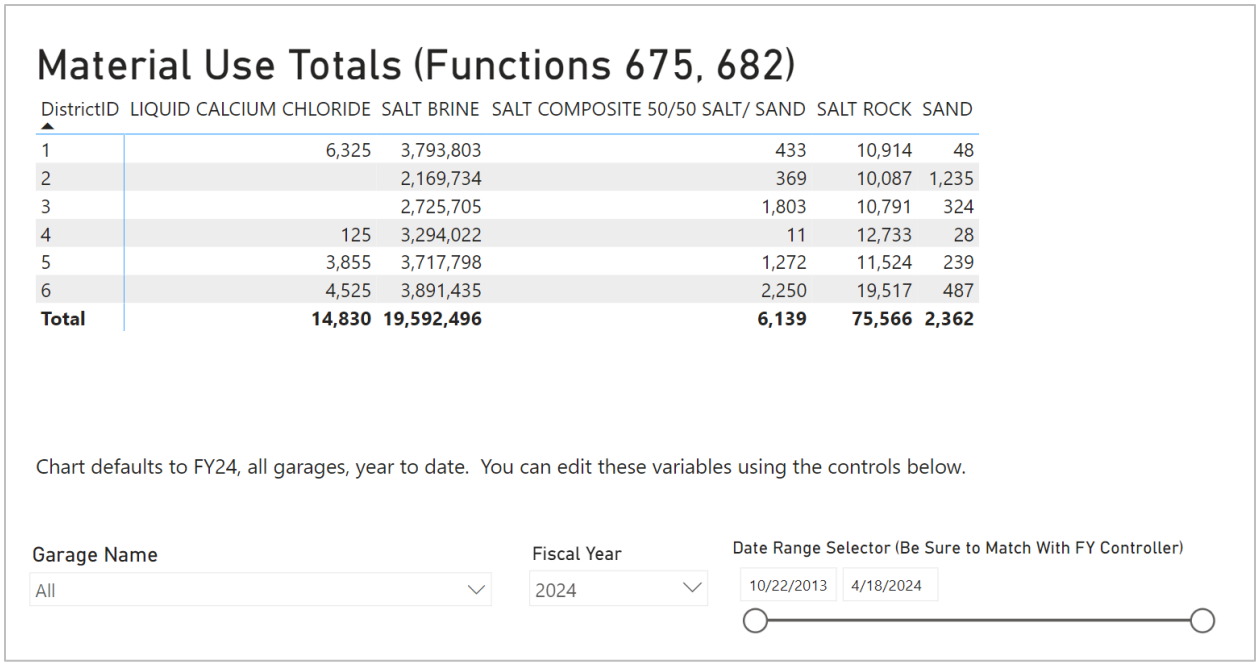


Figure 16. Material Usage Dashboard (Iowa DOT)

As shown in Table 9, the main purpose of the Material Usage and Storm Reporting Dashboard is to focus on weather variables as reported by garages on daily logs, to help garages see what data were logged. Garage managers can use to self-regulate and make sure the data are as accurate as possible. Internal only, allows for full picture and used at district post-season meetings for discussion on what was reported. The performance measures in the dashboard show material usage by garage for the current season plus it displays weather data as reported by the garage field staff through their daily logs. This dashboard has no analytics. Data sources include manually filled reports of salt usage by field staff. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Field staff report weather information manually as well. Field staff can use RWIS sites as a comparison to field reports, and central office can check for any outliers in the data based on RWIS data. Data are added and pulled from Iowa DOT's MMS and RMS. The dashboard is refreshed daily, and the main users are internal and garage managers and field staff.

Table 9. Material Usage and Storm Reporting Dashboard Overview

Purpose	Like the first dashboard but focuses on weather variables used in dashboard #1 as reported by garages on daily logs. Helps garages see what data were logged. Garage managers can use to self-regulate and make sure the data are as accurate as possible. Internal only, allows for full picture and used at district post-season meetings for discussion on what was reported
Performance Measures	This dashboard shows all material usage by garage for the current season plus it displays weather data as reported by the garage field staff through their daily logs. No analytics. Summarizes inputs for dashboard #1. Can see where storms were more active based on daily logs.
Data Sources	Field staff reports salt usage manually and will review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Field staff report weather information manually as well. Field staff can use RWIS sites as a comparison to field reports, and central office can check for any outliers in the data based on RWIS data. Data are added and pulled from Iowa DOT's MMS, RMS.
Refresh Rate	Daily refresh
Users/Access	Internal, garage managers and field staff
Platform/Software	Microsoft PowerBI

4.2.5 Public Dashboard General Overview

The public dashboard is a high-level summary from multiple dashboards including data of the WSI dashboard, which offers a visual representation of winter severity based on data entered by garage staff. Publicly accessible, this dashboard provides a comparison of the current winter season with the past five years. It's used not only internally but also by management and legislators who have become familiar with interpreting and utilizing the data presented. While the public site showcases an overview, the internal version contains more detailed garage specific WSI data.

Additionally, there are charts from the Salt Usage Dashboard on the public dashboard that tracks salt usage over a five-year period and is simply meant to be a public performance page. The Materials Uses and Storm Reporting Dashboard is used for more thorough analysis.

Snow Accumulation Dashboard is dedicated to presenting yearly snowfall data over the last five years, and similar to the Salt Usage Chart Dashboard is simply meant for public performance with the Materials Uses and Storm Reporting Dashboard being the more comprehensive data source.

The Salt Budget Dashboard is specifically designed to monitor the $15 million salt budget, this dashboard is primarily used internally for executive-level analysis statewide. It encompasses various aspects of winter operations funding, including snow fence contracts, overhead garage budgets, training, AVL, winter forecasting services, temp worker job postings, and winter administration. Notably, it excludes labor and fuel, which are budgeted separately under district charges. The tool is utilized to manage the salt budget

strategically and it aids in planning for restocking salt sheds before the end of the season. Table 10 provides details of the Public Dashboard.

The purpose of the public dashboard is to present the public with Iowa DOT's performance. The performance measures include weather severity index, total snow accumulation, precipitation events, salt usage, and valuable salt and capacity. Year to year comparisons for all but the on-hand salt and capacity is also done. The measures can be reviewed statewide. The data sources are same as previously mentioned dashboards. This dashboard is refreshed daily and is open for public viewing. Figure 17 shows an example of the winter severity index dashboard which displays the average winter weather severity score for the state based on storm duration, storm frequency, snowfall amount and temperature.

Figure 18 shows the yearly total snow accumulation, and Figure 19 shows the total precipitation events.

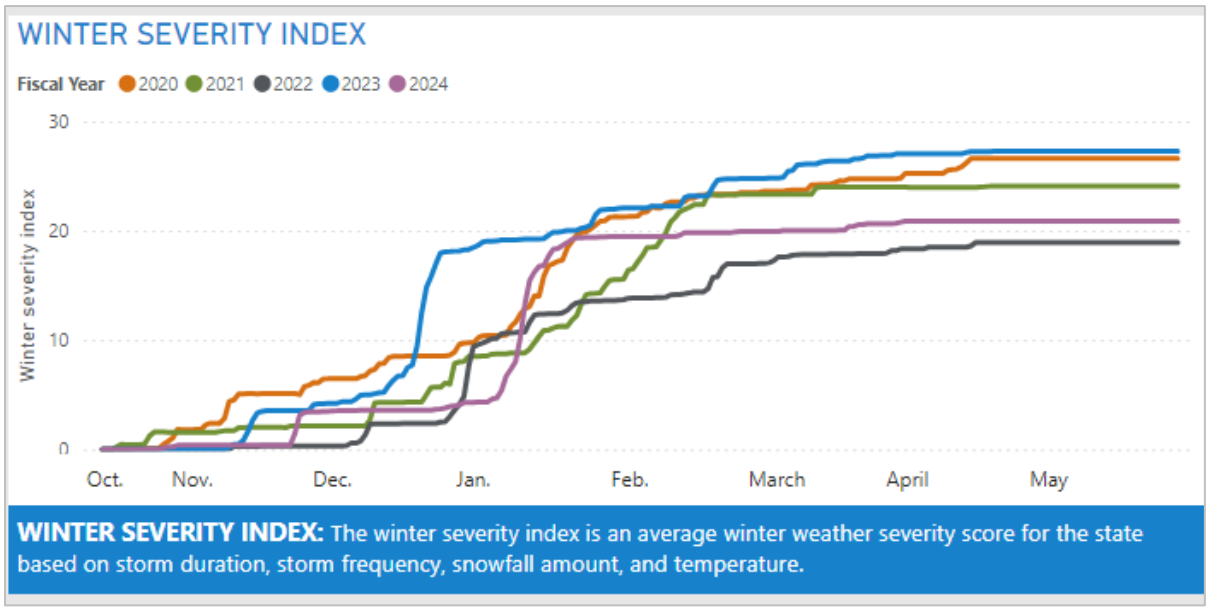


Figure 17. Winter Severity Index (Iowa DOT)

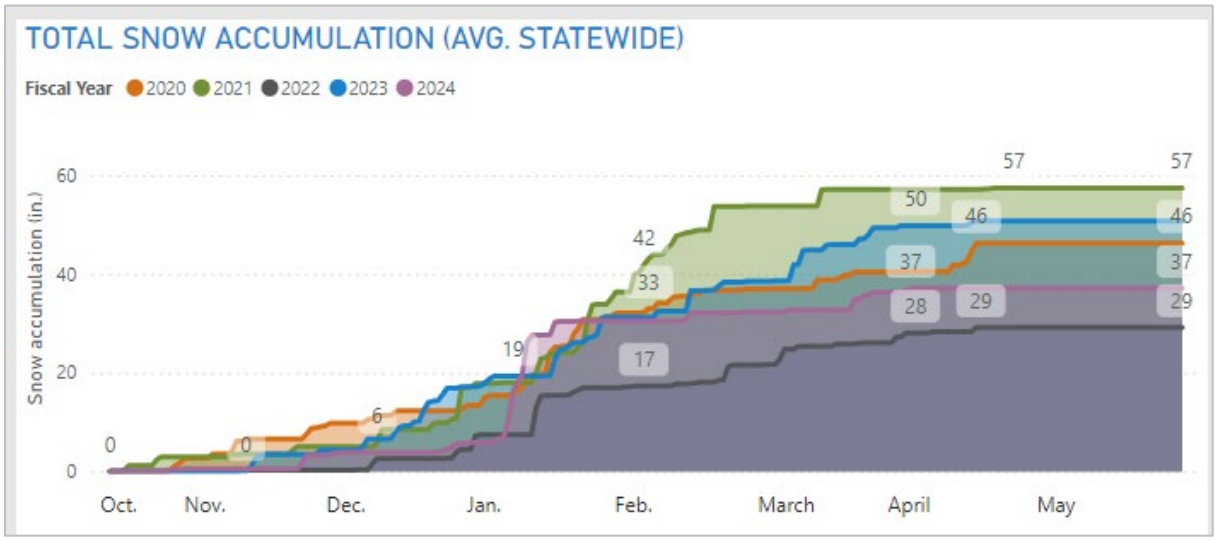


Figure 18. Total Snow Accumulation (Iowa DOT)

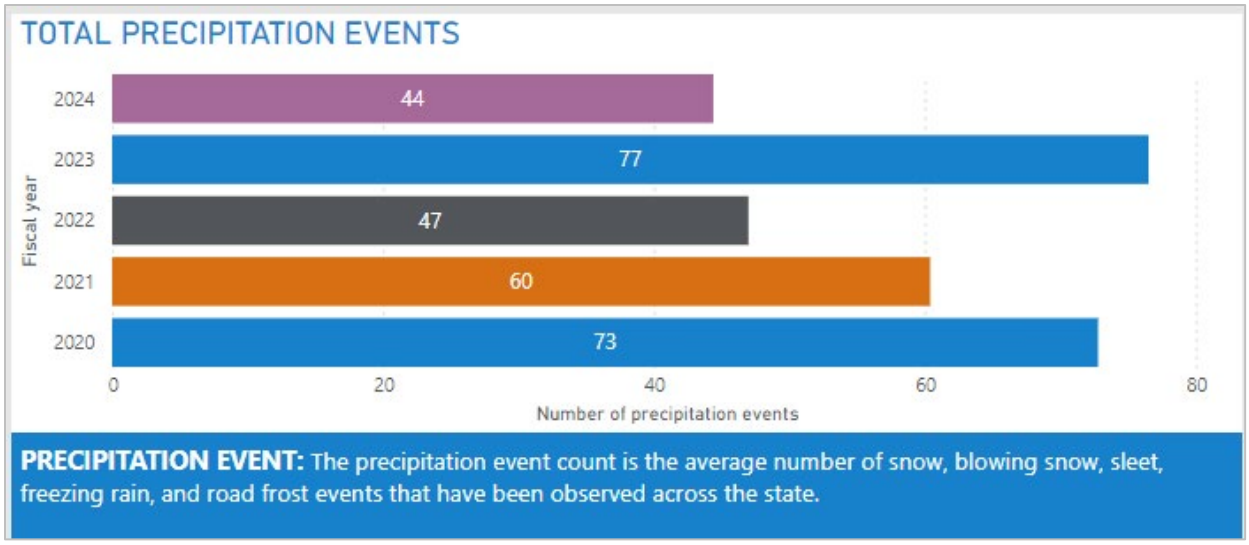


Figure 19. Total Precipitation Events (Iowa DOT)

Table 10. Public Dashboard Overview

Purpose	To present the public with Iowa DOT's performance. Helpful for discussions with management and legislators, especially mid-season when projections show that more salt is needed.
Performance Measures	Weather severity index, total snow accumulation, precipitation events, salt usage, and valuable salt and capacity. Year to year comparisons for all but the on-hand salt and capacity. Statewide review.
Data Sources	Field staff reports salt usage manually and will review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Field staff report weather information manually as well. Data are added and pulled from Iowa DOT's MMS and RMS.
Refresh Rate	Daily refresh
Users/Access	Public
Platform/Software	Microsoft PowerBI Widgets
Source	https://www.arcgis.com/apps/dashboards/8fa8eb99dc164f879a96db717c15356e

4.2.6 Salt Budget Dashboard General Overview

The salt budget dashboard is used to track the status of the $15 million salt budget. Salt budget is heavily monitored for potential to use in other places. This dashboard helps manage expectations for what is "available" in this line item. The average amount of salt is used to set the upcoming salt contract amounts, so this dashboard helps with understanding these historical averages. The dashboard is also used for end of season re-fill to help manage budget. Table 11 provides details of the Salt Budget Dashboard.

Table 11. Salt Budget Dashboard Overview

Purpose	This dashboard is used to track the status of the $15 million salt budget. Salt budget is heavily monitored for potential to use in other places. This helps manage expectations for what is "available" in this line item. The average amount of salt is used to set the upcoming salt contract amounts, so this dashboard helps with understanding these historical averages. It is used for end of season re-fill to help manage budget for the winter season.
Performance Measures	Cost broken down to garage level. Track orders, paid, delivered, administration fees, along with an estimated range to get to the end of the winter season (based on a 5-year average). Provides previous average, minimum, and maximum costs.
Data Sources	Salt data usage is added and pulled from Iowa DOT's MMS; RMS. RMS has data on shed salt capacity. Includes all materials.
Refresh Rate	Daily refresh
Users/Access	Winter Operations Administrator; Internal and administrative users only
Platform/Software	Microsoft PowerBI

As shown in Table 11, the performance measures include cost displays broken down to garage level, track orders, fees for various purposes and estimated range to get to the end of the winter season (based on a 5-year average). It provides average, minimum, and maximum costs of previous years. The data sources for this dashboard involves salt data usage obtained from Iowa DOT's MMS and RMS. The dashboard is refreshed daily, and the users include Winter Operations Administrator, Internal and administrative users only. Figure 20 and Figure 21 shows an example of on hand salt and capacity budget along with the salt usage.

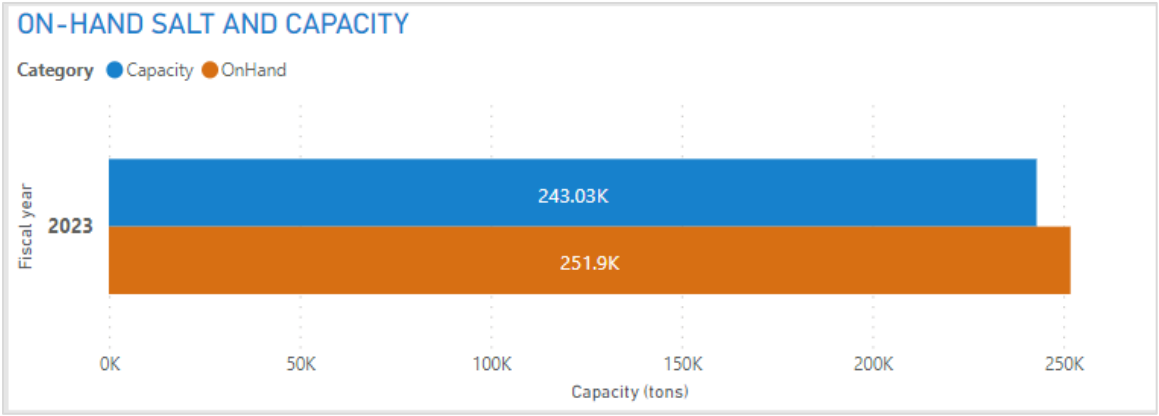


Figure 20. On Hand Salt and Capacity (Iowa DOT)

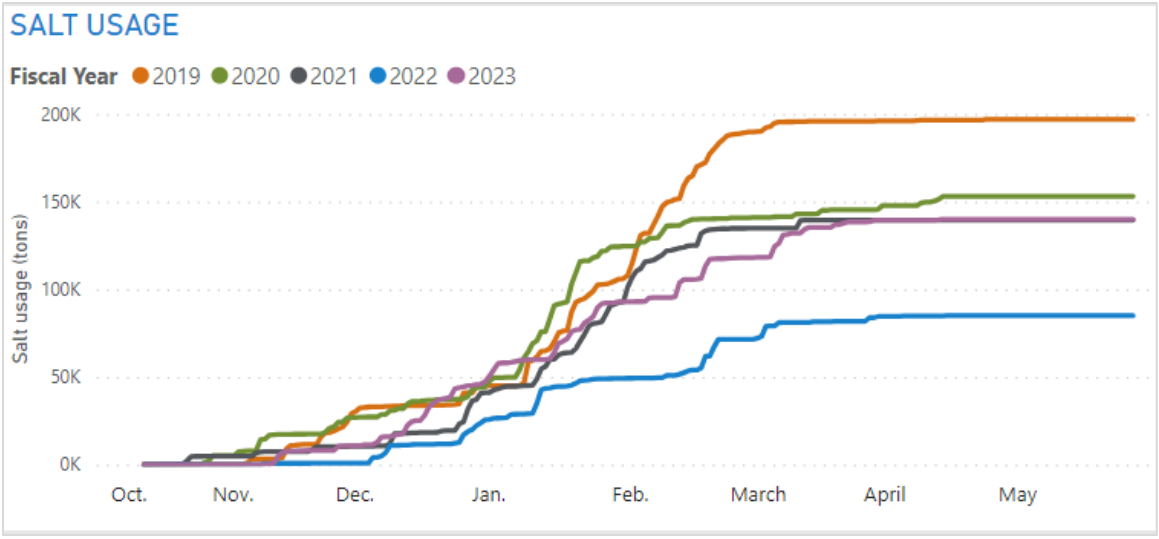


Figure 21. Salt Usage Dashboard (Iowa DOT)

4.2.7 Other General Dashboard Information

The data provided to these dashboards involving the salt used and weather conditions comes from field staff, and it's compared against the AVL data and can be adjusted as needed to ensure accuracy. When data is being collected, the field staff are responsible for their own plan with how they will be treating the roads they are assigned. They are provided parameters and targets to stay within so that they are in line with how the Central Office wants the roads to be treated. The MMS is used to track maintenance actions taken as well as road and weather conditions. The data for the dashboards is refreshed daily by the RMS system. The dashboards are all created using PowerBI and the public uses widgets from PowerBI plus.

Some improvements the Iowa DOT is looking to make to their winter dashboards include working with a different AVL provider in 2024. Internally, a storm or daily weather index is being worked on that will help predict weather severity.

4.2.8 Development of Dashboards

In the development of winter dashboards, the need for a dashboard typically arises when central figures in dashboard management, notice repeated requests for specific data or when higher management seeks specific information. Their involvement streamlines data management, reducing their workload, and although field staff rarely request dashboards directly, there is a desire for more accessible data representation.

When designing dashboards, collaboration with end-users is key. Examples are shared, and if managers are the intended users, all six primary dashboards are incorporated. There's a winter steering group available, if necessary, though it hasn't been actively involved for some time. The Winter Operations Administrator along with the Data Management Analyst take charge of dashboard development, with the Data Management Analyst overseeing the Extract, Transform, Load (ETL) process, particularly data cleaning from RWIS via Structured Query Language (SQL) database, handled by the IT team. The process prioritizes the use of unfiltered data from the legally logged RMS to enable error identification in input, primarily benefiting garage operations. Data storage primarily occurs within SQL databases, with the oldest

available data for certain dashboards dating back to 2013, while others are typically focused on five-year trends or single fiscal year insights, like the Salt Dashboard. The main data source for these dashboards is the MMS and RMS, which is a legal log. No formal process is required to verify accuracy. The dashboard does allow for field personnel to review data quickly and determine if there was a data entry error in RMS, which can then be mitigated. The data within the dashboards are developed to present the previous five years or just the current seasonal year.

Challenges during development involved limitations arising from calculations and data constraints, leading to ongoing refinements as user interaction increased. Technical issues led to the exclusion of a speed dashboard due to data processing challenges, and RWIS sensor unreliability prevented its inclusion in analyses.

The development of new dashboards in Iowa DOT are initiated by the Winter Operations Administrator along with the Data Management Analyst. Dashboards are typically developed based on requests from other management, field operations, and/or public requesting the same data insights; leading the development of a dashboard to manage these requests. Rare for any field personnel to specifically request a dashboard but might wish to review data in an easy manner, which leads to a dashboard. During development, the team may reach out to and share draft dashboards with end users for feedback. If the dashboard is for garage management, they will include all district managers in this feedback. When necessary, a steering committee may be implemented during the design phase but not very often.

The lead developers of these dashboards are the Winter Operations Administrator and the Data Management Analyst. Once developed, IT maintains the dashboard. IT will assist with the cleaning processes for the data loaded into the dashboard. All data are stored in a SQL database and many of the analytics are done within the SQL database, not in the dashboard platform.

Having a complete understanding of the data being used and knowing the audience that will use the dashboard is the key advice Iowa DOT provided to other agencies.

4.2.9 System Operations and Maintenance

This section describes the Iowa DOT's system operations and maintenance procedures for the winter dashboards.

The hosting of these dashboards for viewing occurs through three distinct methods:

- Publicly accessible sites on the website,
- Technically public but not openly shared, and
- Those requiring a PowerBI pro license for viewing, allocated to a small group.

The dashboards are technically accessible publicly, the material usage and weather dashboards are not advertised but can be accessed through the DOT site with dedicated links. This removes the need for password access to dashboards that are shared with partner agencies.

The Data Management Analyst maintains the frontend of the dashboards and IT maintains the database side of the dashboards. Data updates are varied, with the RMS updated manually while the dashboards refresh automatically. Responsibility for data updates falls on IT, particularly if any issues arise on the database side, although a designated winter operations staff oversees the PowerBI side and reviews

aspects external to the database. Maintenance for both the dashboards system and databases is handled jointly by the Data Management Analyst for PowerBI and IT for the database.

The costs and resources involved in the development, implementation, maintenance, and enhancement of these dashboards aren't meticulously tracked, but minimal efforts are needed for ongoing maintenance, especially for updates in new seasons. The costs primarily lie in the development phase, with ongoing maintenance and storage costs being comparatively lower and less rigorously tracked.

The initial development involves more significant efforts, requiring collaboration with IT and users, prioritizing these operations over others due to their significance. The Data Management Analyst and the Winter Operations Administrator focus on refining analytic methodologies within SQL, aligning with policies and guidelines such as salt prediction, and any policy changes prompt collaboration between the Data Management Analyst and IT to recalibrate calculations within SQL.

The costs primarily lie in the development phase, with ongoing maintenance and storage costs being comparatively lower and less rigorously tracked.

4.2.10 Benefits and Lessons Learned

The winter dashboards are very useful because it helps everyone from the management level to the garage level understand and measure how resources are being used during winter maintenance operations. The dashboards also create a form of healthy competition between garages as they can compare, but also work together to meet target resource usage.

One lesson learned from the development of these winter dashboards was that it is best to keep them simple and easy to understand for users. The data should start out small and grow over time. The staff should not be forced to use it and the data should be presented as it is. A challenge that had to be overcome when developing the dashboards was the cost it would take to develop the first dashboard. However, with the pressure to save money on salt expenses, the benefits far outweighed the costs.

4.2.11 Plans for the Future and Potential Enhancements

This section goes over future plans for the winter dashboards and possible enhancements that could be made. A tool for comparing individual storms as projected and what actually occurred, is also being developed. Beyond that there are no plans for the future besides potentially adding more dashboards.

Some potential dashboards that would be useful for development include, a speed based data dashboard, a dashboard using friction sensors, using weather information to compute road conditions, and image analysis using dashcam data.

Overall, there are many ideas for potential dashboards in the future, but it is difficult to see the benefits of them if the use cases are not fully understood and outweigh the cost of development.

4.2.12 Key Point

- The salt prediction is calculating and comparing anticipated versus actual salt usage rates. It operates by forecasting the expected salt usage and then cross-referencing it with real-time data. This comparison provides essential insights into the efficiency and accuracy of salt usage throughout operations. Its primary function is to offer a clear overview of anticipated versus actual

usage, enabling more informed decisions based on these insights. This helps facilitate conversations between garage managers on ways to help keep salt usage on target.

- The main source of the data for these dashboards are Iowa DOT's MMS and RMS, which are their legal logs with high data quality. Other data sources have been tested such as speed and RWIS data; however, the data was not fully trusted, resulting in it not being used.
- An advice for developing a dashboard is to have a complete understanding of the data being used and to know the audience that is going to be using the dashboard. The data should start out small and grow over time. The staff should not be forced to use it and the data should be presented as it is.
- A challenge that had to be overcome when developing the dashboards was the cost it would take to develop the first dashboard. However, with the pressure to save money on salt expenses, the benefits far outweighed the costs.
- Future enhancements are to explore filling data gaps with crowdsource data. Potential dashboards that would be useful for development include a speed-based data dashboard, a dashboard using friction sensors, using weather information to compute road conditions, and image analysis using dashcam data.

4.3 Case Study 2: Kentucky Transportation Cabinet

4.3.1 Introduction

As shown in Figure 22, KYTC is divided into 12 Department of Highway Districts that help keep the routes safe and passable during the snow and ice season.

KYTC manages 27,600 total lane miles with 1,000 state-owned plow trucks with over 1,800 state employees and 400 contracted plow trucks. KYTC maintains 93% of the state-owned roadways. In the 2022-2023 winter season, KYTC applied approximately 136,000 tons of sodium chloride and 1,405,000 gallons of liquids (sodium chloride brine and calcium chloride brine). The cost of salt last season was $98.72 per ton resulting in $20.3 million dollars for material costs. The average accumulated winter season index was 119[2]. These data were reported to Clear Roads Winter Data Survey.

Development for winter dashboards started in 2012 due to a shortage of salt during winter maintenance. The KYTC sought a more effective way to track material usage to avoid similar issues in the future. Utilizing GIS data, historical analyses were conducted to understand the causes of the salt shortage. Additionally, in 2014, KYTC established a partnership with Waze to access real-time traffic data. After this, KYTC aimed to integrate weather information from the National Weather Service (NWS), Waze, and alerts in their practices. To achieve this, the department began collaborating with developers in 2015 to create winter dashboards.

[2] https://mrcc.purdue.edu/research/awssi/indexAwssi.jsp

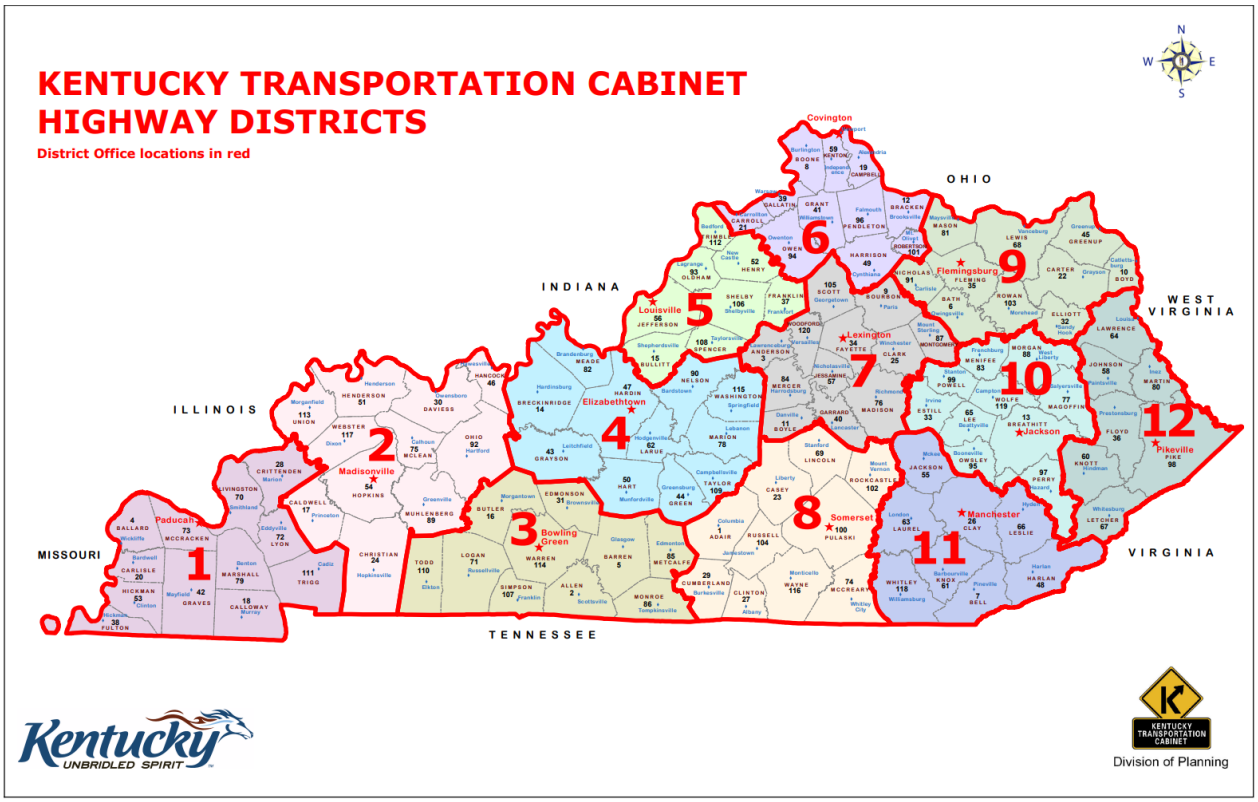


Figure 22. KYTC Districts

4.3.2 GoKY Dashboard General Overview

The GoKY Dashboard in Figure 23 is utilized for accessing real-time traffic information, including congestion areas, accidents, road hazards, weather conditions, traffic camera feeds, and other relevant data. A general overview of the dashboard is provided in Table 12. This dashboard serves as the main source of real-time roadway information for both the public and agency use. The purpose of the dashboard is to allow users to make more informed decisions when traveling in the state. By leveraging data from reliable sources KYTC is able to provide up-to-date information related to roadways on a scalable platform like google maps. This dashboard transitioned from ESRI to Google Maps not just for a fresh look, but for critical performance improvements. The original platform struggled with user surges, leading to inaccurate information and frustrating delays. Google Maps, with its robust scalability and faster refresh rates, ensured reliable access and real-time data even during peak periods. Additionally, Google Cloud offered cost-effectiveness and access to advanced features like traffic layer integration and data streaming, significantly enhancing the dashboard's functionality. This may clarify the difference between traffic layer viewing and data availability from Google.

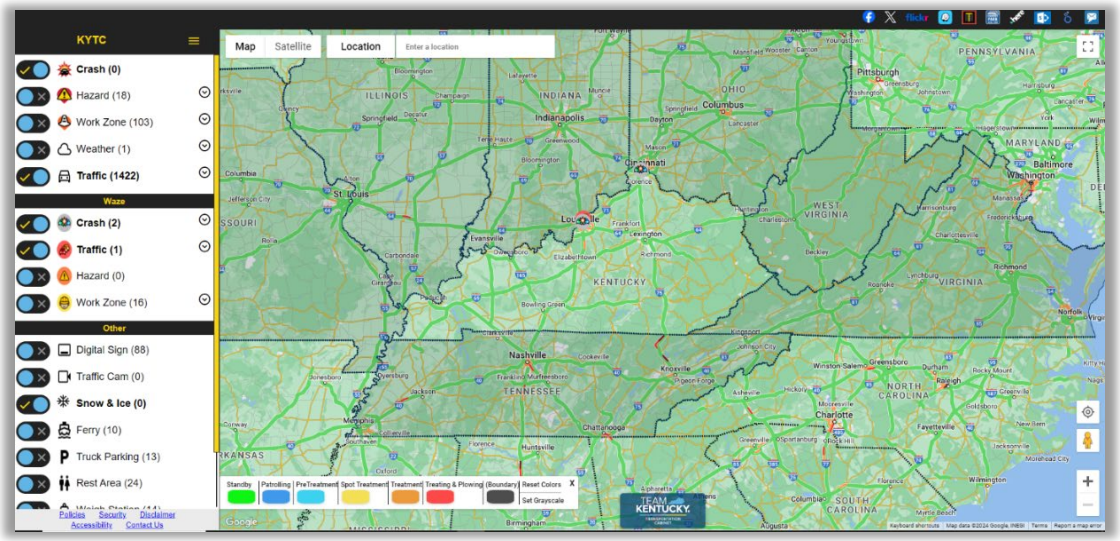


Figure 23. GoKY Dashboard (Kentucky TC)

Table 12. GoKY Dashboard Overview

Purpose	Used to view live traffic data and contains information such as locations of congestion, crashes, hazards, weather conditions, traffic cameras, and more.
Performance Measures	Availability, scalability, and can support one million concurrent users
Data Sources	HERE traffic speeds, Waze reports, Traffic Management Center (TMC) reports, maintenance weather reports, traffic cameras, Dynamic Message Sign (DMS) messages
Refresh Rate	Every 2 minutes
Users/Access	The public
Platform/Software	Google Cloud
Source	https://goky.ky.gov/

Real-Time Data

The dashboard leverages a multitude of data sources, including HERE traffic speeds, verified by other Waze users (not necessarily by KYTC), TMC updates, maintenance weather responses, traffic cameras, and DMS messages. This comprehensive data pool refreshes every two minutes, ensuring users have the most current picture of Kentucky's roadways. Additionally, traffic cameras and DMS message displays provide visual aids for enhanced situational awareness.

Scalability and Reliability

Built on Google Cloud's robust platform, GoKY boasts exceptional scalability, seamlessly managing even peak user volumes. This ensures consistent and reliable access to critical information, even during unforeseen circumstances like emergencies or natural disasters.

Data-Driven Decision Making

Beyond public information, GoKY empowers KYTC staff and partner agencies with valuable data-driven insights. This intelligence informs crucial decisions regarding resource allocation, response strategies, and overall transportation management. Notably, GoKY played a significant role in coordinating road closures and recovery efforts during past natural disasters.

Continuous Improvement

While the current user interface is undergoing mobile optimization, the GoKY dashboard remains committed to ongoing development. Future iterations promise exciting new features, potentially including static data layers like rest areas, truck parking locations, and weather radar integration. Additionally, the exploration of RWIS data and outward-facing dashcam views hold promise for further enhancements.

4.3.3 KYTC Roadway Weather Decision Support Systems (DSS) Dashboard General Overview

KYTC Roadway Weather Decision Support Systems (DSS) Dashboard as shown in Figure 24 is a support tool designed mainly for staff use in the agency. It provides real time AVL data from salt trucks, camera feeds, and a storm severity index, that update at each half mile interval. While its main use case is for agencies to make more informed decisions based on real time data, this dashboard has been proven to be useful for Public Information Officers (POIs) when responding to public inquiries related to traffic.

As shown in Table 13 the GoKY Dashboard's purpose is to provide real-time traffic information, including congestion locations, crash reports, hazards, weather conditions, traffic camera feeds, and more. By combining all these data outputs, the GoKY Dashboard is able to provide a comprehensive overview of current roadway conditions. The dashboard provides various filters to easily find the data sources that are needed based on use case. This includes things like location of crashes, traffic, hazards, work zones, rest areas, digital sign, and many others. Roads are also color coded with a legend at the bottom to display specific roadway conditions.

The dashboard is built on the Google Cloud platform, ensuring availability and scalability, so that any influx of users can be adjusted to. Data sources for the dashboard include HERE traffic speeds, Waze reports, TMC reports, maintenance weather reports, traffic cameras, and DMS messages. The system overwrites the data every two minutes, and updates for passes and salt are pulled from a Google Sheet until an end date is added. It is important to note that the system does not store historical data; it is purely a real-time tool. According to KYTC personnel, this process is currently under review to become more automated.

The system has more detailed information than its public version. Although the link is public, it is not widely publicized and is mostly shared with partner agencies. This approach eliminates the need for password sharing. Additionally, this was effective in eliminating any issues related to authentication that may come up during off-hours.

Looking ahead, the next iteration of this tool enhancement will include a trend-tracking feature. it is worth noting that the current system may become obsolete and could be retired in a year or so once the updated version is developed. One of the limitations of the current system is that none of the real-time speed data providers KYTC has worked with can provide volume data, which could help determine the reasons for slowdowns. Currently there exists a confusion on which platform needs to be used for the next generation

of the system. It was noted that since ESRI is limited on historical view of data and Looker Studio is limited on layering (visualizations), both of these are currently used.

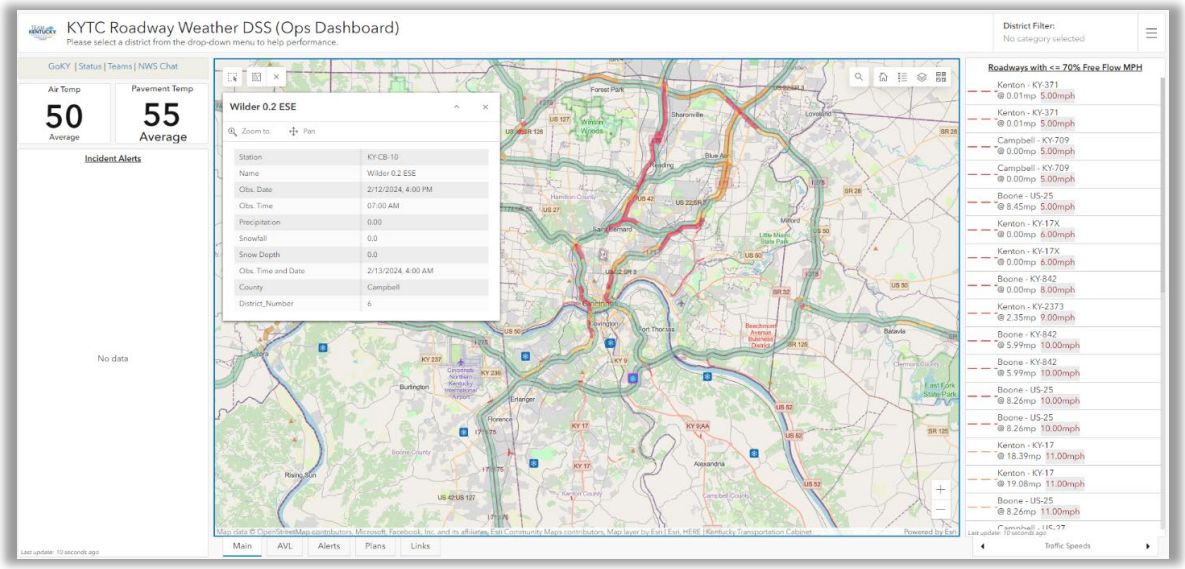


Figure 24. KYTC Roadway Weather Decision Support Systems (DSS) Dashboard (Kentucky TC)

Table 13. KYTC Roadway Weather Decision Support System (DSS) Dashboard Overview

Purpose	Provides real-time decision-making data that includes salt, AVL data, cameras, and storm severity index
Performance Measures	Salt usage, vehicle location, camera access for visualization, and storm severity index. All in one spot joined to roadway segment.
Data Sources	AVL, cameras
Refresh Rate	Every 2 minutes
Users/Access	District and central office staff, Public
Platform/Software	Google Cloud, ESRI
Source	https://kytc.maps.arcgis.com/apps/dashboards/7e6fad274c5c4ae58c152e475dfe11f1

4.3.4 GoKY: ITS Real-Time Information Dashboard / Real Time ITS Data Studio Dashboard

GoKY: ITS Real-Time Information Dashboard /ITS Data Studio Dashboard, also known as ITS Data Studio, is a tool designed to help decision making related to short term trends related to weather and traffic as displayed in Figure 25 and Figure 26. The tool is available to the public but is mainly used by KYTC internally. By utilizing data from a diverse range of platforms, average speeds, minimum speeds, mile points, and routes can be monitored. From these recovery movements and downward progressions can be tracked as well. This dashboard also contains a storm severity Index, which is a comprehensive scored system that inputs air temperature, wind, and radar values, to output granular weather impact insights at 1/10th mile

segments. This dashboard also contains a unique scoring system developed by KYTC known as the storm severity Index.

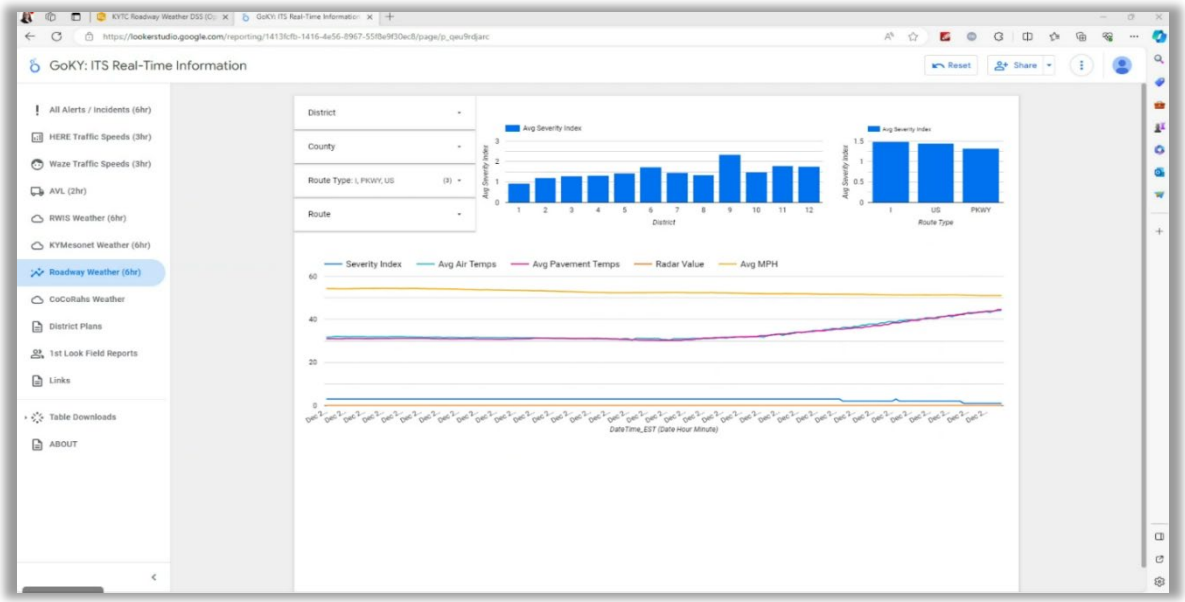


Figure 25. GoKY: ITS Real-Time Information Dashboard / Real Time ITS Data Studio Dashboard (Kentucky TC)

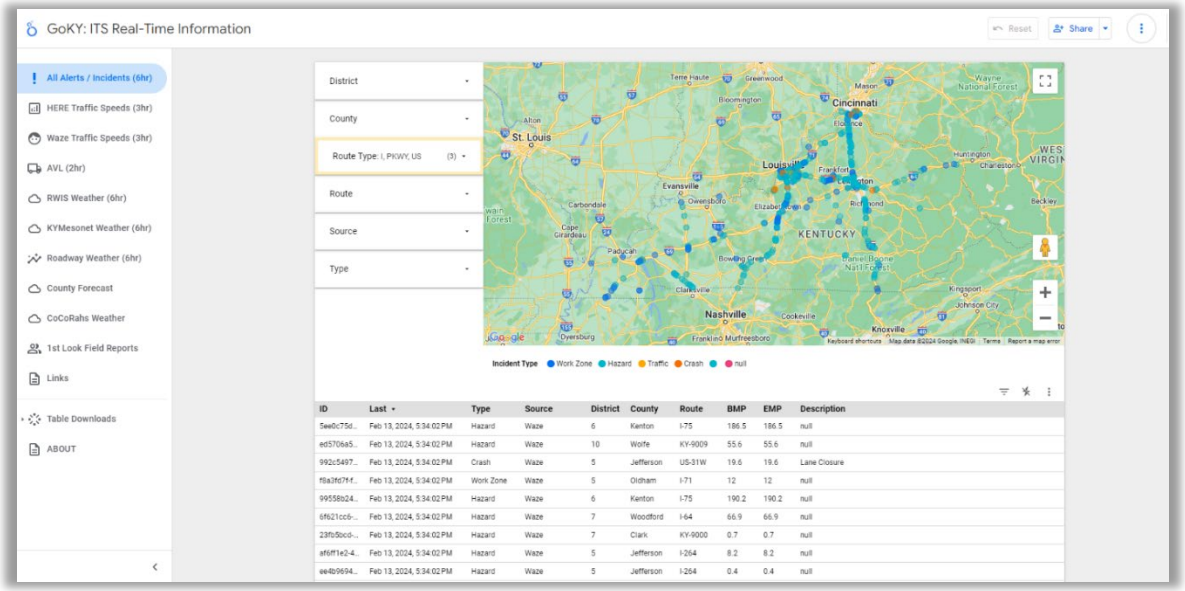


Figure 26. GoKY: ITS Real-Time Information Dashboard / Real Time ITS Data Studio Dashboard (Kentucky TC)

Table 14 shows that the purpose of the KYTC Roadway Weather DSS Dashboard is to provide real-time decision-making data for salt usage, AVL data, cameras, and storm severity index. It is a comprehensive tool that combines these various data sources into a single platform, allowing district and central office staff to access and visualize information easily.

The dashboard is built on the Google Cloud platform and utilizes ESRI software for mapping and geospatial analysis. The dashboard is accessible to the public and is hosted on the Looker Studio platform and Google Cloud. Most feeds refresh every 2 minutes, with AVL data refreshing every 2-3 minutes to ensure the most up-to-date information is available for users. However, this system does not store historical data and is purely used for real time information. By breaking down the network into half mile segments, users can click on different parts of the road to view data points such as pavement temperature and air temperature. Each piece of segment is also provided their own storm severity index. The GoKY ITS Real-Time Information Dashboard serves the purpose of displaying short-term trends and aiding in decision support. It is designed to provide the public with real-time information on traffic conditions and other relevant data. The dashboard's performance is measured by its uptime and scalability, allowing it to handle millions of records.

Data sources for the dashboard include TMC data, Waze reports, HERE traffic data, AVL data, RWIS data, KYMesonet weather data, and CoCoRahs precipitation data. With the tool being available on Looker Studio, the platform offers a very familiar and user-friendly interface for those who are familiar with google products and divides different data sources into tabs such as RWIS Weather, Waze Traffic, and Roadway Weather. A map featuring different incident types is also available with color codes for each.

In summary, this dashboard is a comprehensive tool that combines weather, speed, and severity data to provide real-time or trending insights. It should be noted that the uniqueness of this view is the time-depth. Despite some limitations, it is an example of data visualization for facilitating informed decision-making. The KYTC plans to continue improving the dashboard and addressing its limitations in future iterations.

Table 14. GoKY: ITS Real-Time Information Dashboard / ITS Data Studio Dashboard Overview

Purpose	To show short-term trends and help facilitate decision support
Performance Measures	Uptime and scalable to report on millions of records
Data Sources	TMC, Waze, HERE, AVL, RWIS, KYMesonet, CoCoRahs
Refresh Rate	Every 2 minutes on most feeds and every 2-3 for AVL
Users/Access	The public
Platform/Software	Looker Studio + Google Cloud
Source	https://lookerstudio.google.com/u/0/reporting/1413fcfb-1416-4e56-8967-55f8e9f30ec8/page/p_pbm4eo88qc

4.3.5 Material Usage Dashboard

Material Usage Dashboard as shown in Figure 27 is a tool to track material usage and summarize inventory information. A general overview of the dashboard is provided in Table 15. By utilizing Geotab assets which contain both inventory and AVL data, manually entered inventory data can be analyzed. Safety metrics are also able to be tracked an analyzed such as seatbelt usage, speeding, and harsh braking. This tool is purely meant for internal use and while the focus on the tool at first was salt usage, it now encompasses overall asset management with the goal to enhance resource efficiency, specifically in contract heavy areas.

Material Usage Dashboard leverages GeoTab assets to analyze manually entered inventory data. This dashboard is not open to the public and remains as an internal tool during development. While GPS coverage reaches 100%, AVL data currently sits at 85-90%, with daily card integration in development.

Beyond tracking material use, the dashboard expands into the realm of safety, pulling metrics like seatbelt usage, speeding, and harsh braking from GeoTab's onboard systems. GeoTab's diverse functionalities also offer potential for camera integration, temporary work zone identification, and more. On the other hand, the Geotab Safety Scorecard feature is a separate product, only available within the Geotab platform.

Initially focused on salt usage, the dashboard's scope has broadened to encompass overall asset management, aiming to enhance resource efficiency, particularly in contract-heavy areas. Its adaptability allows for future enhancements and creation of additional dashboards. Although the team do not yet have the AVL automated integration complete, they actively explore utilizing GeoTab's AVL data more effectively. While material usage currently relies on manual updates, integration with Trimble's AVL enhancements promises automation.

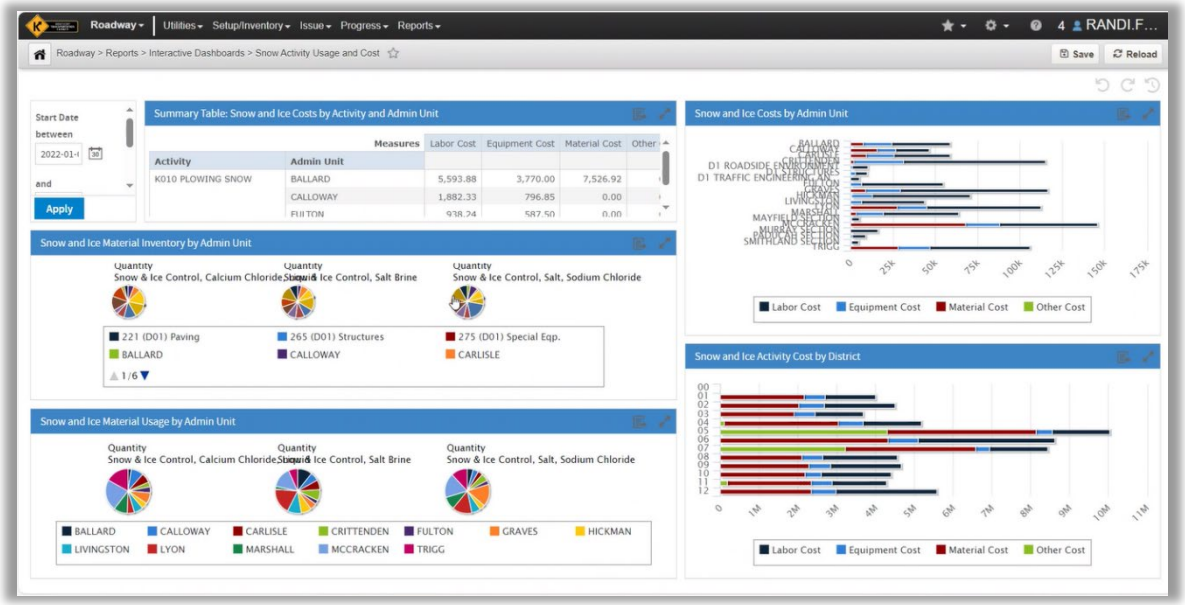


Figure 27. Material Usage Dashboard (Kentucky TC)

Table 15. Material Usage Dashboard Overview

Purpose	Serves as a material usage dashboard that summarizes inventory information
Performance Measures	Material usage, safety, labor cost, equipment cost
Data Sources	OS Information (Manual Entry via Trimble)
Refresh Rate	Daily
Users/Access	Internal
Platform/Software	OMS by Trimble (formerly Agile Assets)

4.3.6 Previous Dashboards

A migration from the former Elastic Search platform to Google Cloud/Data Studio caused changes in dashboard layouts, making previous user interfaces inaccessible. One lesson learned from the development of this dashboard is that switching vendors may result in the loss of some dashboard views, requiring manual recreation. Figure 28 through Figure 30 represent some of the previous dashboards that KYTC are working to recreate in the future.

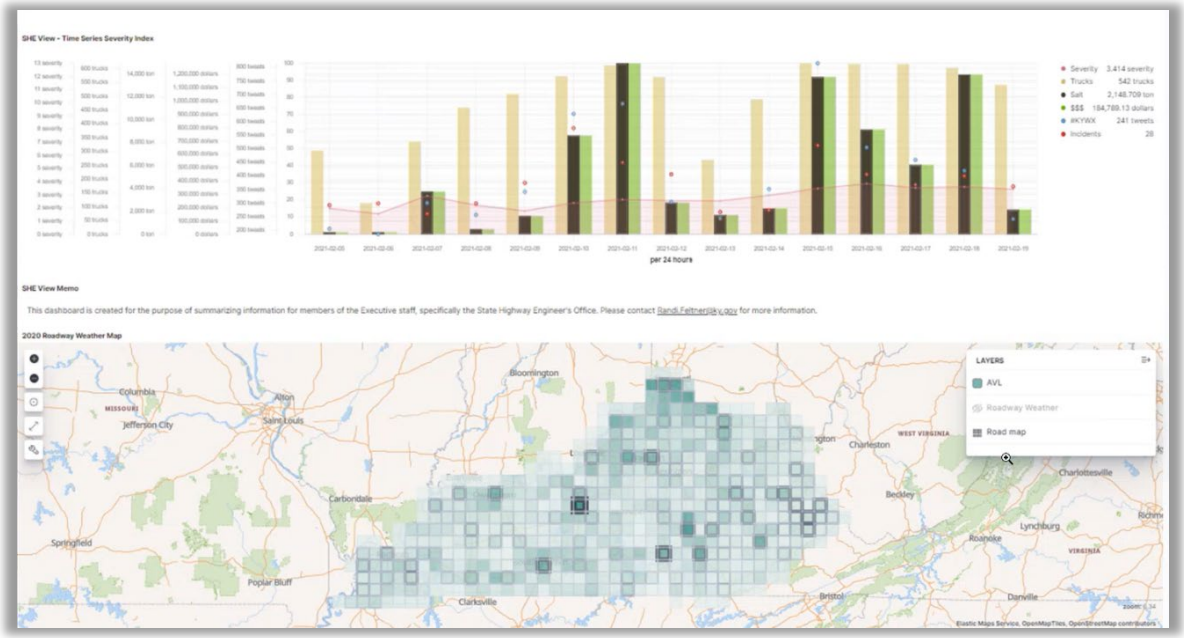


Figure 28. Time Series Severity Index and Roadway Weather Map (Kentucky TC)

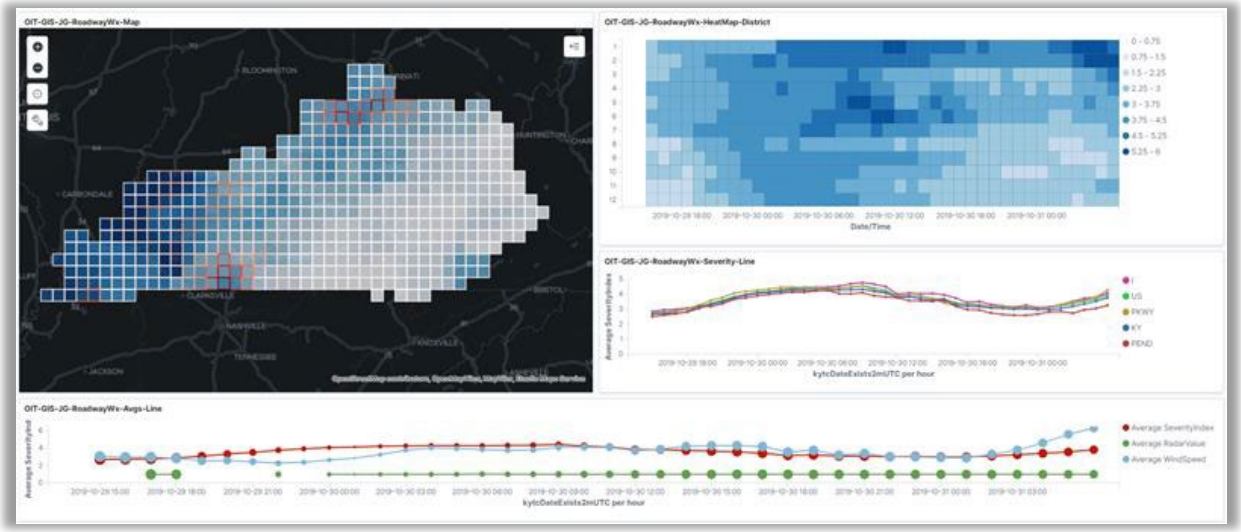


Figure 29. Weather Severity Heatmap (Kentucky TC)

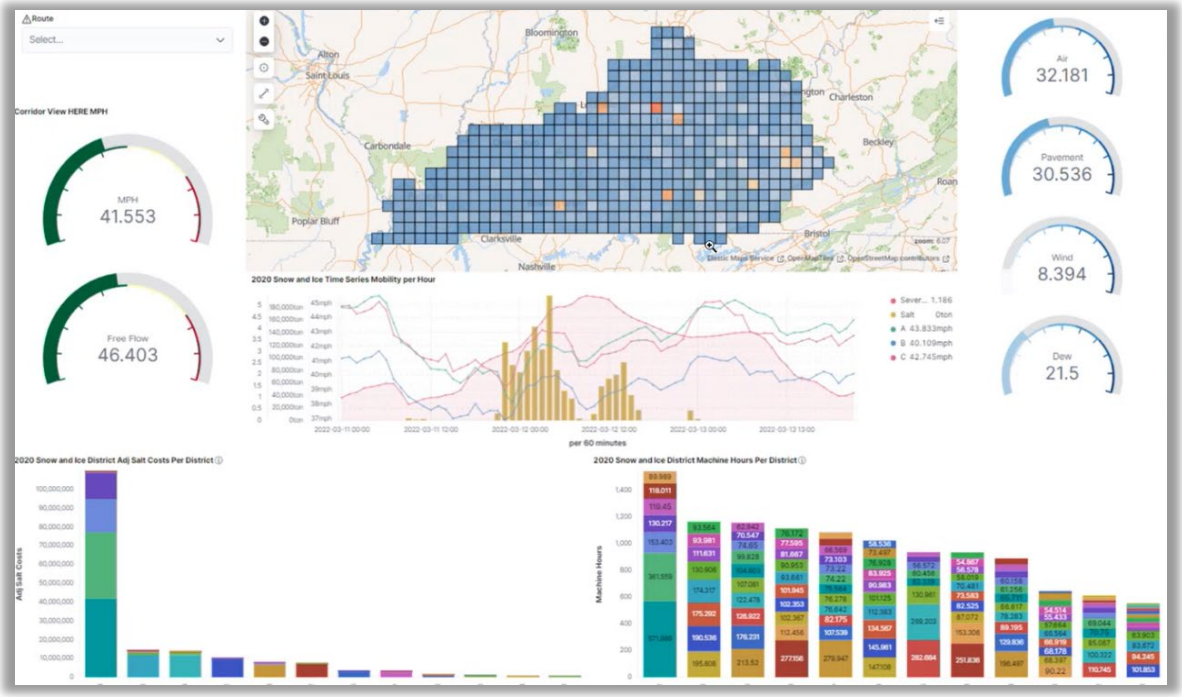


Figure 30. Operational Resource Data (Kentucky TC)

4.3.7 Development of Dashboards

Winter Dashboards were developed due to the requests that KYTC received and the value that could be provided by dashboards when developing strategic plans moving forward. As the dashboards were implemented and the processes became more formalized, additional request were then being made due to their effectiveness, leading to the need to create more dashboards to accommodate various needs. When a request is made, the development team decides what data inputs will be needed for the dashboard and the steps it would take to create it.

An internal team of developers and stakeholders are the ones who primarily assisted in the development of dashboards. While there are no formal processes currently made to verify the accuracy of the performance measures, errors are notified to the appropriate people if they were to occur. Due to the nature of weather during the winter season, what types of issue that can occur with equipment is still being explored as well as how the data is being affected. The data gathered for these dashboards is stored in Looker Studio and Google Cloud and queried back up to 6 hours, with further queries for data further back currently in the works. No major issues or challenges were noted by KYTC during the development of the dashboards.

4.3.8 System Operations and Maintenance

The dashboards are all being hosted for viewing on either Looker Studio or Google Cloud. These two platforms have the advantage of being easily scalable to deal with increased number of users and having easy integration with other google services such as google maps.

The dashboards are all maintained by a team of systems IT consultants and the platforms Looker Studio and Google Cloud are responsible for maintaining, storing, and updating the data. The costs and resources that are used to maintain these dashboards are not directly tracked.

4.3.9 Benefits and Lessons Learned

This section goes over the benefits and lessons learned from developing the winter dashboards. In terms of data quality, some key lessons that were learned were that AVL data can be inaccurate due to the weather conditions during the winter season. The severity of snowstorms and other weather variables can cause errors in the equipment used to track data. Therefore, it is very important to understand where the data is coming from and the reliability of the data quality before implementing it into dashboards.

When switching data vendors, it's important to recognize that the data previously being used in dashboards may be affected which can lead to different outputs on the dashboards. Before switching vendors, its best to always have a plan for testing and updating dashboards after the switch. Furthermore, vendors do not always provide an update when changes are made to the data, which could potentially affect the dashboards. It is key to consistently test dashboards and stay up to date with vendor changes.

The data being utilized in each of the dashboards is key to what will be displayed so it is important to use only relevant data by applying proper filters. This could involve removing potential outliers or removing unnecessary variables.

Relating to project management for the dashboards, keeping the team relatively small and selecting those who are knowledgeable of the operations and technology proved to be beneficial. Being specific with the scope of the project was also key to focus on creating the primary functionalities the dashboard should provide. Additionally, the right data platform needs to be selected for real-time and historical data.

4.3.10 Plans for the Future and Potential Enhancements

KYTC has five areas that they feel could undergo potential future enhancements involving their dashboards.

- The first is in the mobile optimization. The user interface that is currently being used on mobile devices for their dashboards is undergoing optimization and is improving its user interface.
- The second area is in static data layers. This would involve adding rest areas and truck parking locations, which would provide additional value to users who are traveling and utilize these dashboards.
- The third area involves weather radar integration. By integrating weather radar information into dashboards, travelers could receive crucial information to make more informed decisions.
- The fourth area for potential improvement would be to implement RWIS data. This would allow users to have access to weather information that can provide more detailed weather information for specific areas. This could allow travelers to prepare for icy roads or avoid unsafe driving conditions.
- Lastly, outward-facing dashcam view could provide real-time visual information on the roads, which could lead to both the public and KYTC staff to be more aware of the condition of roads.

Overall, these enhancements are all capable of making drastic improvements to the dashboards that are currently being used by the public and agency in the areas of functionality, user experience, and the types of information that is currently being provided.

4.3.11 Key Point

- KYTC started the development of dashboards due to the need to track material usage such as salt during the winter maintenance season in an efficient way.
- GoKY Dashboard is used for accessing real time traffic data and is the main source of real-time roadway information.
- KYTC DSS Dashboard is a tool for agency staff that provides real-time AVL data along with other data sets linked to roadways. GoKY ITS Real-Time Information Dashboard/Real Time ITS Data Studio helps make decisions based on short term trends related to weather and traffic.
- All platforms are hosted for viewing on either Looker Studio or Google Cloud. This is key for scaling up for more users during weather events. It is setup similar to TV streamers to prevent buffering issues.
- A lesson that the KYTC learned from developing the winter dashboards was that due to the nature and unpredictability of the winter season, AVL data can be inaccurate.
- When switching data vendors, it's important to recognize that the data previously being used in dashboards may be affected, which can lead to different outputs on the dashboards. Before switching vendors, its best to always have a plan for testing and updating dashboards after the switch.
- Future enhancements will allow KYTC to implement more of their dashboards to mobile devices making data more accessible on the go and bringing in additional data sources.

4.4 Case Study 3: North Dakota Department of Transportation

4.4.1 Introduction

North Dakota DOT (NDDOT) is divided into 8 Districts (refer Figure 31) that is responsible for the maintaining surface transportation including highways, bridges, rail, transit, pedestrian, and bicycle paths across the state.

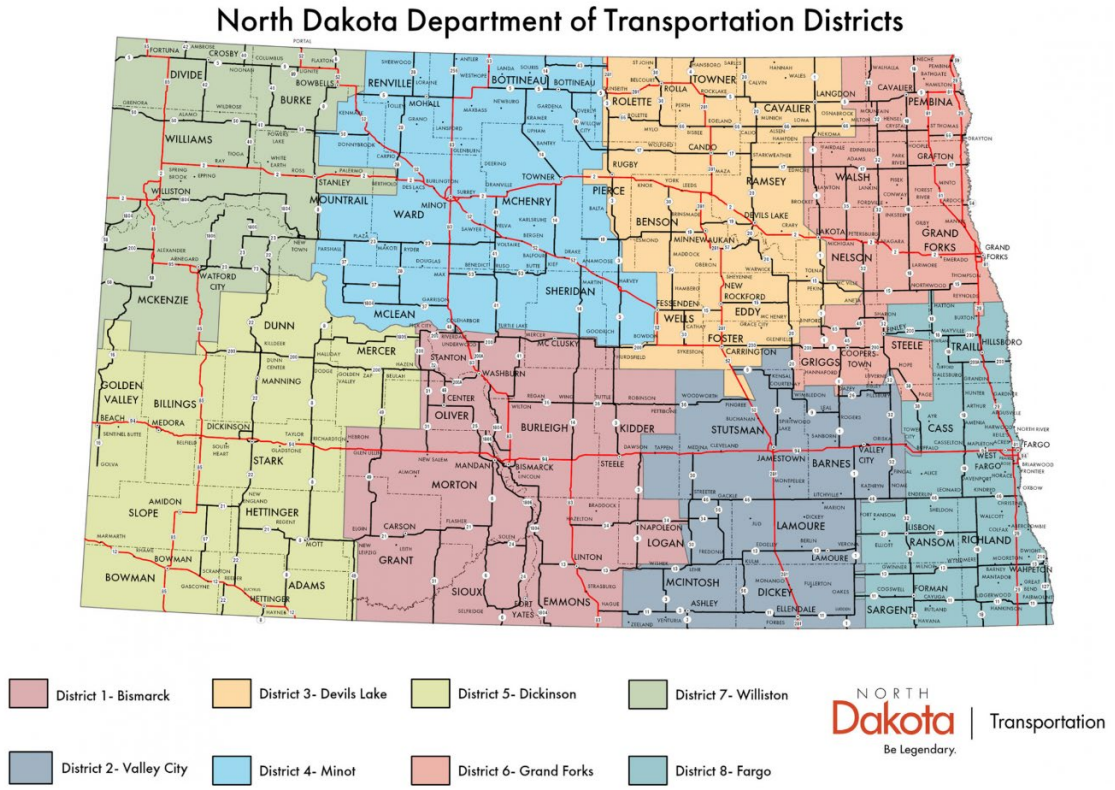


Figure 31. NDDOT Transportation Districts

NDDOT manages 17,300 total lane miles with 359 state-owned plow trucks with over 372 state employees. NDDOT maintains 98% of the state-owned roadways. In the 2022-2023 winter season, NDDOT applied approximately 46,000 tons of sodium chloride and 3,173,000 gallons of liquids (sodium chloride brine) and 593,000 gallons of agricultural byproduct. The cost of salt in 2022 winter season was $105 per ton, resulting in $5.9 million dollars for material costs. The average accumulated winter season index was 2272[3]. These data were reported to the Clear Roads Winter Data Survey.

Development for winter dashboards began in 2020 when NDDOT's main goal was to establish speed recovery performance metrics. This effort stemmed from the growing need to quantity performance measures that could no longer be done manually. Shortly after, NDDOT was awarded a grant that same year that enabled the creation of data-driven dashboards to assist in these endeavors. These dashboards were created in collaboration with North Dakota State University (NDSU).

4.4.2 Maintenance Dashboard

The Maintenance Dashboard is a tool that is still currently being developed by NDDOT. The goal of the dashboard is to integrate in-house material usage inventory and finance data. The Maintenance Dashboard, as seen in Figure 32 and Table 16, aims to track the cost of snow and ice control. The dashboard sorts the data by garage level and is used mostly by maintenance crew, management, and district representatives. It will utilize data from the Maintenance Equipment Tracking System (METS) and Finance

[3] https://mrcc.purdue.edu/research/awssi/indexAwssi.jsp

Data from PeopleSoft. The dashboard will be updated monthly and accessible to decision-makers and districts. It is built on the ESRI platform.

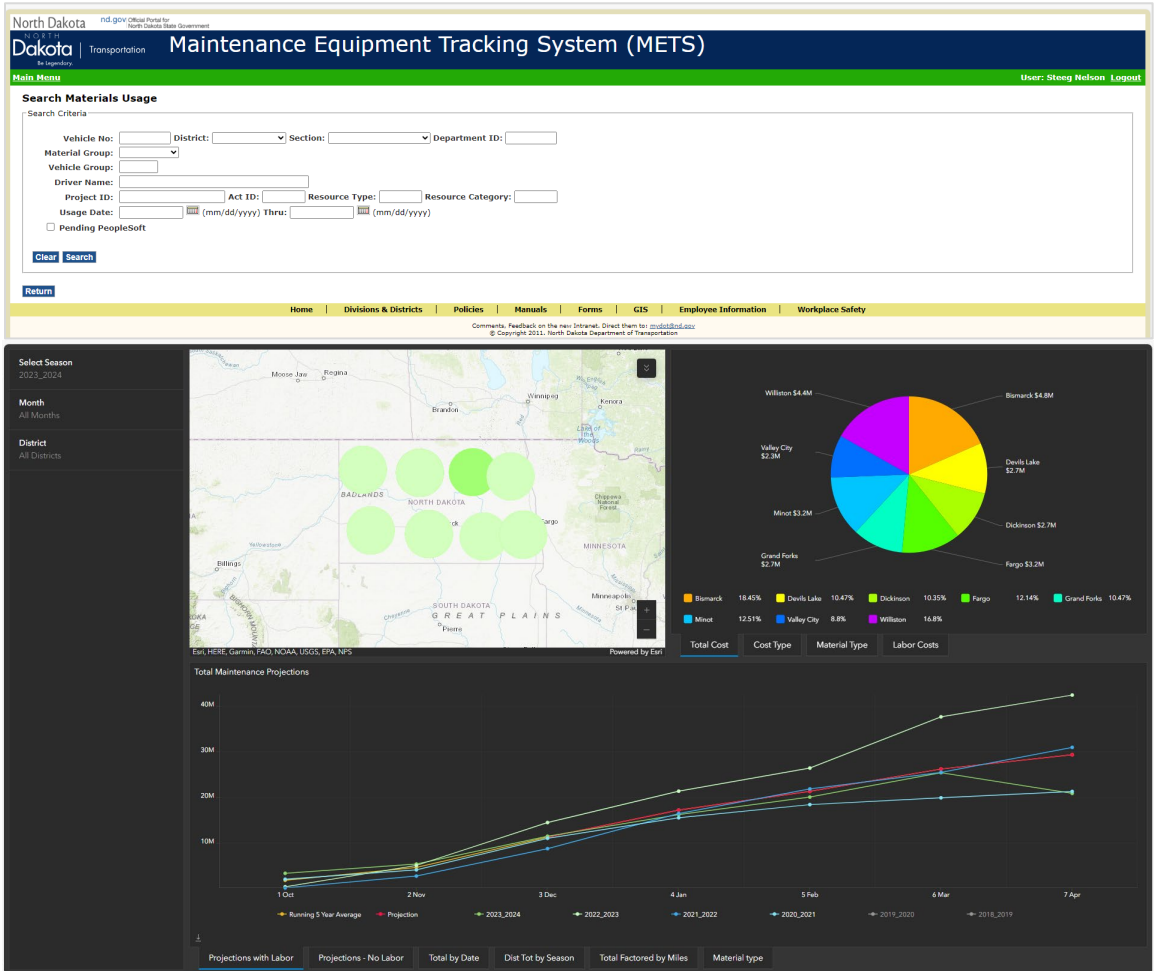


Figure 32. Maintenance Dashboard (North Dakota DOT)

Table 16. Maintenance Dashboard Overview

Purpose	This dashboard is still being developed; the goal is for it to be able to track the cost of snow and ice control.
Performance Measures	Cost of snow and ice control
Data Sources	Maintenance Equipment Tracking System (METS), Finance Data (via People Soft), and Automatic Vehicle Location (AVL)
Refresh Rate	Updated monthly
Users/Access	Decision makers and districts have access
Platform/Software	ESRI

The tool displays a map of the state and pie charts and graph to create an easy-to-read user interface. Each district is color coded, and historical data from previous months can be viewed so that users may create a direct cost comparison between the months and districts based on their material usage cost.

Future implementation includes connecting AVL data that would be updated in real time. The dashboard filter would be setup at the route level and would be used to compare material usage, performance, and road conditions.

4.4.3 Maintenance Speed Recovery Dashboard

The Maintenance Speed Recovery Dashboard is a tool that tracks the amount of time it takes for vehicle speeds to return to normal travel speeds due to snowstorms. If the speed of vehicles recovers to a rate of 90% of pre-storm speed, then it is determined that normal travel speeds have resumed. This dashboard can view historical data up to one year. By determining which districts speed recovery rates are slower than the rest, the NDDOT can allocate resources effectively to those areas.

Table 17 shows that the Maintenance Speed Recovery Dashboard is designed to monitor the time it takes for vehicle speeds to return to normal levels after snowstorm events. It uses data from the MDSS, roadway sensors (Automatic Traffic Recorders or ATR), and radar sensors on RWIS towers at 10-12 locations. The dashboard is updated every 24 hours and is accessible to districts. It is built on the ESRI platform.

The tool provides points along road segments that contain metrics such as average recovery time, snow recovery, friction, and speeds. Historical data is also provided to make direct comparisons between time periods for all the various metrics.

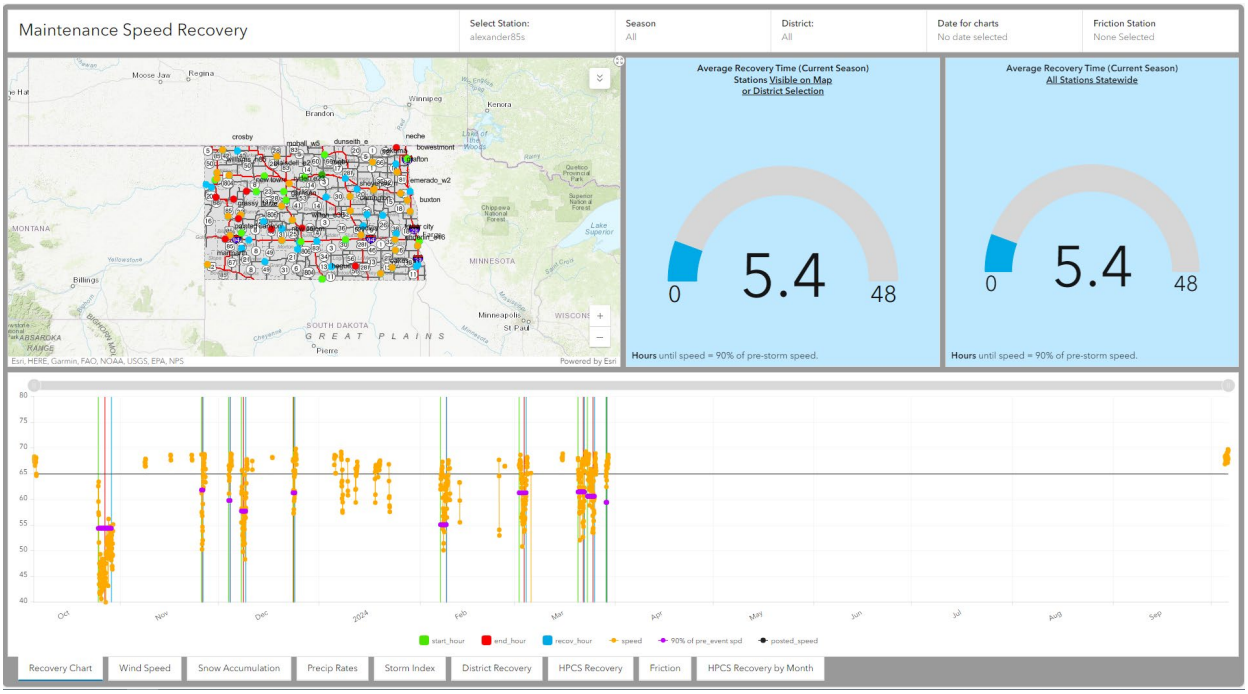


Figure 33. Maintenance Speed Recovery Dashboard (North Dakota DOT)

Table 17. Maintenance Speed Recovery Dashboard Overview

Purpose	Tracks how long vehicle speeds return to normal travel speed due to snowstorm events
Performance Measures	Snowstorm travel speed

Data Sources	Data is provided by MDSS, roadway sensors in the form of Automatic Traffic Recorders (ATR), radar sensors on RWIS towers (10-12 locations)
Refresh Rate	24 hours
Users/Access	Districts
Platform/Software	ESRI

4.4.4 Road Condition Dashboard

The Road Condition Dashboard is a tool designed to present real time data related to the road conditions within the state. The tool is mainly used by field operations and snowplow drivers and the dashboard presents variables such as visibility, weather conditions and the state of the roads themselves.

The Road Condition Dashboard's purpose, as noted in Table 18, is to offer real-time data on road conditions, focusing on mobility, weather, and road condition performance measures. Data is sourced from the Road Condition Reporting System (RCRS), and the dashboard is updated in real-time. It is accessible to internal users, field operators, maintenance personnel, and patrol teams, and is built on the ESRI platform. This tool provides road condition data in the form of bar graphs and pie chart and can organize them by district to display how much of the road segments in different districts are Seasonal/Good, Scattered Wet/Slush, and Wet/Slush. At the garage level, staff can compare road conditions in neighboring areas to see how a storm is progressing across the state.

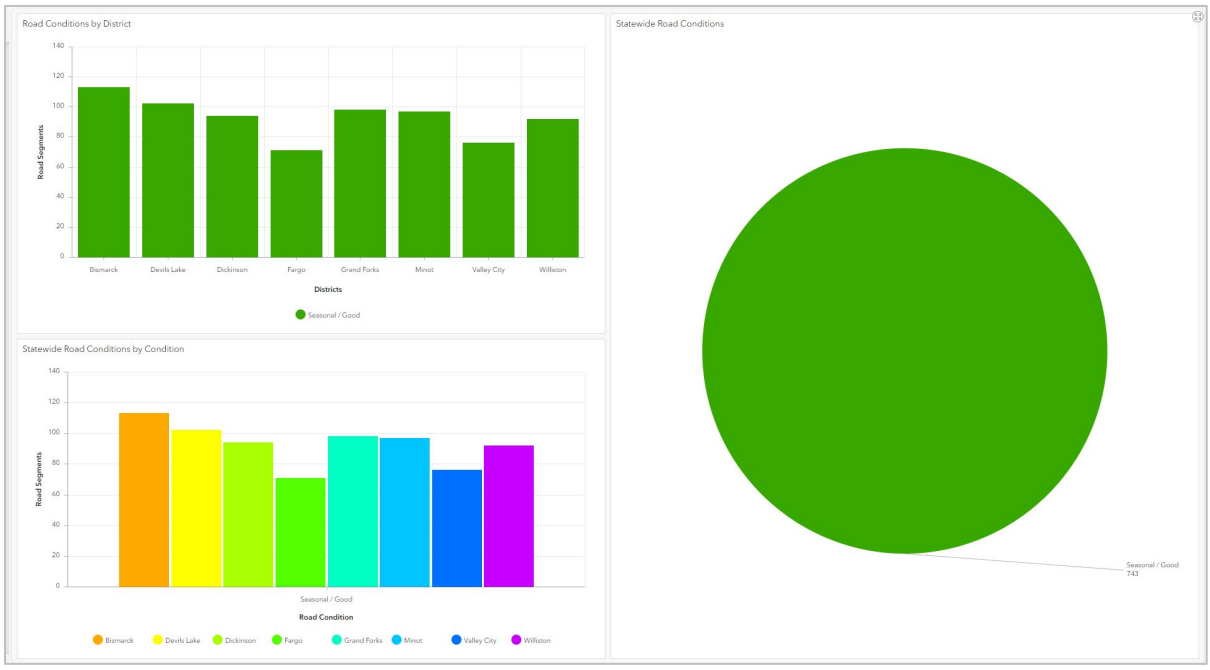


Figure 34. Road Condition Dashboard (North Dakota DOT)

Table 18. Road Condition Dashboard Overview

Purpose	Provide real time data of road conditions
Performance Measures	Mobility, weather, road condition
Data Sources	Road Condition Reporting System (RCRS)
Refresh Rate	Real time
Users/Access	Internal, field operators, maintenance, patrol
Platform/Software	ESRI

4.4.5 North Dakota Roads Dashboard

North Dakota Roads Dashboard visualizes current road conditions and sources data from RCRS as well as incident reports from local state and highway patrol. Without a TMC currently in place, this dashboard serves as the primary way to view road conditions in real time. This dashboard is also the data source of the Road Conditions Dashboard.

The North Dakota Roads Dashboard as seen in Table 19 is designed to track incidents and feed data into the Road Condition Dashboard. It focuses on performance measures related to road conditions, incidents, and weather. Data sources include the RCRS, state radios, and highway patrol reports. The dashboard is updated through manual input from the maintenance managers and is accessible to the public. It is built on the ESRI platform. The map on the ESRI platform provides filters for precipitation, visibility, condition, and travel speed. This allows users to find areas with the selected inputs and get a better understanding of road conditions.

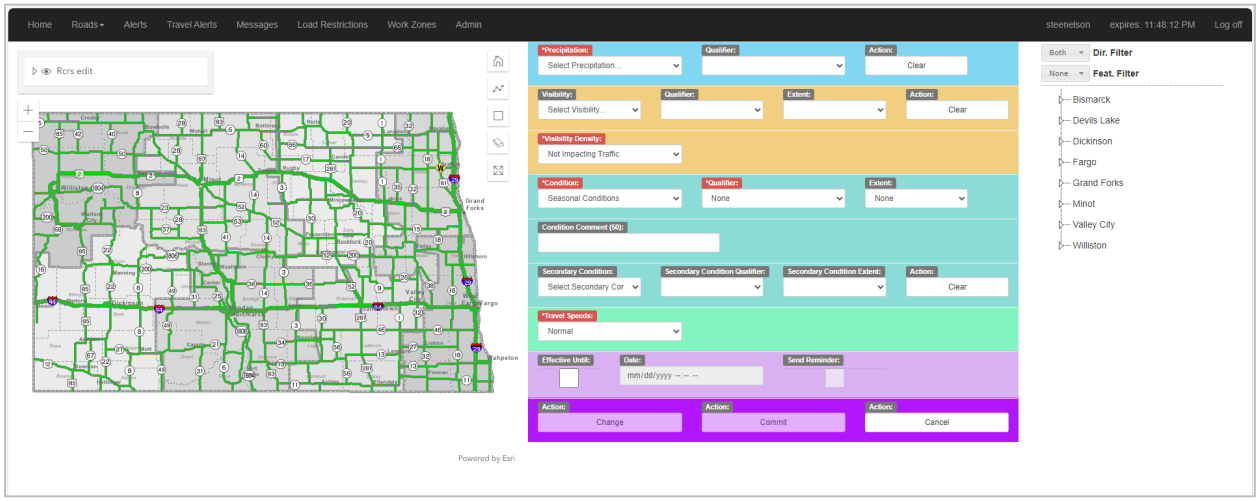


Figure 35. North Dakota Roads Dashboard (North Dakota DOT)

Table 19. North Dakota Roads Dashboard Overview

Purpose	Tracks incidents and feed into the Road Condition Dashboard
Performance Measures	Road conditions, incidents, weather
Data Sources	RCRS, state radios, highway patrol
Refresh Rate	Manual input
Users/Access	Public access
Platform/Software	ESRI
Source	https://gis.dot.nd.gov/external/rcrs/Account/Login?ReturnUrl=%2Fexternal%2Frcrs%2FRoads%2FMap

4.4.6 NDDOT Dashboard

The NDDOT Dashboard, as shown in Figure 36, is a tool that provides a thorough overview of the current state of NDDOT transportation infrastructure. It presents various metrics such as, conditions of roads and bridges, safety and Vision Zero, customer service indicators, types of transportation, available roads, and traffic volumes. Another function of the dashboard is to analyze road conditions through road imagery and specific performance metrics. Some of these metrics include temperature, wind, precipitation levels, friction, and visibility. The NDDOT Dashboard measures performance based on average travel speed recovery time for the current season, as well as factors like weather and mobility. Data is sourced from the dashboard datasheet and live data feed. The dashboard is updated daily and is accessible to the public. It is built on the ESRI platform.

This dashboard provides various data for different road segments such as air temperature, dew point, surface temperature, friction, relative humidity and more. It also provides images of the road and serves as a general summary of roadside conditions.

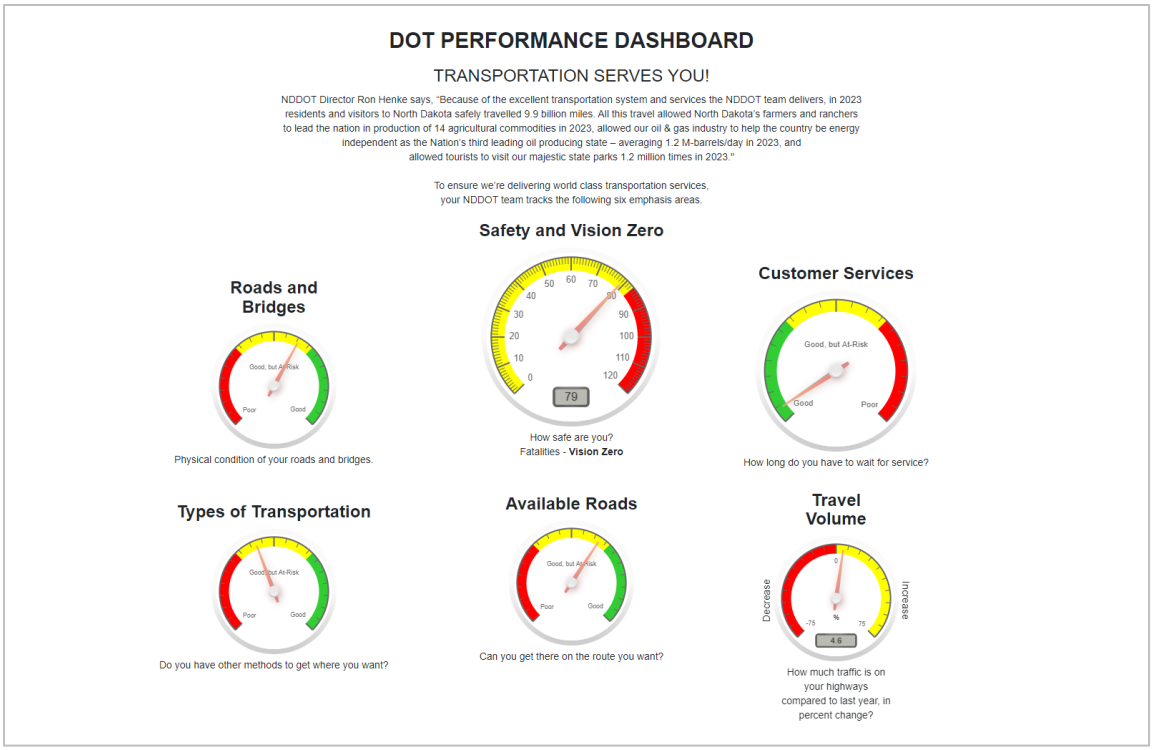


Figure 36. NDDOT Dashboard (North Dakota DOT)

Table 20. NDDOT Dashboard Overview

Purpose	Thorough understanding of the current state of NDDOT transportation infrastructure
Performance Measures	Average travel speed recovery time for the current season, weather, mobility
Data Sources	Dashboard datasheet, live data feed
Refresh Rate	Updated daily
Users/Access	Public access
Platform/Software	ESRI
Source	https://www.dot.nd.gov/dot/view/dotdashboard.aspx

4.4.7 Development of Dashboards

The development of maintenance dashboards was the result of a collaboration between a team of state maintenance engineers and the NDSU. This initiative stemmed from the NDDOT planning division's interest in leveraging speed data to enhance their operations. During the COVID-19 pandemic the need for speed recovery data was emphasized, prompting a strong effort to prioritize its collection and analysis.

The team then successfully secured a state grant to facilitate the development of these dashboards. This funding not only enabled the acquisition of the tools needed, but also provided the necessary resources and expertise to ensure the success of these developments. Through planning and collaboration, the team

was able to design and implement effective maintenance dashboards that have since become integral to the NDDOT's operations.

4.4.8 System Operations and Maintenance

Funding from a grant supported the development, implementation, maintenance, and enhancement of sixteen sites, with costs varying from $100,000 to $120,000. The following year, an additional seventy-three sites were included in the contract. The finance group played a key role in managing costs, ensuring that staff hours were allocated in accordance with internal policies.

4.4.9 Benefits and Lessons Learned

The implementation of these winter maintenance dashboards has resulted in improved LOS on roads utilizing dashboard data. They support decision-making for resource allocation, offer valuable training insights, enable real-time monitoring of roadway conditions, and track material usage and labor costs.

Additionally, these dashboards automate specific processes, saving time, and provide the flexibility to view and extract data at any time. This capability allows for easier tracking of the impact of decisions made by state decision-makers. Notably, the National Cooperative Highway Research Program (NCHRP) utilized data from these dashboards for a study on snow and ice control measures, which was then presented to the state.

4.4.10 Plans for the Future and Potential Enhancements

NDDOT is exploring several enhancements for its winter dashboards. These include tracking weather severity alongside speed for normalization, monitoring salt usage on winter maintenance roads, implementing more predictive and proactive measures, and expanding AVL controller information and AVL pavement temperature data.

Moreover, NDDOT plans to develop new data sources and dashboards. This includes establishing a TMC to monitor area-wide traffic conditions and deploy management strategies as needed. Additionally, they aim to create smart corridors, sections of roadway equipped with dynamic signs that adjust based on roadway conditions.

4.4.11 Key Points

- Development for winter dashboards started when NDDOT wanted a way to establish speed recovery metrics and there was a need to quantify performance metrics that was no longer manually feasible.
- Utilizing the university that has a long history of collaboration with NDDOT for the development of these dashboard helps minimize the needs for internal resources.
- During the COVID-19 pandemic the need for speed recovery data was emphasized, prompting a strong effort to prioritize its collection and analysis.
- The Maintenance Dashboard integrates in-house material usage inventory and finance data by tracking the cost of snow and ice control. The Maintenance Speed Recovery Dashboard tracks the amount of time it takes for vehicle speeds to return to normal travel speeds. The Road Condition

Dashboard presents real time data related to road conditions such as visibility, weather conditions, and the state of the roads. North Dakota Roads Dashboard tracks road conditions, incidents, and acts a data source for the Road Conditions Dashboard.

- The NDDOT Dashboard provides an overview of the current state of NDDOT transportation infrastructure with various metrics such as conditions of roads, bridges, safety, Vision Zero, customer service indications, types of transportation, available roads, and traffic volume.
- NDDOT has learned that implementing winter maintenance dashboards has allowed the agency to utilize data to enhance the LOS of intersections that are being analyzed. Furthermore, by tracking material usage, speed, and other metrics, the DOT can allocate resources more effectively and offer training insights.
- A valuable enhancement that NDDOT plans to make in the future is, tracking the salt usage on maintenance roads. This is a very valuable metric to track and will allow NDDOT to make sure the roads are being maintained within budget and expectations, while also potentially leading to increased efficiency.

4.5 Case Study 4: Ohio Department of Transportation

4.5.1 Introduction

Ohio DOT (ODOT) is divided into 12 districts as shown in Figure 37.

Figure 37. Ohio DOT Districts

ODOT manages 42,700 total lane miles with 1,700 state-owned plow trucks with over 2,360 state employees and 350 seasonal workers. ODOT maintains 95% of the state-owned roadways. In the 2022-2023 winter season, ODOT applied approximately 403,800 tons of sodium chloride and 9,126,000 gallons of liquids (sodium chloride brine and calcium chloride brine). The cost of salt last season was $60.20 per ton resulting in $25.0 million dollars for material costs. The average accumulated winter season index was 238[4]. These data were reported to Clear Roads Winter Data Survey.

The ODOT started dashboarding with a goal to transform the data on spreadsheets into user friendly dashboards. While they have not developed dedicated dashboards for snowplow GPS/AVL data, they recognize the potential and do offer a mobile-friendly GPS/AVL dashboard and are piloting a "real-time evaluator" tool. The real-time evaluator tool, or in other words the real-time snow and ice dashboard, visualizes current conditions such as vehicle speed and weather data. Vehicle speed data are gathered from probe data, and weather data are obtained from RWIS. Additionally, ODOT has a Snow and Ice Performance Evaluator Tool Dashboard that is a comprehensive solution for analyzing post-storm snow and ice removal performance across districts. The Snow and Ice Performance Evaluator Tool performs post-storm analysis and shows the route recovery performance metric, aiding managers in evaluating staffing and operational efficiency. ODOT does a Mobile AVL Dashboard to view number of trucks available in a district, compared to how many being used at a glance on a mobile device. The Snow and Ice Dashboard is a crucial tool for maintaining efficient snow and ice removal throughout the season. It requires strategic planning and resource allocation, serving as an essential resource for both district-level and county-level managers. In short, ODOT is actively weaving data visualization into their decision-making, and integrating GPS/AVL data is likely on the horizon.

4.5.2 Real-Time Snow and Ice Dashboard

The real-time snow and ice dashboard checks if winter maintenance goals are met during a snowstorm. It also evaluates snow and ice data in real time and allows users to view vehicle speed and RWIS data. Figure 38 shows a screenshot of the real-time snow and ice dashboard. Table 21 provides an overview of the real-time snow and ice dashboard.

[4] https://mrcc.purdue.edu/research/awssi/indexAwssi.jsp

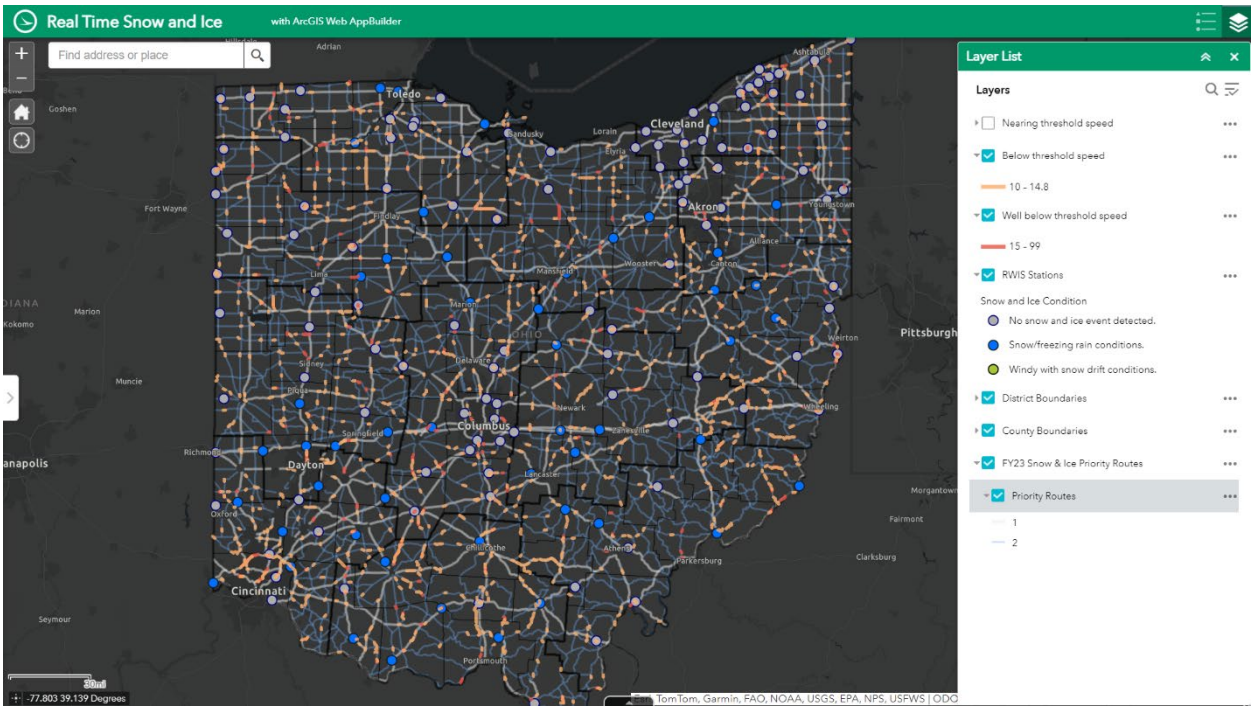


Figure 38. Real-Time Snow and Ice Dashboard (Ohio DOT)

Table 21. Real-Time Snow and Ice Dashboard Overview

Purpose	Checks if winter maintenance goals are being met during a snowstorm. Evaluates snow and ice data in real time and allows users to view probe data and RWIS data. Helps aid in the allocation of resources.
Performance Measures	Speed conditions, weather conditions
Data Sources	Speed data (via INRIX), weather data (via RWIS)
Refresh Rate	Real-time/ every few minutes
Users/Access	County managers
Platform/Software	ESRI

Fueled by data from two sources, the map displays both speed and weather information. Speed data, gathered through the INRIX API, allows for comparison with expected speeds on each road segment. Deviations are highlighted in orange and red, indicating potential slowdowns and areas requiring intervention. Additionally, internal RWIS data provides real-time updates on weather conditions, allowing managers to anticipate further challenges.

With data refreshed every few minutes, the map acts as a dynamic command center. County managers can monitor performance against set goals, allocate resources strategically, and make informed decisions based on the latest conditions. This empowers them to respond proactively to storm events, enabling efficient snow and ice removal and maintaining public safety. While the dashboard is currently limited to internal access, the real-time snow and ice web map plays a vital role in keeping the county moving during winter storms.

4.5.3 The Snow and Ice Performance Evaluator Tool Dashboard

The Snow and Ice Performance Evaluator Tool Dashboard is a comprehensive solution for analyzing post-storm snow and ice removal performance across districts and counties. It is designed to identify routes that have not met recovery goals, with a benchmark set at 96% recovery. This tool allows for a detailed exploration of these routes. Figure 39 and Figure 40 show examples of the Snow and Ice Performance Evaluator Tool Dashboard. Table 22 provides details of the real-time snow and ice dashboard.

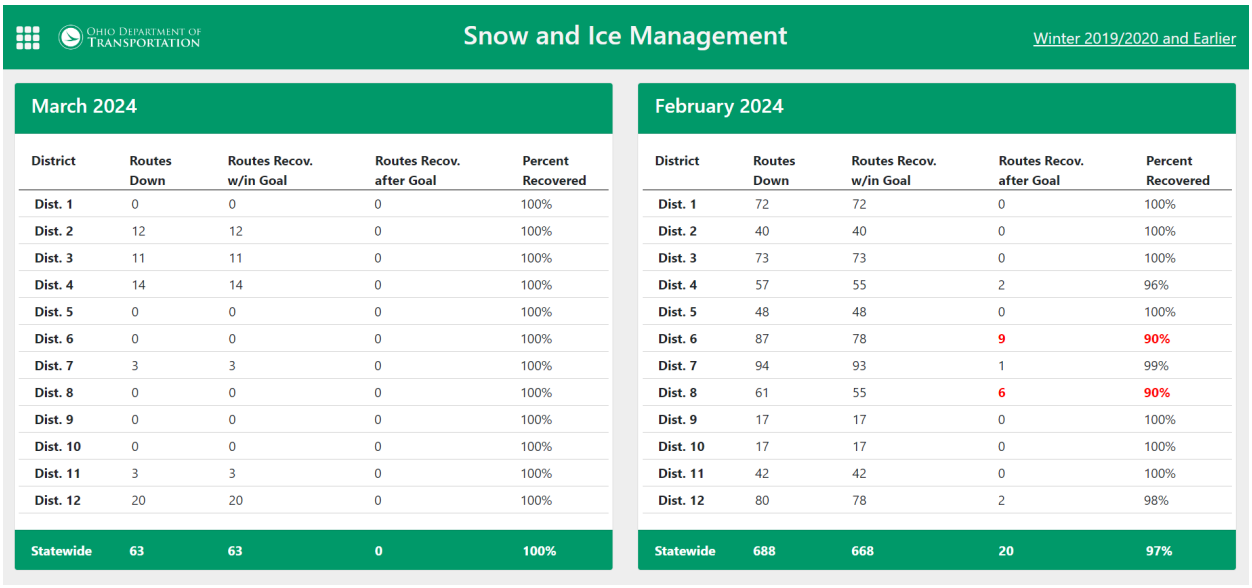


Figure 39. Snow and Ice Performance Evaluator Tool Dashboard - Statewide View (Ohio DOT)

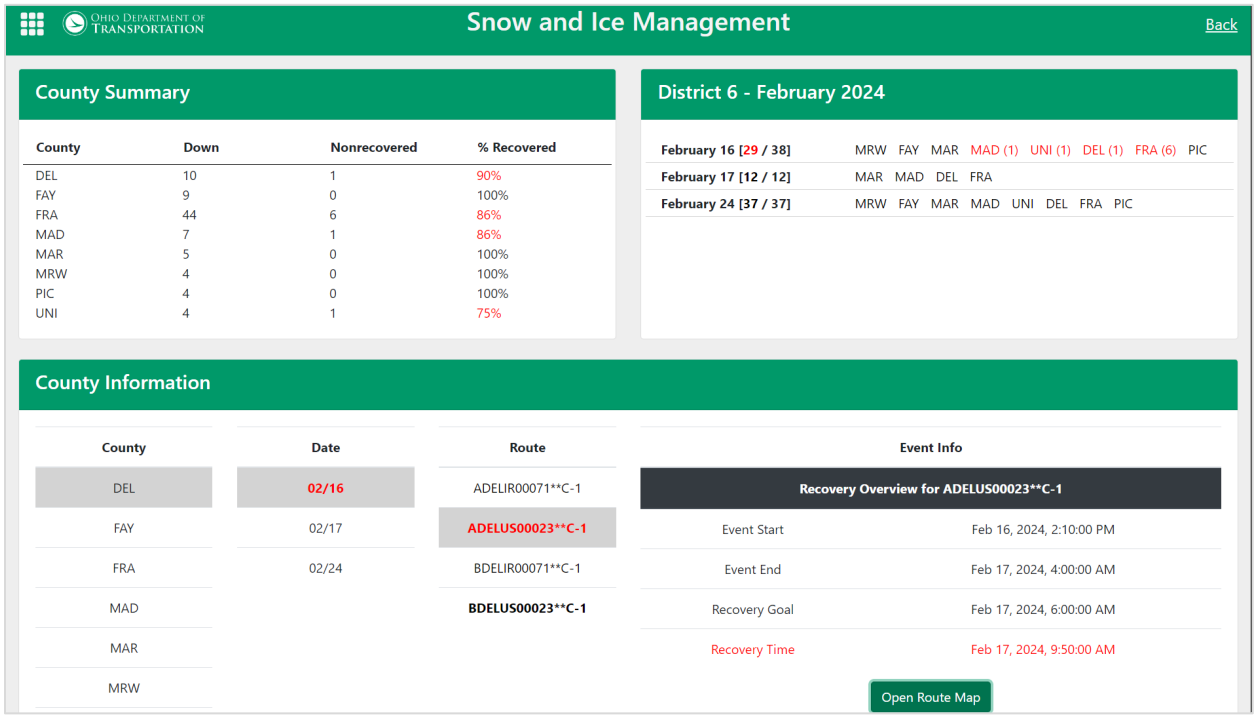


Figure 40. Snow and Ice Performance Evaluator Tool Dashboard - District View (Ohio DOT)

Table 22. Snow and Ice Performance Evaluator Tool Dashboard Overview

Purpose	Determine if recovery goals are being hit after a snowstorm and organize it by district and county.
Performance Measures	Storm start, storm end, recovery goal, time recovered
Data Sources	RWIS, INRIX
Refresh Rate	Monthly
Users/Access	District highway managers and county. Results are used by leadership.
Platform/Software	Python/SQL, TSMO data warehouse
Source	https://www.apwa.org/resource/snow-ice-performance-evaluator/

As shown in Table 22 the snow and ice performance evaluator tool dashboard to determine if recovery goals are being hit after a snowstorm and organizes it by district and county. It is a comprehensive solution for analyzing post-storm snow and ice removal performance across districts and counties. It is designed to identify routes that have not met recovery goals, with a benchmark set at 96% recovery. This tool allows for a detailed exploration of these routes.

The performance measures within the dashboard are multifaceted. It tracks recovery goals and times for different priority routes, with a 2-hour goal for priority 1 routes and a 4-hour goal for priority 2 routes. The tool measures the downtime for each route based on real-time probe speed data provided by INRIX. It also defines the start of a storm based on a combination of RWIS and probe data and to end a storm, only RWIS data is considered. The probe data is then utilized to determine the route recovery which accounts for both weather conditions and speed impact. The success of recovery is measured by how quickly after the end of a storm routes return to speeds that are within 10 mph of the historical average speed recovery is achieved when a route is within 10 mph of the historical speed for at least one consecutive hour.

The dashboard utilizes multiple data sources. INRIX provides real-time speed data for tracking downtime, while RWIS triggers the start and end of a storm and helps define recovery periods. The TSMO data warehouse houses historical speed data, which is used to measure recovery success.

From a technical standpoint, this dashboard is powered by Python and SQL scripts that process data and drive analysis. The results are displayed on a website that allows for interaction. After each storm, a manual trigger is activated for analysis and reporting. To keep leadership informed, quarterly reports summarizing overall performance are sent out.

The functionality of the dashboard is designed to be user-friendly and informative. A Statewide/District view allows leaders, Highway Maintenance Administrators (HMA), and Roadway Service Managers to analyze performance within their areas, while a county-wide view offers managers an overview of the effectiveness of the storm response. Route details are available for a more granular analysis, particularly for specific routes that have not met recovery goals. Managers can provide feedback to be incorporated into the dashboard about incidents that may impact recovery.

4.5.4 Snow and Ice Dashboard

The Snow and Ice Dashboard is a crucial tool for maintaining efficient snow and ice removal throughout the season. It requires strategic planning and resource allocation, serving as an essential resource for both district-level and county-level managers.

The dashboard tracks the usage of materials such as salt and sand throughout the season, presenting yearly totals and historical snapshots dating back to 2015. It also offers real-time insight into the current material inventory across all garages, ensuring preparedness for upcoming storms. Additionally, it allows for the analysis of labor hours, truck miles, and total costs associated with snow and ice removal efforts, offering valuable insights into operational efficiency. Figure 41 through Figure 43 show examples of the dashboard.

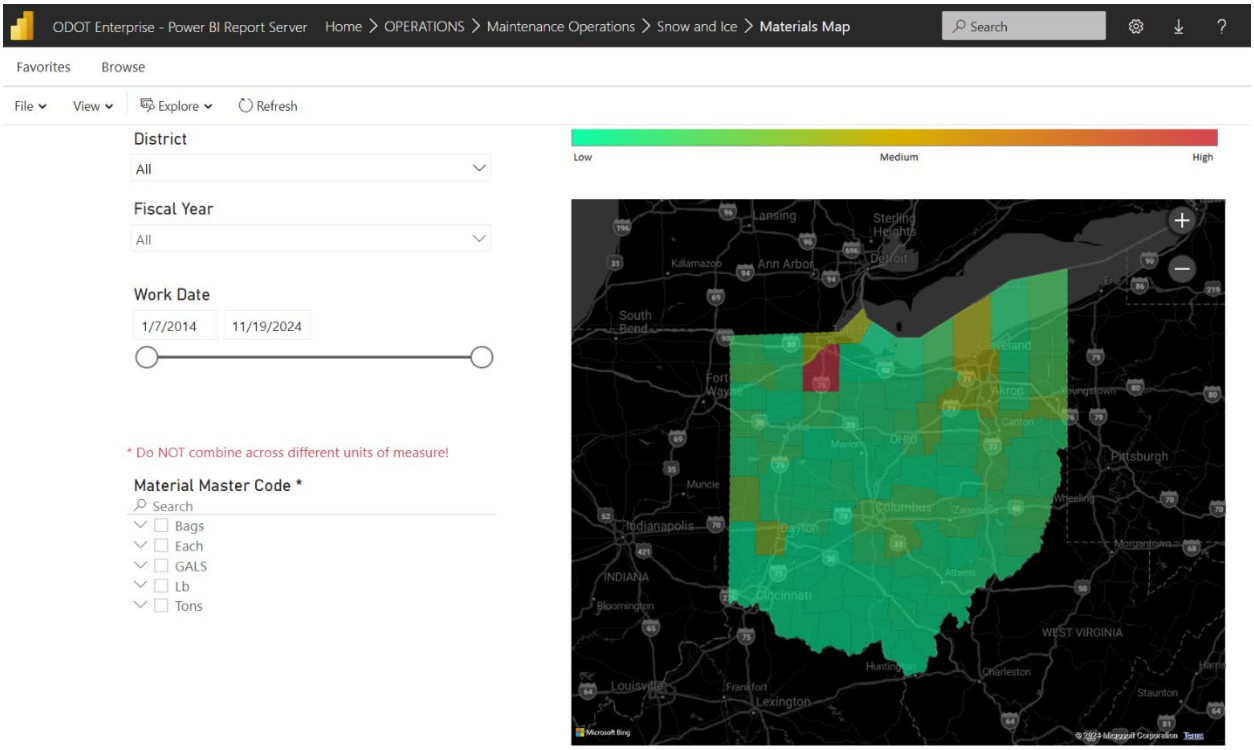


Figure 41. Snow and Ice Material Map (Ohio DOT)

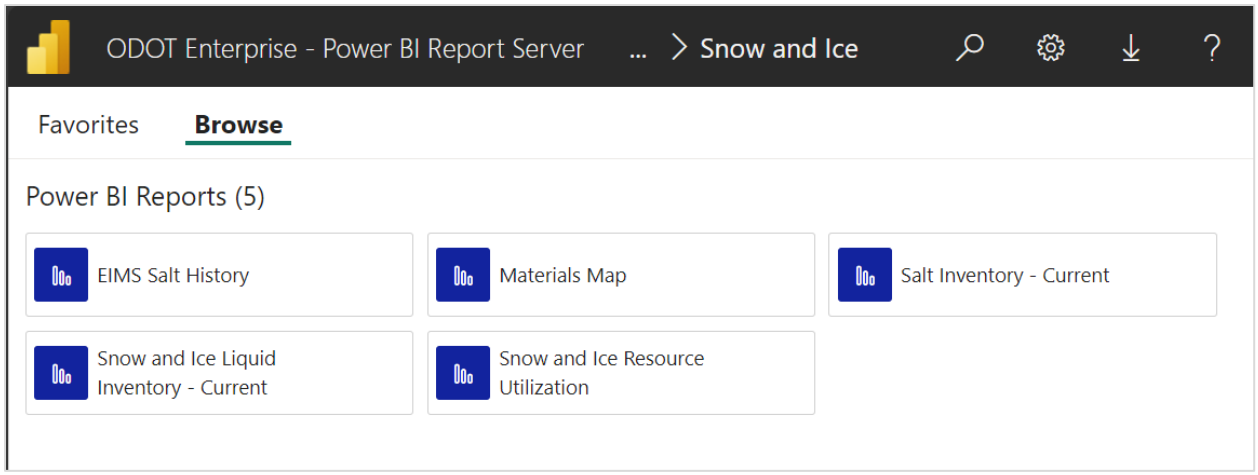


Figure 42. Snow and Ice Maintenance Operations (Ohio DOT)

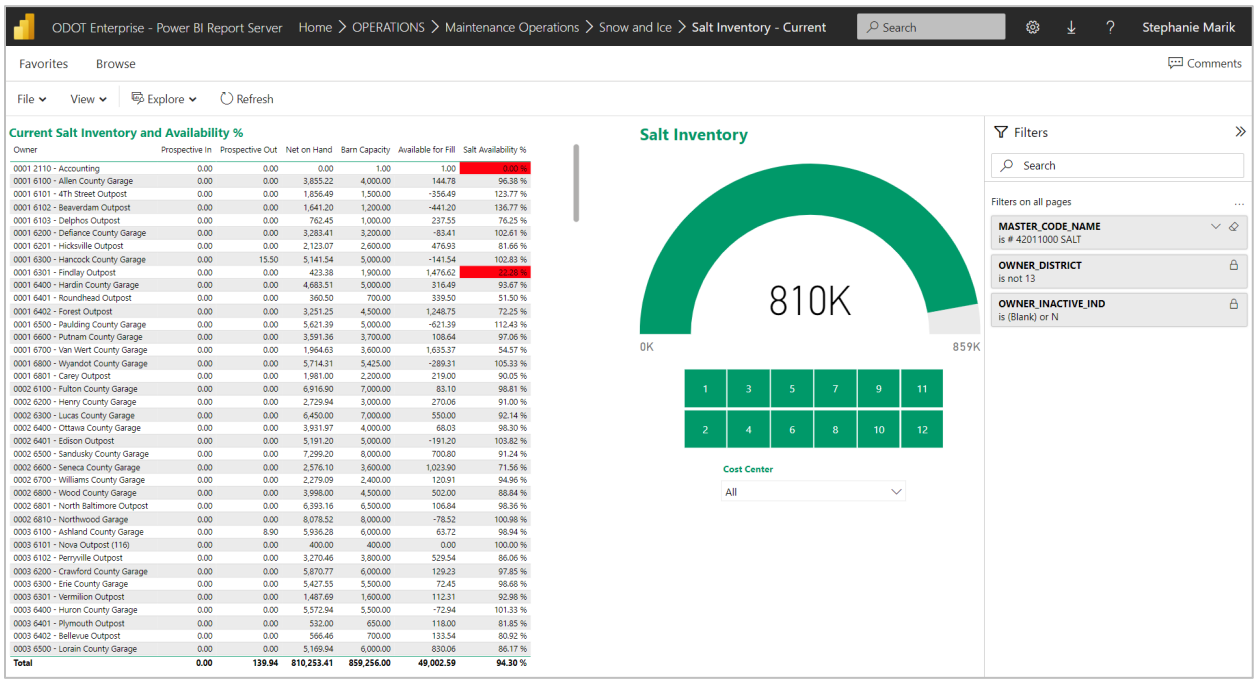


Figure 43. Snow and Ice Dashboard (Ohio DOT)

As shown in Table 23, The Snow and Ice Dashboard Resources Reporting Dashboards are a crucial tool for maintaining efficient snow and ice removal throughout the season. They require strategic planning and resource allocation, serving as an essential resource for both district-level managers and the HMA.

Table 23. Snow and Ice Resources Reporting Dashboards Overview

Purpose	Provides an overview of materials and costs for each season
Performance Measures	How much material was used in the season, totals per year, labor hours, truck miles, total cost, historical records, current inventory, average salt usage
Data Sources	Inventory Management System (via EIMS)
Refresh Rate	Daily
Users/Access	District level, Highway Maintenance Administration (HMA)
Platform/Software	PowerBI

The dashboards track the usage of materials such as salt, and deicer liquids, throughout the season, presenting yearly totals and historical snapshots dating back to 2015. They also update material in the system of record within the next business day. As materials are entered into Enterprise Information Management Systems (EIMS) providing nearly real-time insight into the current material inventory across all garages, ensuring preparedness for upcoming storms. Additionally, they allow for the analysis of labor hours, truck miles, and total costs associated with snow and ice removal efforts, offering valuable insights into operational efficiency.

All information displayed on the dashboards are directly pulled from the EIMS inventory management system, ensuring data accuracy and consistency. Updates occur daily at midnight, reflecting any changes made within the EIMS system. However, delays may occur if garages experience high workloads and have not updated the system promptly.

The dashboards offer several benefits to their users. District managers gain instant visibility into material usage across their respective districts, enabling proactive monitoring and resource allocation. The HMA can eliminate the need for daily inquiries to individual districts, improving overall communication and operational efficiency.

From a technical standpoint, the dashboards use PowerBI as a platform, providing a user-friendly interface for data visualization and interaction. They allow users to track salt and other material usage, monitor salt shed capacity and inventory, and access daily snapshots of resource utilization.

Several enhancements are planned for these dashboards. These include integrating data from the salt usage dashboard with a separate ordering system, offering a more comprehensive view of resource management. A similar dashboard dedicated to tracking liquid de-icing materials is also under development, further expanding the scope of winter resource monitoring. Different time frames, usage coming from inventory system, database shows usage in a particular day.

4.5.5 Mobile AVL Dashboard Overview

The Mobile AVL Dashboard has been developed to load easily on a mobile phone, providing a user-friendly interface for real-time spot checks. Although the map may take a little longer to load, it provides a comprehensive view of all trucks available in a district and how many are out on the routes.

The primary purpose of the dashboards is to serve as an AVL/GPS - hydraulic/salt treatment dashboard. Users can select a district and pull all truck data from the last 30 minutes, including salt application rate

and speed. Despite some issues with the accuracy of the hydraulics data systems, the mobile dashboards provide valuable insights into AVL on the fly, allowing users to see trucks up/down and crews working on snow and ice. An example of the dashboard is shown in Figure 44.

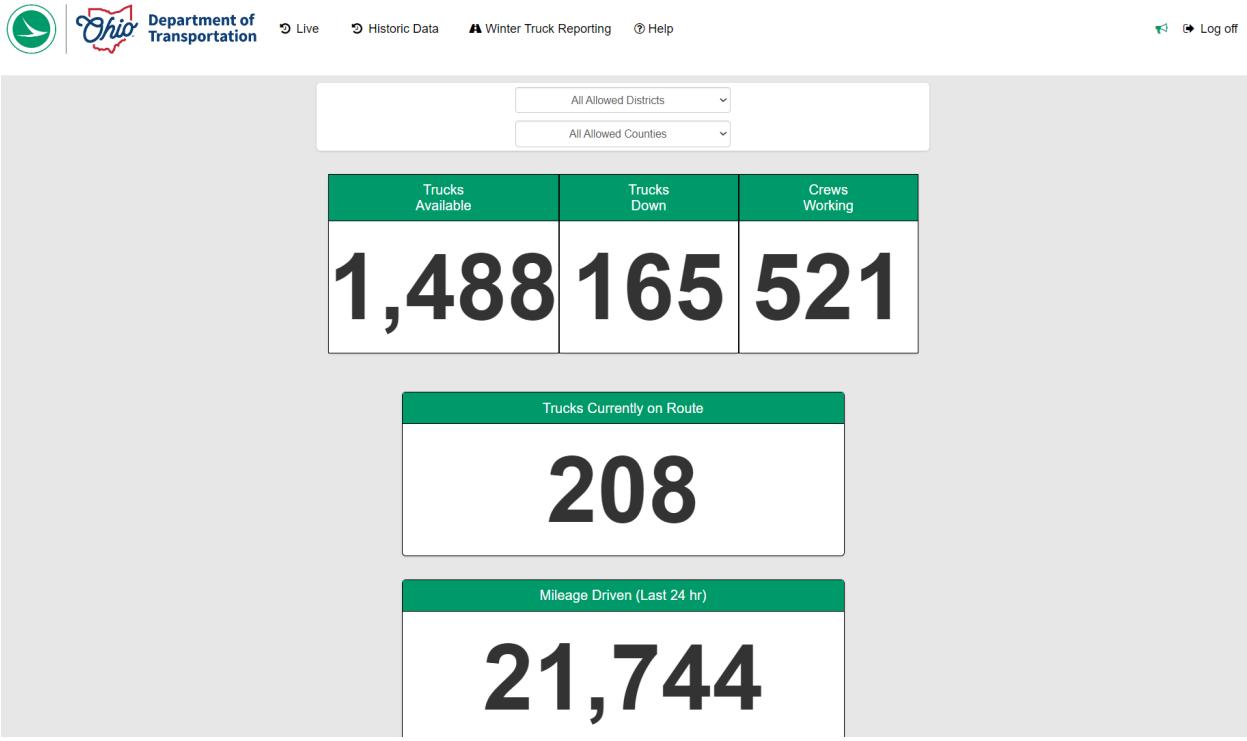


Figure 44. Mobile AVL Dashboard (Ohio DOT)

As shown in Table 24, the purpose of the Mobile AVL Dashboard is to view the number of trucks available in a district, compared to how many being used. Can also view salt application rate and speed based on district. The Mobile AVL Dashboard has been developed to load easily on a mobile phone, providing a user-friendly interface for real-time spot checks. Although the map may take a little longer to load, it provides a comprehensive view of all trucks available in a district and how many are out on the routes.

Table 24. Mobile AVL Dashboard Overview

Purpose	To view the number of trucks available in a district, compared to how many are being used. Can also view salt application rate and speed based on district. Used to view AVL data quickly on mobile devices.
Performance Measures	Application rate, speed, and miles driven
Data Sources	AVL, manual winter truck reporting
Refresh Rate	Real-time
Users/Access	Public and leadership
Platform/Software	AVL website
Source	https://www.odotgpsavl.net/Account/Login?ReturnUrl=%2F

The dashboards utilize GPS/AVL data to track trucks currently on the route, specifically those outside of the geofence of the garage. They also include a Truck Usage History Dashboard and a Winter Truck Reporting feature. The latter requires manual updates every morning by daily morning entry, every 2 hours during storms, and shift changes. These updates populate the dashboard with the latest truck availability information.

The primary purpose of the dashboards is to serve as an AVL/GPS - hydraulic/salt treatment dashboard. Users can select a district and pull all truck data from the last 30 minutes, including salt application rate and speed. Despite some issues with the accuracy of the hydraulics data systems, the mobile dashboards provide valuable insights into AVL on the fly, allowing users to see trucks available and crews working on snow and ice.

Performance measures include tracking trucks up/down, crews working on snow and ice, and miles driven (both 24 hours and 2 hours). The data sources for these dashboards include AVL and manually entered data from county managers or timekeepers, reported every morning and every two hours during an active event.

The dashboards refresh in real time, providing up-to-date information for users. They are particularly useful for communication, allowing the public and leadership to stay informed about ongoing operations. The dashboards are hosted on the AVL website, ensuring easy access for all users.

4.5.6 Development of Dashboards

In the development of winter dashboards, the need for a dashboard typically arises when central figures in dashboard management, notice repeated requests for specific data or when higher management seeks specific information. Their involvement streamlines data management, reducing their workload, and although field staff rarely request dashboards directly, there is a desire for more accessible data representation.

Dashboards are constructed based on specific needs. Requests for development funding are submitted to the IT department, which then evaluates the most suitable tools and options based on the intended use of the dashboard. This discussion continues until the foundational structure of the dashboard is established. The traffic management team oversees the performance of these dashboards. While there is no formal process for evaluating the performance of these dashboards, familiarity with the software and data can aid in identifying potential inaccuracies or areas for improvement. The team of people with PowerBI skills has been instrumental in the development of the dashboards and assists in managing the servers on the backend.

During the development process, several challenges were encountered, including the creation of scripts for goal calculations due to their complexity. The assistance of a senior developer was invaluable in addressing these issues and redesigning the scripts. Data quality has also been an issue and must be checked to ensure the most accurate readings are being used. These checks are performed manually and have quality thresholds in place to ensure standard procedures are followed.

4.5.7 System Operations and Maintenance

The hosting of these dashboards for viewing occurs through the following methods:

- Publicly accessible sites on the website, and

- Internal agency dashboards.

These systems are maintained by senior developers and the IT department. The software for these dashboards includes PowerBI, Python, and SQL. ODOT had no issues or concerns in the system operations and maintenance of their dashboards.

4.5.8 Benefits and Lessons Learned

The implementation of these dashboards has yielded numerous benefits to ODOT. ODOT Districts now have access to vital, relevant data at any time. The use of GPS/AVL data allows for real-time tracking of truck locations. Districts can utilize the available data to make informed decisions, and the impact of these decisions on routes can be measured. Leadership can use the information provided by the dashboards to make strategic decisions, and the communication division can use the data to highlight ODOT's efforts to assist the public and promote its work.

4.5.9 Plans for the Future and Potential Enhancements

Several enhancements are planned for the future. These include adding liquids to the dashboards, merging salt ordering data in the Services and Support section, and enhancing the front end of the dashboard that displays the financial year summary. ODOT is exploring new data sources and may potentially create additional dashboards related to weather data.

4.5.10 Key Point

- ODOT started dashboarding to transform the data on spreadsheets into user-friendly dashboards. While they have not developed dedicated dashboards for GPS/AVL data, they recognize the potential.
- They offer a mobile-friendly GPS/AVL dashboard and are piloting a "real-time evaluator" tool that analyzes routes and publishes insights on recovery times, aiding managers in evaluating staffing and operational efficiency.
- The purpose of the snow and Ice dashboard is to check if winter maintenance goals are being met during a snowstorm. The dashboard also evaluates snow and ice data in real-time and allows users to view probe data and RWIS data and helps aid in the allocation of resources.
- The snow and ice performance evaluator tool dashboards are used to determine if recovery goals are being hit after a snowstorm and organize it by district and county. Snow and ice dashboards provide an overview of materials and costs for each season.
- From a technical standpoint, the dashboards use PowerBI as a platform, Python, and SQL scripts.
- The mobile AVL dashboard is to view the number of trucks available in a district, compared to how many are being used. You can also view salt application rate and speed based on district.
- The dashboards refresh in real-time, providing up-to-date information for users. They are particularly useful for communication, allowing the public and leadership to stay informed about ongoing operations. The dashboards are hosted on the AVL website, ensuring easy access for all users.

- ODOT is actively weaving data visualization into its decision-making, and further integration of GPS/AVL data with dashboards is likely on the horizon.
- One of the major benefits of the dashboards is that Ohio DOT can pull information quickly and accurately.
- Also, these dashboards have evolved over the years so the data can be compared between historical to current data in near real time without waiting for monthly reports.

4.6 Case Study 5: Virginia Department of Transportation

4.6.1 Introduction

VDOT has nine districts as shown in Figure 45 Each district contains a maintenance superintendent and a maintenance supervisor.

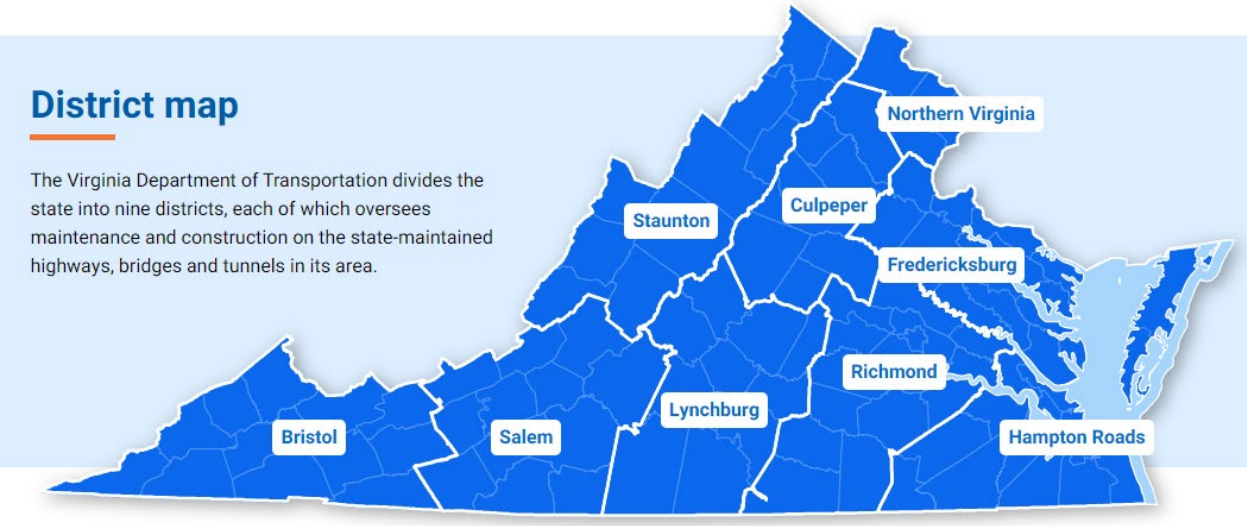


Figure 45. Virginia DOT Districts

VDOT manages 125,000 total lane miles with 2,500 state-owned plow trucks and 6,500 private or local owned plow trucks. VDOT maintains 10% of the state-owned roadways and 90% is maintained by private contractors. In the 2022-2023 winter season, VDOT spent $108 Million on snow and ice operations. The average accumulated winter season index was 76[5]. These data were reported to the Clear Roads Winter Data Survey.

As presented in Section 1.2, VDOT contracts out much of the equipment and labor for operations. VDOT started dashboarding with the goal of streamlining the process of analyzing hired equipment data for statewide snow and ice control contractors. The data provided to their dashboards originates from multiple sources and refreshes in a range of real-time to daily. PowerBI is the main dashboarding software utilized since it is interoperable with everything else VDOT internally uses, including Power Automate with

[5] https://mrcc.purdue.edu/research/awssi/indexAwssi.jsp

reporting tools as well as emails. These dashboards allow all resources to be fused for a comprehensive situational awareness review. VDOT has:

- Winter Preparedness Dashboard,
- Winter Weather Event Dashboard,
- Full Inventory Dashboard,
- Material Inventory Dashboard,
- M7B Registration Dashboard,
- Minimum Guaranteed Payment (MGP) Look-up Dashboard,
- Equipment Verification Dashboard,
- Equipment Look-up Dashboard,
- Emergency Management Center Dashboard, and
- Damage Assessment Dashboard.

The following sections provide details on each of the winter maintenance dashboards VDOT utilizes for insights into their winter operations.

4.6.2 Winter Preparedness Dashboard

The Winter Preparedness Dashboard is used to visualize statewide data which includes equipment and vendor details broken down by district, equipment type, and salt availability. VDOT utilizes the winter preparedness dashboard to visualize key data related to snow removal across the state. This dashboard serves as a central hub for both internal leadership and the public, offering insights into VDOT's equipment, vendor network, and salt availability. At its core, the dashboard displays equipment and vendor details, including multi-year and yearly agreements. Additionally, the dashboard tracks material and equipment usage, location, and status, offering performance measures during critical winter events. Figure 46 shows an example of the Winter Preparedness Dashboard displaying the amount of equipment by district. Table 25 provides details of the Winter Preparedness Dashboard, showing the purpose of the dashboard, performance measures, data sources, refresh rate, users/access, and platform/software.

Figure 46. Winter Preparedness Dashboard (Virginia DOT)

Table 25. Winter Preparedness Dashboard Overview

Purpose	Visualize statewide data yearly which includes equipment and vendor details broken down by district, type, and salt available.
Performance Measures	Material and equipment usage, location, and status
Data Sources	Districts self-report, salt is updated by garage personnel, Severe Weather Application Systems (SWAS)
Refresh Rate	30 minutes
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

While offering valuable insights, the dashboard also acknowledges limitations. The current system relies on manual entry for salt availability data, which introduces potential discrepancies. Additionally, not all data sources are fully integrated into a single, unified system of record. Despite these limitations, the winter preparedness dashboard remains a valuable tool for VDOT to assess its readiness, efficiently allocate resources, and make informed decisions throughout the winter season.

4.6.3 Winter Weather Event Dashboard

The Winter Weather Event Dashboard provides weather event information as soon as someone begins to mobilize within their Severe Weather Application Systems (SWAS). In response to winter weather events, VDOT employs this as a dedicated dashboard to monitor critical data in real time. This platform automatically activates as soon as personnel begin mobilizing in the SWAS, offering valuable insights throughout the event's duration. Once the event concludes and SWAS activity ceases, the dashboard returns to a blank state. Figure 47 shows the example of the Winter Weather Event Dashboard. Table 26 provides details of the Winter Weather Event Dashboard.

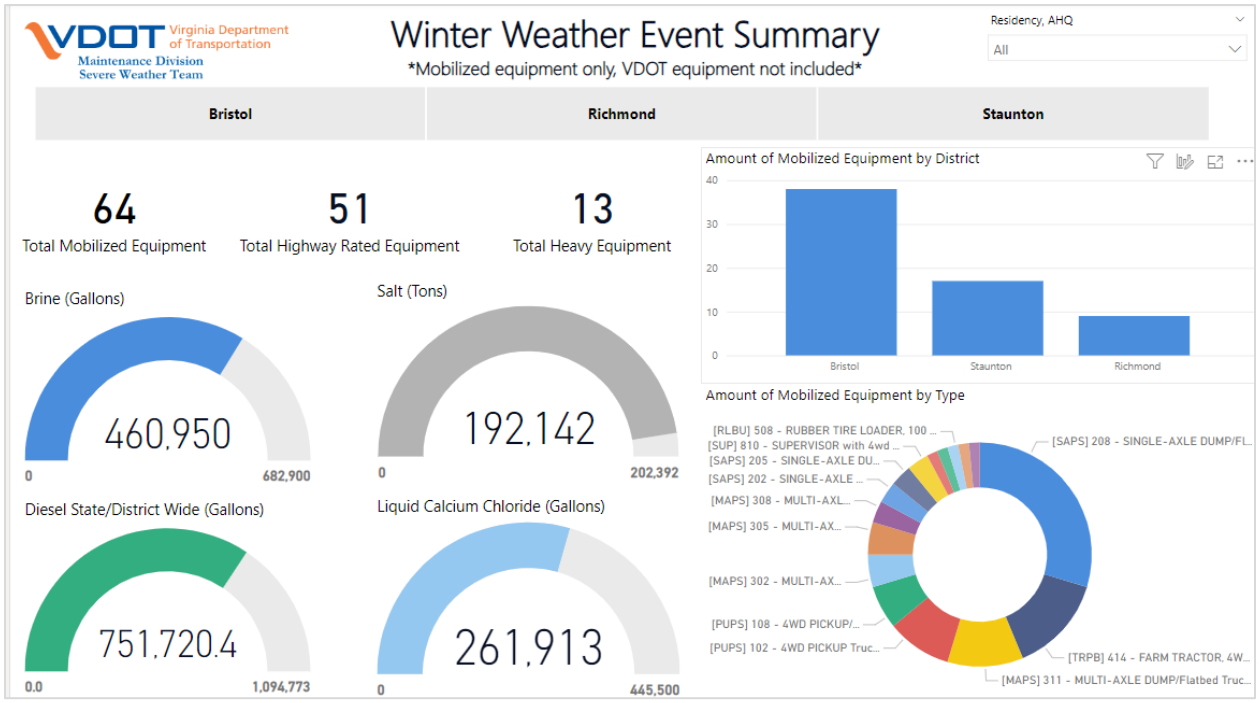


Figure 47. Winter Weather Event Dashboard (Virginia DOT)

Table 26. Winter Weather Event Dashboard Overview

Purpose	Provides weather event information as soon as someone accesses SWAS
Performance Measures	Equipment and material amount only for locations that are in an active event
Data Sources	Fuel system, SWAS
Refresh Rate	30 minutes
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

Data for the dashboard originates from multiple sources. Information on hired equipment vendors is collected through SWAS. VDOT equipment details are self-reported by individual districts. Area headquarters' personnel currently manually enter salt availability data, though it is linked to other materials and equipment at any selected location. Other crucial information, such as operational hours, is gathered through SWAS and integrated into a central data warehouse.

The dashboard updates automatically every 30 minutes, providing near real-time insights for authorized users. While it is a public-facing dashboard, primary usage falls on VDOT leadership during winter operations. PowerBI serves as the underlying platform for visualization and data presentation.

As shown in Table 26 the purpose of the Winter Weather Event Dashboard is to provide weather event information as soon as someone accesses SWAS. Focusing on key performance measures, the dashboard provides an overview of resources deployed during an event. This includes tracking the number of mobilized pieces of equipment, categorized by specific areas within the state. Additionally, it monitors

crucial supplies like salt, brine, and fuel, assisting in informed decision-making during critical response phases.

Data for the dashboard are gathered from various sources. Fuel level information is automatically updated daily from the designated fuel system. Similarly, real-time activity within SWAS feeds directly into the platform. Notably, the dashboard only populates with data once trucks are documented as mobilized within SWAS, ensuring a direct correlation between displayed information and ongoing operations.

Like the Winter Preparedness Dashboard, this platform refreshes every 30 minutes, maintaining near real-time insights for authorized users. Public access is available to anyone within the commonwealth, while VDOT leadership remains the primary user base during active events. PowerBI serves as the platform for data visualization and presentation.

By providing a centralized hub for monitoring VINs, resources, and supplies, the winter weather event dashboard empowers VDOT leadership to make informed decisions throughout response efforts. While limited to active events triggered in SWAS, this platform remains a valuable tool for ensuring efficient resource allocation and effective management during critical winter weather situations.

4.6.4 Full Inventory Dashboard

The Full Inventory Dashboard is utilized to break down and summarize fuel data. Fuel management plays a crucial role in VDOT's operations. This dashboard allows VDOT for gaining insights into fuel usage and optimizing resource allocation. This platform offers a comprehensive breakdown of fuel data, providing valuable information for both leadership and the public. Figure 48 shows the fuel inventory dashboard displaying the amount of gasoline and diesel. Table 27 shows the purpose, performance metrics, data sources, refresh rate, users, and software information of the full inventory dashboard data.

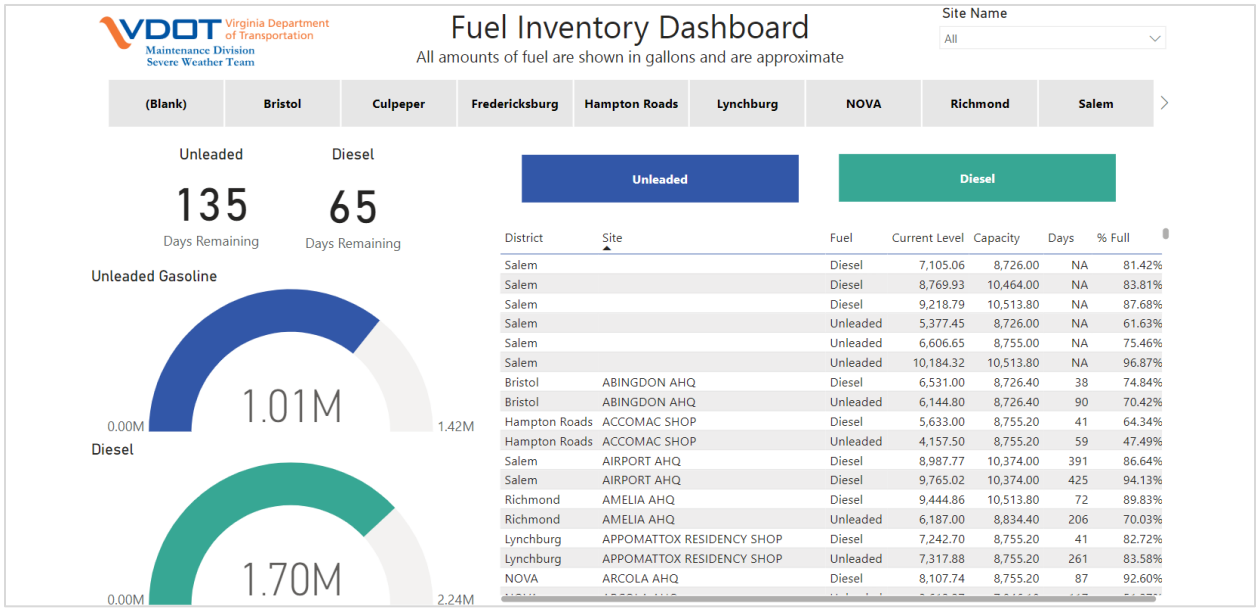


Figure 48. Full Inventory Dashboard (Virginia DOT)

Table 27. Full Inventory Dashboard Overview

Purpose	To breakdown and summarize fuel data
Performance Measures	Calculate an average burn rate using past data and organize it based on fuel type, districts, and amount of fuel.
Data Sources	Fuel System
Refresh Rate	Daily
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

The dashboard allows users to filter data down to specific sites, enabling a granular view of fuel consumption across VDOT's facilities. Its core functionality lies in calculating burn rates. Leveraging historical data, the dashboard calculates estimated fuel consumption based on fuel type, individual districts, and the state's total fuel inventory. This information helps identify potential inefficiencies and opportunities for improvement.

Data for the dashboard originates directly from VDOT's fuel system. However, it is important to note that the refresh rate is daily, meaning the displayed information reflects the previous day's data. While not real-time, this daily update offers a valuable snapshot of fuel usage trends.

Like the other dashboards discussed, public access is granted to anyone within the commonwealth, fostering transparency. However, primary usage falls on VDOT leadership, who leverage the insights to make informed decisions regarding fuel procurement, logistics, and resource allocation. PowerBI serves as the platform for data visualization and presentation.

4.6.5 Material Inventory Dashboard

The Material Inventory Dashboard was created for ensuring the efficient management of materials which is crucial for VDOT operations. To achieve this, VDOT utilizes a dedicated material inventory dashboard, offering insights into material usage and inventory levels across the state. Figure 49 shows the material inventory dashboard and Table 28 shows the purpose, performance measures, data sources, refresh rate, users, and software for the dashboard.

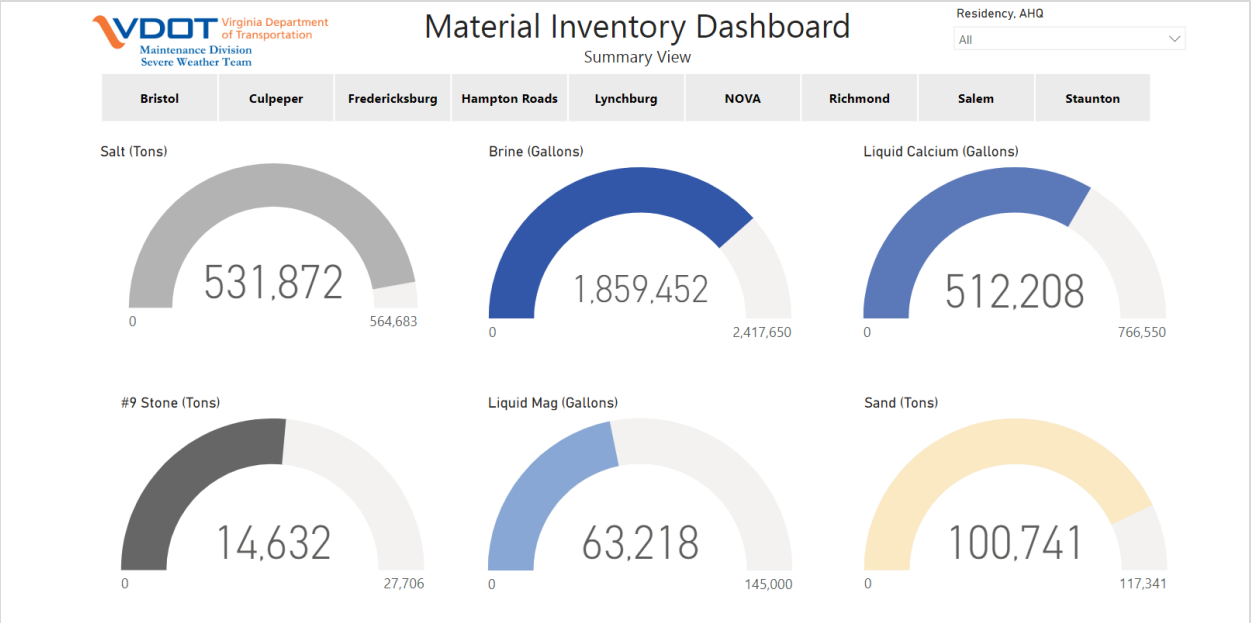


Figure 49. Material Inventory Dashboard (Virginia DOT)

Table 28. Material Inventory Dashboard Overview

Purpose	Material inventory data
Performance Measures	Material usage, availability, locations, and types
Data Sources	Field staff
Refresh Rate	Daily
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

As shown in Table 28, the purpose of the Material Inventory Dashboard is to display the material inventory of VDOT. The dashboard primarily caters to two goals: firstly, providing a breakdown of materials used, and secondly, comparing those figures with what is currently ordered and on hand. This comparison allows for proactive identification of potential shortages or surpluses, enabling informed decision-making regarding material procurement and allocation. The data for the dashboard is manually entered by field staff, ensuring timely updates. While the primary refresh rate is daily, more frequent updates can occur depending on individual garage practices. This approach offers a balance between timeliness and data accuracy.

Public access is available to anyone within the commonwealth, fostering transparency in VDOT's material management practices. However, primary usage falls on VDOT leadership, particularly local leaders and upper management. Garages directly input data, eliminating the need for them to rely on the dashboard itself. Notably, users can customize their view to tailor the information to their specific needs. Additionally, frequently used filters may be incorporated as default settings for all users, enhancing the overall user experience.

4.6.6 M7B Registration Dashboard

The M7B registration dashboard offers two core functionalities. It acts as a searchable vendor information hub, drawing data directly from VDOT's SWAS. This centralized platform also empowers users to streamline vendor management and troubleshoot any SWAS-related issues faced by vendors. Table 29 shows the purpose, performance measures, data sources, refresh rate, users, and software for the dashboard which is discussed later in the general dashboard overview section.

As shown in Table 29 the M7B registration dashboard is to switch off from manual reporting for vendor information and to have a vendor item search that would be based on vendor agreements. The dashboard tracks key performance measures associated with M7B contractor vehicle registration. It displays the number of active contracts and tracks the progress of contractor vehicles going through the equipment registration process. This information helps VDOT identify potential bottlenecks and inefficiencies, aiming to achieve optimal self-reporting of equipment by contractors.

Data for the dashboard is automatically refreshed every 30 minutes, providing near-real-time insights. While public access is available to anyone within the commonwealth, primary usage falls on VDOT leadership. PowerBI serves as the platform for data visualization and presentation.

Table 29. M7B Registration Dashboard

Purpose	To visualize and provide insight into the amount of M7B vendor and truck agreements by status and location.
Performance Measures	Number of vendors, amount of equipment, status of agreements
Data Sources	SWAS
Refresh Rate	30 minutes
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

4.6.7 Minimum Guaranteed Payment (MGP) Look-Up Dashboard

MGP Look-Up Dashboard is used to obtain a database to look at vendors' MGP to help decide who to call in for work. For some winter weather events, VDOT utilizes MGP agreements with contractors. These agreements ensure contractors receive a baseline payment even in low-snow seasons, while VDOT retains the flexibility to call upon their services when needed. To manage these agreements effectively, VDOT employs the MGP Look-Up Dashboard.

This dashboard serves two primary purposes. Firstly, it provides a detailed table summarizing data pulled from SWAS. This table offers VDOT insights into contractor activity, enabling informed decisions about who to call upon during specific events. For instance, if a contractor with a minimum payment has not yet fulfilled their work quota, VDOT may prioritize them over other vendors without such agreements.

Secondly, the dashboard acts as a tool for ensuring fair distribution of work and timely payments. With access to individual MGP details, financial personnel within each district can monitor progress towards minimum payments. This allows them to strategically distribute workload throughout the season and ensure all contractors receive their guaranteed payments promptly. Additionally, the dashboard provides end-of-season insights into outstanding payments, facilitating efficient financial management.

It is important to note that the data displayed on the MGP Look-Up Dashboard requires some manual interpretation and manipulation by VDOT staff. Additionally, the refresh rate is not automated, meaning updates occur as needed. Despite these limitations, the dashboard remains a valuable tool for VDOT to manage MGP agreements effectively, ensuring fair treatment of contractors and optimal resource allocation during winter weather events.

The dashboard is primarily used by VDOT's area headquarters and residencies, which leverage the information for decision-making throughout the winter season. PowerBI serves as the platform for data visualization and presentation.

Residency	Area HQ	Vendor	Truck Name	Plate Number	Min Payment Amount	Total Paid	Total Owed
Abingdon Residency	Abingdon AHQ	Arian Kestner	1999 GMC TopKick	39171UA	$7,800	$7,605	$19
Abingdon Residency	Abingdon AHQ	Jones Road & Bridge Inc	2006 CAT 12H	N/A	$8,000	$1,600	$6,40
Abingdon Residency	Abingdon AHQ	Mcvey Enterprise Services & Construction	1986 MACK 250	UB88840	$6,800	$2,775	$4,02
Abingdon Residency	North Bristol AHQ	Clark Services LLC	2004 Ford F550	UB89085	$6,000	$1,125	$4,87
Abingdon Residency	North Bristol AHQ	Clark Services LLC	2017 John Deere 5100E	N/A	$6,000	$1,575	$4,42
Bedford Residency	Bedford Residency Office	Bedford Mobile Home Movers Inc	1994 JOHN DEERE 6300	N A	$3,750	$562.5	$3,187.
Bedford Residency	Bedford Residency Office	Bedford Mobile Home Movers Inc	1996 FORD DUMPTRUCK	UB34322	$10,000	$500	$9,50
Bedford Residency	Bedford Residency Office	Bedford Mobile Home Movers Inc	1996 INTERNATIONAL DUMPTRUCK	UA60103	$10,000	$9,375	$62
Bedford Residency	Bedford Residency Office	Bedford Mobile Home Movers Inc	1997 KENWORTH DUMPTRUCK	UA60104	$10,000	$6,375	$3,62
Bedford Residency	Bedford Residency Office	Bedford Mobile Home Movers Inc	1999 CHAMPION MOTORGRADER	NA	$7,350	$0	$7,35
Bedford Residency	Bedford Residency Office	Bedford Mobile Home Movers Inc	2010 JOHN DEERE 6430	NA	$5,250	$2,012.5	$3,237.
Bedford Residency	Big Island AHQ	Bedford Mobile Home Movers Inc	2000 MACK DUMPTRUCK	UB34375	$10,000	$7,250	$2,75
Bedford Residency	Big Island AHQ	Peaks Forage and Livestock	1997 John Deere 7810	NA	$6,600	$2,310	$4,29
Bedford Residency	Big Island AHQ	Peaks Forage and Livestock	2002 John Deere 7210	NA	$5,550	$1,942.5	$3,607.
Bedford Residency	Big Island AHQ	William Sanderson	1996 Volvo Autocar	TX166001	$10,000	$0	$10,00
Bedford Residency	Big Island AHQ	William Sanderson III	1991 John Deere 3255	N/A	$5,250	$0	$5,25
Bedford Residency	Big Island AHQ	William Sanderson III	1995 International 4900	92-631	$8,600	$0	$8,60
Bedford Residency	Burnt Chimney AHQ	Chad Hodges	1989 Chevy 3500	TX265817	$9,600	$0	$9,60
Bedford Residency	Burnt Chimney AHQ	James Michael Meredith	2006 Mack CV700	UB75369	$10,000	$0	$10,00
Bedford Residency	Burnt Chimney AHQ	Jason Altice	1989 John Deere 4650	N/A	$6,150	$0	$6,15
Total							$5,290,686.2

Figure 50. MGP Look-Up Dashboard (Virginia DOT)

Table 30. MGP Look-Up Dashboard Overview

Purpose	Provide VDOT Insight into a vendor minimum guaranteed payment for financial planning purposes.
Performance Measures	Table of details from SWAS
Data Sources	SWAS and manual data
Refresh Rate	As needed
Users/Access	District/ Residency/ Area headquarters
Platform/Software	PowerBI

4.6.8 Equipment Verification Dashboard

The Equipment Verification Dashboard provides a database of equipment/vendor inspection details that was used to check the readiness of snow and ice removal equipment. This dashboard offers two core functionalities. Firstly, it acts as a searchable equipment verification hub, drawing data directly from VDOT's SWAS and equipment verification system. This centralized platform empowers users to streamline vendor management and troubleshoot any SWAS-related issues faced by vendors.

Secondly, the dashboard tracks key performance measures associated with M7B contractor vehicle registration. It displays the number of active contracts and tracks the progress of contractor vehicles going through the equipment verification process. This information helps VDOT identify potential bottlenecks and inefficiencies, aiming to achieve optimal self-reporting of equipment by contractors. As shown in Table 31 the equipment verification dashboard provides a database of equipment/vendor inspection details that was used to check the readiness of snow and ice removal equipment.

Data for the dashboard is automatically refreshed every 30 minutes, ensuring near-real-time insights. While public access is available to anyone within the commonwealth, primary usage falls on VDOT leadership. PowerBI serves as the platform for data visualization and presentation.

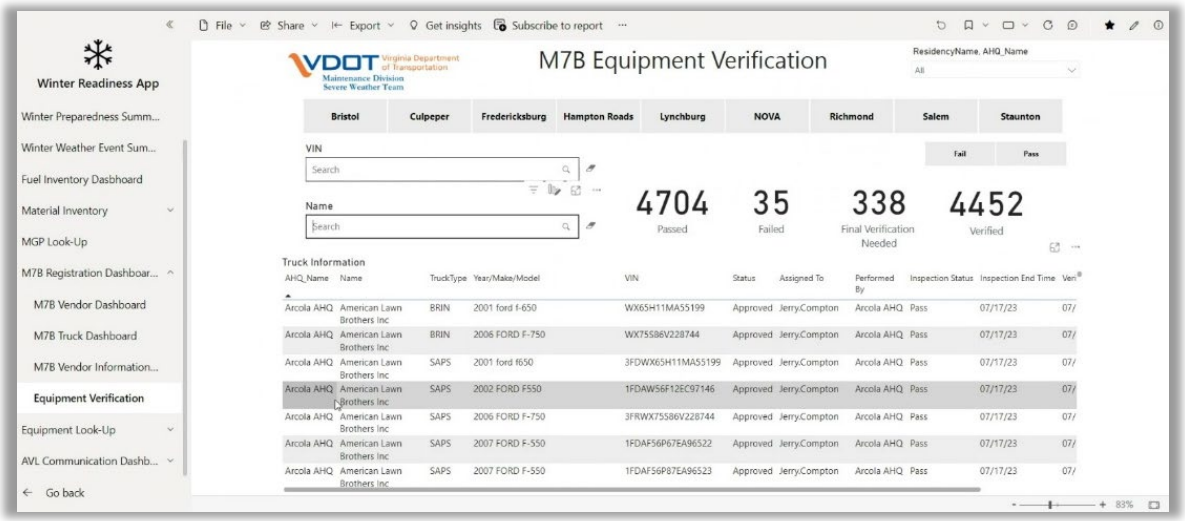


Figure 51. M7B Equipment Verification Dashboard (Virginia DOT)

Table 31. Equipment Verification Dashboard Overview

Purpose	Provides a database of equipment/vendor inspection details that was used to check the readiness of snow and ice removal equipment
Performance Measures	Pass/fail verification of inspection.
Data Sources	Inspection System – CAL AMP K-12 (SYNOVIA)
Refresh Rate	Once a day
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

4.6.9 Equipment Look-Up Dashboard

VDOT relies on a diverse network of vendors and equipment to tackle winter weather events. To ensure efficient management and coordination, VDOT utilizes the Equipment Look-Up Dashboard. This platform offers a comprehensive searchable database, empowering users to locate specific vendors and equipment with ease. Unlike other dashboards limited to M7B program vendors, the Equipment Look-Up Dashboard extends its reach to encompass all VDOT-contracted vendors. This comprehensive approach makes it a

valuable tool for verifying equipment details and streamlining communication across the entire winter operations network.

As shown in Table 32 the equipment look-up dashboard offers a comprehensive searchable database, empowering users to locate specific vendors and equipment with ease. The dashboard goes beyond listing vendors and equipment. It provides key performance measures related to each entry. This includes details regarding active agreements, Automatic Vehicle Location (AVL) orders, equipment installations, and the most recent communication ping from AVL systems. This information allows users to assess equipment readiness and identify potential issues promptly.

Data for the Equipment Look-Up Dashboard is gathered from multiple sources. SWAS provides vendor and agreement information, while the AVL order date system and AVL system itself contribute installation and communication data. With a refresh rate of 30 minutes, the dashboard offers near-real-time insights. While public access is granted to anyone within the commonwealth, primary users come from VDOT's district and residency levels, directly interacting with vendors on the ground. This ensures that those closest to operations have the information they need to make informed decisions and collaborate effectively. PowerBI serves as the underlying platform for data visualization and user interaction.

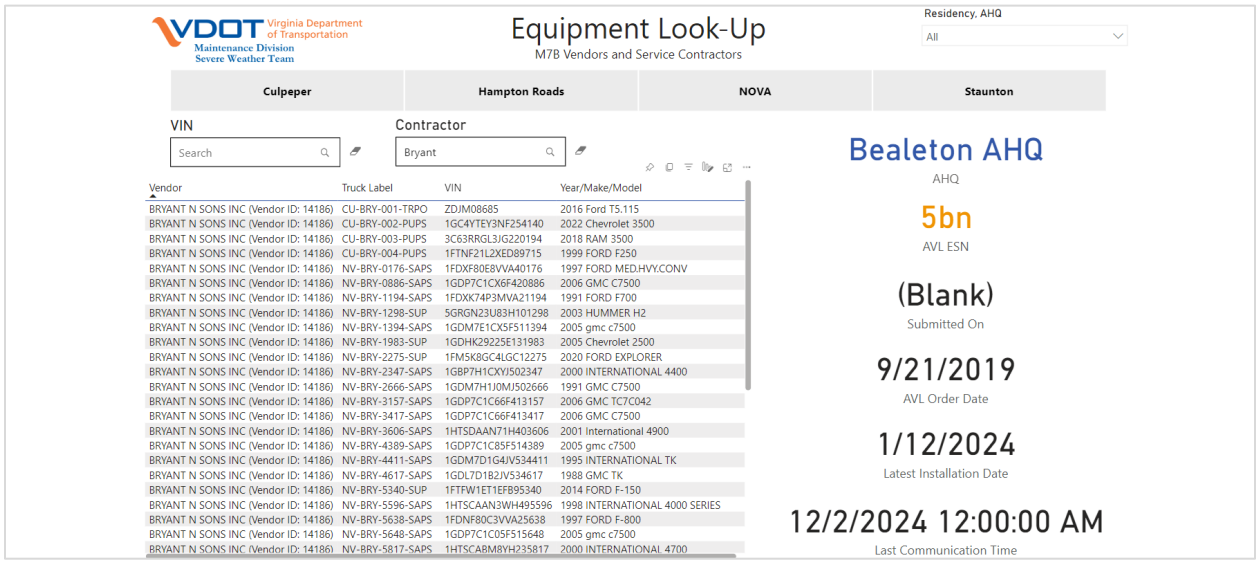


Figure 52. Equipment Look-Up Dashboard (Virginia DOT)

Table 32. Equipment Look-Up Dashboard Overview

Purpose	To allow users to search all vendors and equipment in the database.
Performance Measures	Agreement, Automatic Vehicle Location (AVL) orders, installation, AVL communications last ping
Data Sources	SWAS and AVL
Refresh Rate	Thirty minutes
Users/Access	Anyone in the commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

4.6.10 Emergency Management Center Dashboard

The Emergency Management Center Dashboard is a specialized tool that focuses on emergency management, as shown in Figure 53. Table 33 provides a general overview of the dashboard. The dashboard's primary purpose is to provide comprehensive weather information. This includes data on various weather conditions, with a particular emphasis on snow and radar data. The dashboard's performance is evaluated based on the accuracy and timeliness of these data.

Data used by the dashboard are collected from a variety of sources. These include Data Transmission Network and Dataline (DTN), local storm reports, radar, the National Weather Service (NWS), AVL systems, Waze, and other spatial details such as park and ride locations. This diverse range of data sources allows the center to make informed decisions during emergencies.

One of the key features of the center is its real-time data refresh rate. This ensures that the most current information is always available, which is crucial during emergency situations. The platform is designed to be shared with state partners and districts. It has a flexible permission system that allows for various views on the hub, depending on the access level granted. The center operates on the ArcGIS Online (AGOL) software platform.

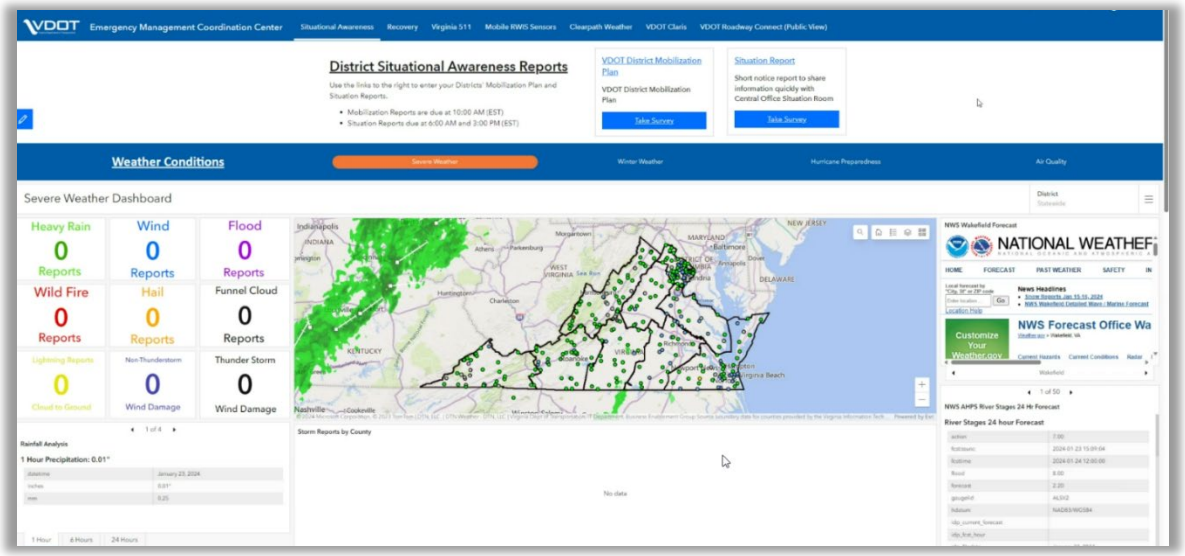


Figure 53. Emergency Management Center Dashboard (Virginia DOT)

Table 33. Emergency Management Center Dashboard Overview

Purpose	Provides all weather information
Performance Measures	Snow and radar
Data Sources	Data Transmission Network (DTN) data, local storm reports, radar, National Weather Service (NWS), AVL, Waze, and other spatial details
Refresh Rate	Real-time
Users/Access	State partners and districts
Platform/Software	ArcGIS Online (AGOL)

4.6.11 Damage Assessments Dashboard

The Damage Assessments Dashboard tracks, manages, and adds value to damages in order to determine if the Federal Emergency Management Agency (FEMA) or FHWA are needed. This dashboard tracks the review/status of the damage reports. VDOT faces the crucial task of assessing damage and initiating repairs efficiently. VDOT utilizes this dedicated Damage Assessments Dashboard powered by AGOL to streamline this process and ensure timely recovery. This dashboard serves several key purposes. Firstly, it provides a centralized platform for tracking and managing all reported damages, offering a comprehensive overview of the situation. This allows VDOT to prioritize repairs based on severity and resource availability. Secondly, the dashboard facilitates the process of adding value to damage assessments. By integrating with relevant systems and procedures, the dashboard can help determine eligibility for federal assistance from FEMA or FHWA, streamlining financial recovery efforts. Thirdly, the dashboard allows VDOT to track the review and approval status of individual damage reports. Figure 54 presents an image of the dashboard, and Table 34 provides additional details.

Performance measures displayed on the dashboard include the status of each damage report, associated images for visual verification, and estimated repair costs. This information empowers VDOT leadership to make informed decisions regarding resource allocation and prioritize critical repairs. Data for the dashboard originates from Survey123, a mobile data collection app utilized by VDOT field crews. This app streamlines the data collection process, capturing information directly at the damage site and feeding it into the dashboard in real-time. This eliminates manual data entry and significantly reduces processing time. Prior to implementing Survey123 and the AGOL dashboard, damage assessments were a manual and time-consuming process, often taking weeks to complete. The digitalized approach has updated VDOT's response, saving weeks of time and enabling a more efficient and data-driven recovery process.

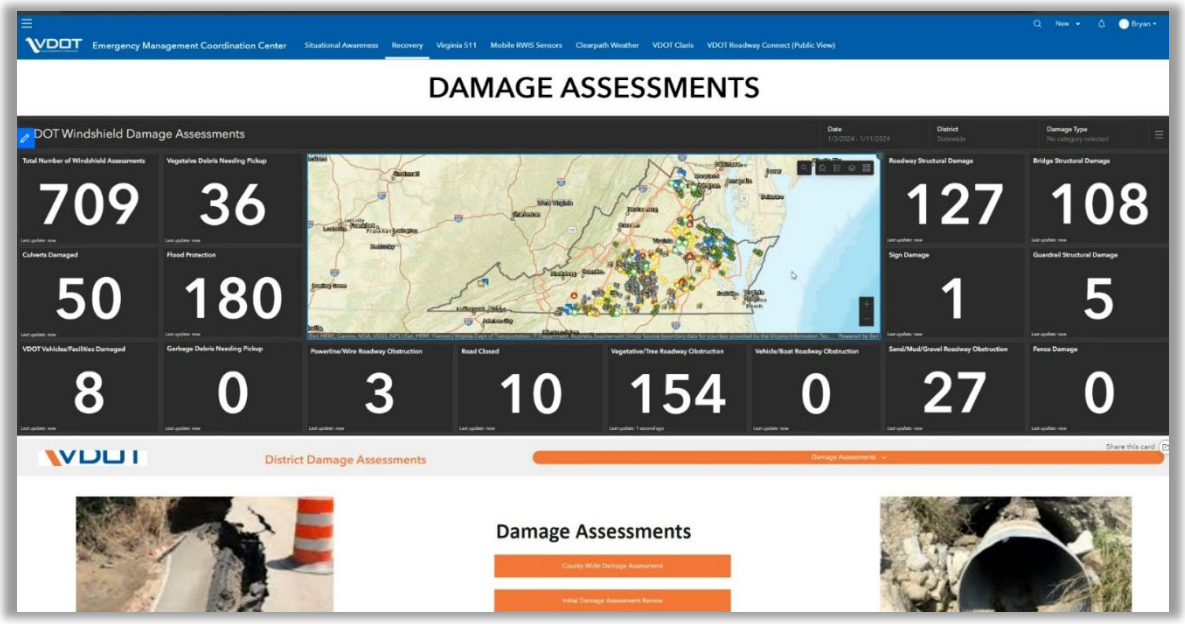


Figure 54. Damage Assessments Dashboard (Virginia DOT)

Table 34. Damage Assessments Dashboard Overview

Purpose	Track, manage, and add value to damages and determine if FEMA or FHWA are needed. This dashboard will also track the review/status of the damage reports.
Performance Measures	Status of reports, images of damage, cost of damage
Data Sources	Survey 123 from field crews
Refresh Rate	Real-time
Users/Access	State districts
Platform/Software	AGOL

4.6.12 Development of Dashboards

The decision for the development of winter operations related dashboards for VDOT is based on whether there is a manual process that can be automated to save time. By having dashboards that automate work, resource sharing has become easier. With the data platforms VDOT has available, they can make as many dashboards as they need. The more people utilizing the dashboards will lead to more enhancements.

A team of Emergency Operations and Management Specialists mostly developed these dashboards. The extract, transform, and load process for the dashboard involved using Power Automate tools, and all data was stored in the cloud and exported and shared from ESRI. The accuracy of the data is usually verified by the provider. When data have errors, it is easily catchable as the team is very familiar with what "normal data" looks like. Most of the data is stored in an IT data warehouse; however, a large-scale data system for PowerBI is in the works. Some of the team uses ESRI cloud storage. Data can be queried as far back as 2019 from ESRI's cloud storage; however, PowerBI cannot go back and view older data since there are so many changes made to historical data.

Some issues that were encountered in the development of these dashboards include issues with internal connections to PowerBI and collaborating with vendors. Since VDOT manages so many contractors that all have difference processes for managing data. No specific issues with ESRI occurred since there were plenty of online resources.

4.6.13 System Operations and Maintenance

The hosting of the dashboards and data update responsibility varies depending on the dashboard. The same team that developed the dashboards, which is the team of Emergency Operations and Management Specialists, is also responsible for their maintenance if there are any issues or enhancements that need to be made. The databases for these dashboards are maintained by ESRI and an Emergency Operations Specialist, and IT maintains the data warehouse for PowerBI. The costs to maintain these dashboards and resources are associated with the personnel who use and maintain them. VDOT has 700 ESRI licenses with cloud services and weather vendors.

4.6.14 Benefits and Lessons Learned

Benefits gained from having these dashboards include having a faster response time thus shorter recovery time, automating workflow, dealing with fewer emails, standardizing processes, resource allocation, and

managing vendors. Lessons learned from creating these dashboards were that going to ESRI conferences helped gain a deeper understanding because the team was able to meet other users and gain in-person assistance. VDOT also noted that ideals for new dashboards can be inspired by speaking to other DOTs. Also, while VDOT has a lot of people skilled in software, better and more effective communication among them can further improve the efficiency and reduce the risk of duplicating efforts.

4.6.15 Plans for the Future and Potential Enhancements

Some future enhancements include: adding 511 data involving road closures during the winter into the emergency response dashboards; and using ArcGIS Velocity for early weather warnings as well as big data analytics with damage assessments and insight for analytics. For dashboards on PowerBI platform, the team would like to explore the possibility of using historical data. A new data miner is also in the works to potentially be implemented for situational awareness around security.

4.6.16 Key Point

- VDOT started dashboarding to streamline the process of exporting data for vendor and truck agreements for statewide snow removal, since 90% of their roadways are maintained by private contractors, but VDOT manages all these operations from private contractors.
- VDOT has ten different dashboards set up for this purpose. Some of the benefits gained from having these dashboards include having a faster response time, automating workflow, dealing with fewer emails, standardizing processes, resource allocation, and managing vendors.
- The data provided to their dashboards originates from multiple sources. Depending on the dashboards, data refresh frequencies range from real-time, thirty minutes, to daily.
- The majority of the dashboards are created using PowerBI. They are interoperable with many tools and systems that VDOT uses internally, such as power automate with reporting tools and emails. This provides VDOT with the ability to streamline the data sharing and integration for one giant situational awareness problem.
- VDOT has many contracted services and data schema that can be a hindrance sometimes for winter maintenance operations and management. Having dashboards interoperable across an agency helps reduce some of the issues. VDOT recommends other DOTs to consider interoperability for their dashboard development.
- The databases for these dashboards are maintained by ESRI and an Emergency Operations Specialist, and IT maintains the data warehouse for PowerBI.
- Some future enhancements include adding 511 data involving road closures during the winter into the emergency response dashboards.

5. Best Practices and Recommendation

The following are some of the best practices and recommendation from this project:

- Best advice for developing a dashboard is to have a complete understanding of the data being used and to know the audience that is going to be using the dashboard.

- The salt prediction is calculating and comparing anticipated versus actual salt usage rates. This helps facilitate conversations between garage managers on ways to help keep salt usage on target.
- A challenge that agencies may have to be overcome when developing the dashboards is the cost it takes to develop the first dashboard. However, the benefits of having dashboards for winter operation far outweighed the costs of developing, implementing and maintaining them.
- All of KYT platforms are hosted for viewing on either Looker Sudio or Google Cloud. This is key for scaling up for more users during weather events. It is setup similar to TV streamers to prevent buffering issues.This is a model that other agencies should consider when developing dashboards.
- When switching data vendors, it's important to recognize that the data previously being used in dashboards may be affected which can lead to different outputs on the dashboards. Before switching vendors, its best to always have a plan for testing and updating dashboards after the switch.
- A lesson that the KYTC learned from developing the winter dashboards was that due to the nature and unpredictability of the winter season, AVL data can be inaccurate.
- Utilizing a partner, such as a university, that has a long history of collaboration with the agency for the development of dashboard helps minimize the needs for internal resources.
- NDDOT has learned that implementing winter maintenance dashboards has allowed the agency to utilize data to enhance the LOS of intersections that are being analyzed.
- By using dashboards to track material usage, speed, and other metrics, the DOT can allocate resources more effectively and offer training insights for winter operations.
- Dashboards that refreshing in real-time and providing up-to-date information for users are particularly useful for communication, allowing the public and leadership to stay informed about ongoing operations.
- Dashboards can help manage private contracts. VDOT uses dashboarding to streamline the process of exporting data for vendor and truck agreements for statewide snow removal, since 90% of their roadways are maintained by private contractors.
- Dashboards can help with decision-making from planning, executing, and reviewing winter operations.

Appendix A – Survey Responses

Available separately; contact the Clear Roads administrative contact (see https://clearroads.org/contact-us/) for access.

Appendix B – Case Study Interview Summary: Iowa DOT

Overview

Virtual interviews were conducted by Ming-Shiun Lee, Mallory Crow, and Allison Balogh of AECOM and coordinated with the assistance of Tina Greenfield Huitt and Craig Bargfrede with the Iowa Department of Transportation (Iowa DOT) on Monday November 27th, 2023, at 9 AM CST.

Iowa DOT Staff Interviews

Meeting attendees on Monday, November 27th included the following individuals:

- Tina Greenfield Huitt
- Craig Bargfrede

Introduction

The Iowa DOT began using dashboards to visualize winter maintenance operation data around the Fiscal Year (FY) 2012. The driving force to start using dashboards was to monitor and track salt usage. It started with an Excel workbook dashboard. By FY 2013, Iowa DOT moved from the Excel workbook to Dundas BI for more enterprise-level business intelligence and to further automate the Excel workbook. The users started with a few offices and IT, but then continued to grow into other bureaus and districts. All dashboards are for after-action analyses.

Salt Dashboard

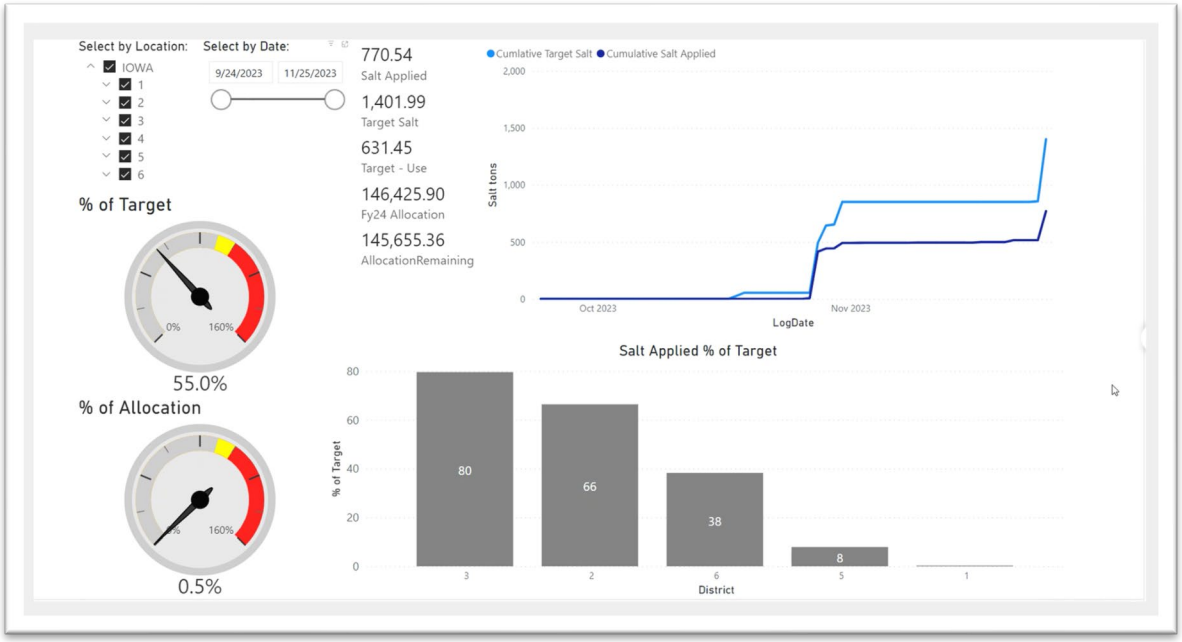
Salt Dashboard Overview

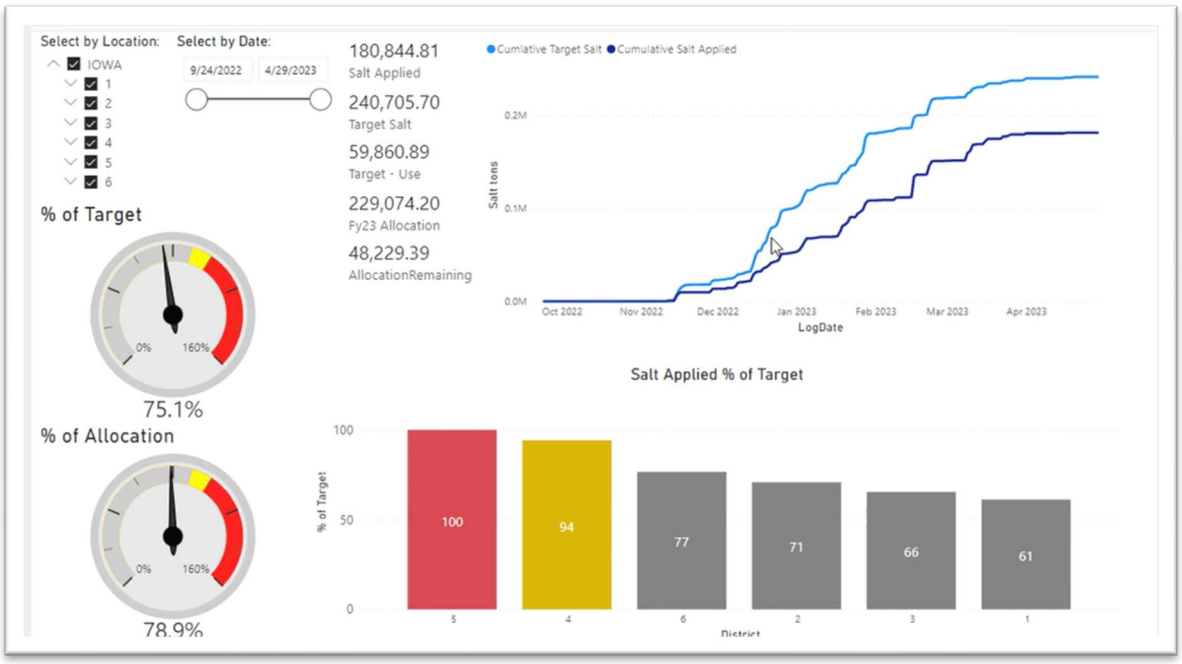
Purpose	Track and monitor salt usage.
Performance Measures	Calculates an anticipated salt usage rate (predictive analytics) and then compares anticipated usage versus actual usage.
Data Sources	Field staff report salt usage manually. Garage managers and field staff then review salt usage gathered by the AVL and adjust as needed. Field staff report weather information manually as well. Weather data was gathered from RWIS. Weather is important since it is used to calculate target ideal salt usage. The salt target uses miles for garage responsibility routes (not miles driven), Level of Service (LOS) priority, and weather. Data are entered and pulled from Iowa DOT's Maintenance Management System (MMS), RMS.
Refresh Rate	Daily refresh
Users/Access	Garage supervisor, district managers, and field division manager utilize the dashboard. Data Management Analyst and Winter Operations Administrator use to assist with administration even though their roles are not included in Field Operations. Data Management Analyst and the Winter Operations Administrator use to review budget and monitor salt requests. Garages and district supervisors review for managing their resources. The Winter Operations Administrator procures the salt, so they use the dashboard to guide procurement needs.
Platform/Software	Microsoft PowerBI

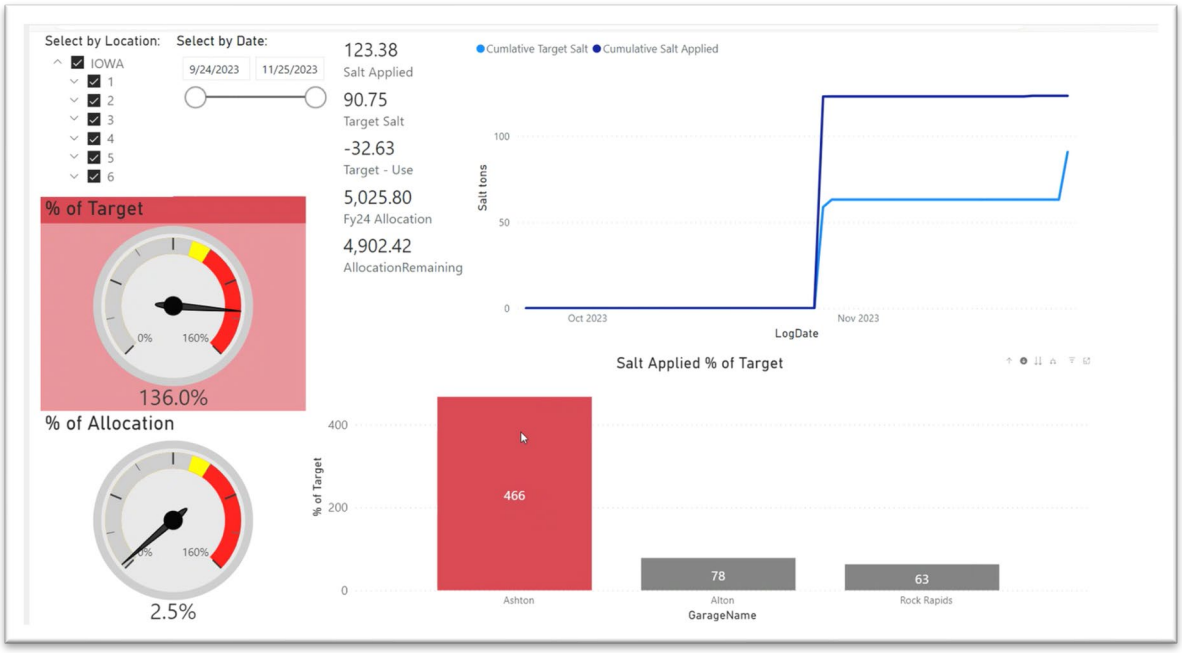
It was noted that the prediction helps but is not always prefect. Fortunately, Iowa DOT has been using the Salt Dashboard for 11 years and the garage managers are used to the model. These insights facilitate conversations between managers on best practices to hit target salt usage. The dashboard is a tool to help education and start conversations with maintenance staff, which helps alleviate concerns regarding staff turnover, particularly at the supervisor level.

Iowa DOT is currently working on a storm or daily weather index instead of a monthly/seasonal index. Current mobility data is not added to prediction/targeted salt usage. Iowa DOT attempted to integrate speed but fell apart because of inaccurate speed data (note that was 10 years ago, so data might be better now). Iowa DOT is currently not using any road surface friction sensor data within their storm index calculations or within their dashboard.

Future enhancements are to explore filling data gaps with crowdsource data. Also, Iowa DOT has already calculated time to bare pavement but has not integrated into the dashboard yet.





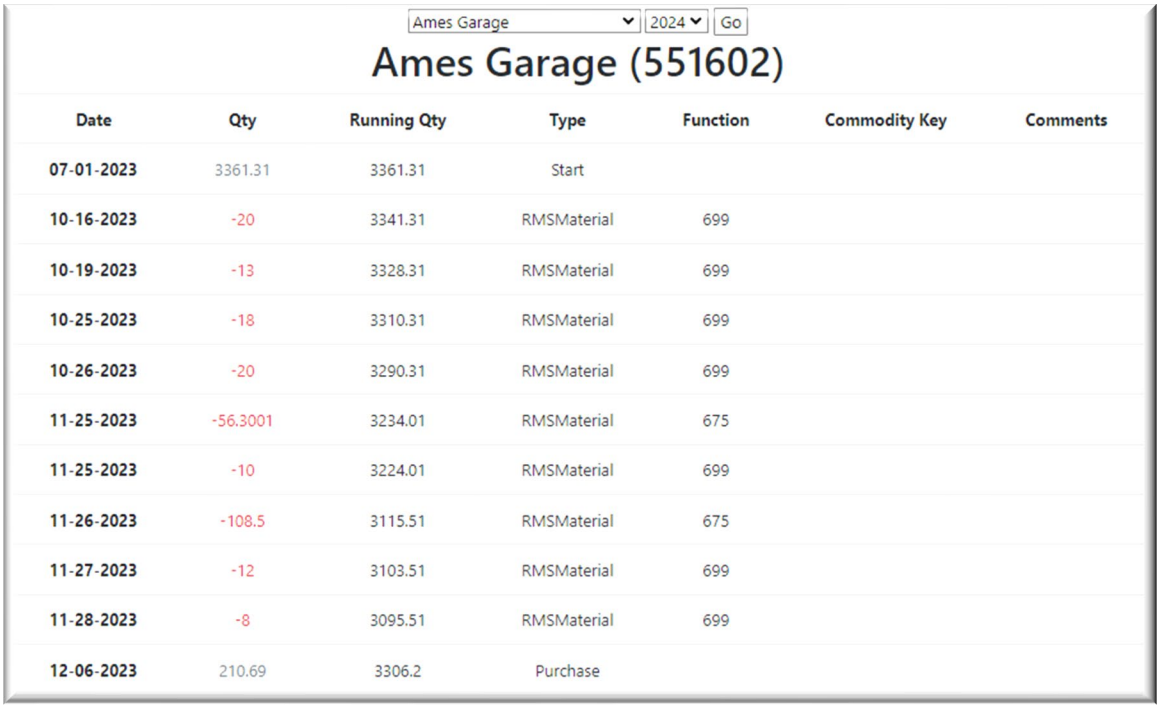


Salt Ledger Dashboard

Salt Ledger Dashboard Overview

Purpose	Keeps a running total of salt on hand by garage and salt usages. Opportunities to manage in a more real-time, better tracking. Helps with tracking when making brine. Not used for ordering future salt.

Performance Measures	Shows daily usage as reported in the garage daily logs, plus it shows when they receive salt and when they sell or transfer salt.
Data Sources	Field staff report salt usage manually and review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Data are added and pulled from Iowa DOT's MMS, RMS.
Refresh Rate	Daily refresh
Users/Access	Garage/district managers use to actively manage resources
Platform/Software	Microsoft PowerBI



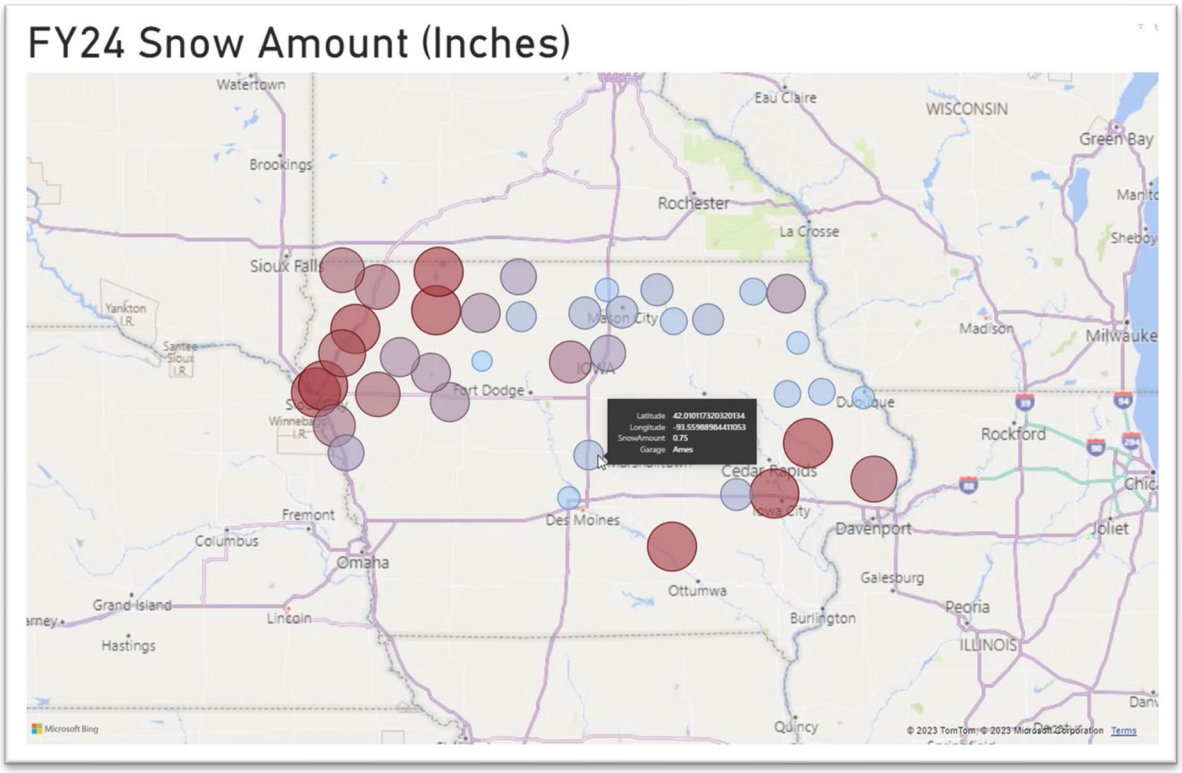
Date	Qty	Running Qty	Type	Function	Commodity Key	Comments
07-01-2023	3361.31	3361.31	Start			
10-16-2023	-20	3341.31	RMSMaterial	699		
10-19-2023	-13	3328.31	RMSMaterial	699		
10-25-2023	-18	3310.31	RMSMaterial	699		
10-26-2023	-20	3290.31	RMSMaterial	699		
11-25-2023	-56.3001	3234.01	RMSMaterial	675		
11-25-2023	-10	3224.01	RMSMaterial	699		
11-26-2023	-108.5	3115.51	RMSMaterial	675		
11-27-2023	-12	3103.51	RMSMaterial	699		
11-28-2023	-8	3095.51	RMSMaterial	699		
12-06-2023	210.69	3306.2	Purchase			

Material Usage and Storm Reporting Dashboard

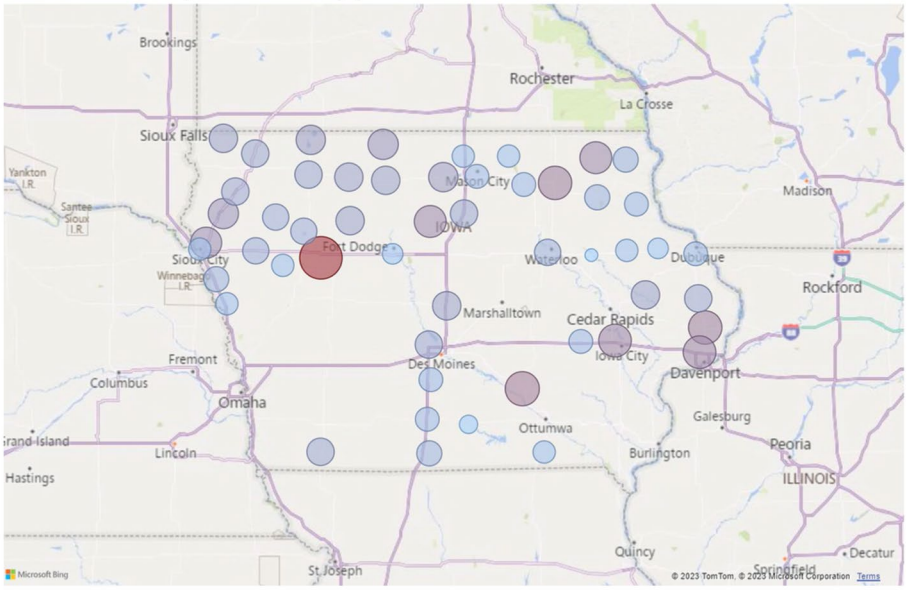
Material Usage and Storm Reporting Dashboard Overview

Purpose	Like the first dashboard but focuses on weather variables used in dashboard #1 as reported by garages on daily logs. Helps garages see what data were logged. Garage managers can use to self-regulate and make sure the data are as accurate as possible. Internal only, allows for full picture and used at district post-season meetings for discussion on what was reported
Performance Measures	This dashboard shows all material usage by garage for the current season plus it displays weather data as reported by the garage field staff through their daily logs. No analytics. Summarizes inputs for dashboard #1. Can see where storms were more active based on daily logs.

Data Sources	Field staff reports salt usage manually and will review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Field staff report weather information manually as well. Can use RWIS sites as a comparison to field reports, and central office can check for any outliers in the data based on RWIS data. Data are added and pulled from Iowa DOT's MMS, RMS.
Refresh Rate	Daily refresh
Users/Access	Internal, garage managers and field staff
Platform/Software	Microsoft PowerBI



FY24 Precipitation Type Hours



Precip Type

- Blowing Snow
- Bridge Frost
- Mixed Precip
- Refreeze
- Road Frost
- Sleet
- Snow

PrecipFY

2024

Total Hours	Precip Type	Garage
19	12	Allison
17	12	Atlantic
8	12	Clarion
64	12	Council Bluffs North
96	12	Council Bluffs South
304	12	Desoto
1	12	Dewitt
693	12	Dubuque
3	12	Greenfield
7	12	Grundy Center
0	12	Latimer
753	12	Maquoketa
275	12	Perry
3	12	Sioux City-Hamilton
6	12	Waverly
7	Blowing Snow	Decorah
5	Blowing Snow	New Hampton
1	Blowing Snow	Sac City
8	Blowing Snow	Waukon
11	Bridge Frost	Bloomfield
5	Bridge Frost	Cedar Rapids
3	Bridge Frost	Clarinda
2	Bridge Frost	Donnellson
5	Bridge Frost	Dubuque
2	Bridge Frost	Dyersville
3	Bridge Frost	Emmetsburg
2	Bridge Frost	Manchester
3	Bridge Frost	Maquoketa
3667		

Material Use Totals (Functions 675, 682)

DistrictID	SALT BRINE	SALT ROCK	SAND
1	45		
2	21,066	74	4
3	56,062	319	
4	1,714		
5	1,967		
6	3,071	10	
Total	**83,925**	**402**	**4**

Chart defaults to FY24, all garages, year to date. You can edit these variables using the controls below.

Garage Name: All

Fiscal Year: 2024

Date Range Selector (Be Sure to Match With FY Controller): 10/22/2013 11/9/2023

Material Use Totals (Functions 675, 682)

DistrictID	LIQUID CALCIUM CHLORIDE	SALT BRINE	SALT COMPOSITE 50/50 SALT/ SAND	SALT ROCK	SAND
1	4,778	6,462,913	1,133	21,843	397
2		4,287,764	1,367	23,386	7,601
3		4,445,462	4,405	18,203	2,127
4	200	5,166,365	312	19,275	461
5	10,577	4,871,524	1,482	14,711	835
6		6,454,703	1,546	31,831	875
Total	**15,555**	**31,688,732**	**10,245**	**129,248**	**12,296**

Chart defaults to FY24, all garages, year to date. You can edit these variables using the controls below.

Garage Name: All

Fiscal Year: 2023

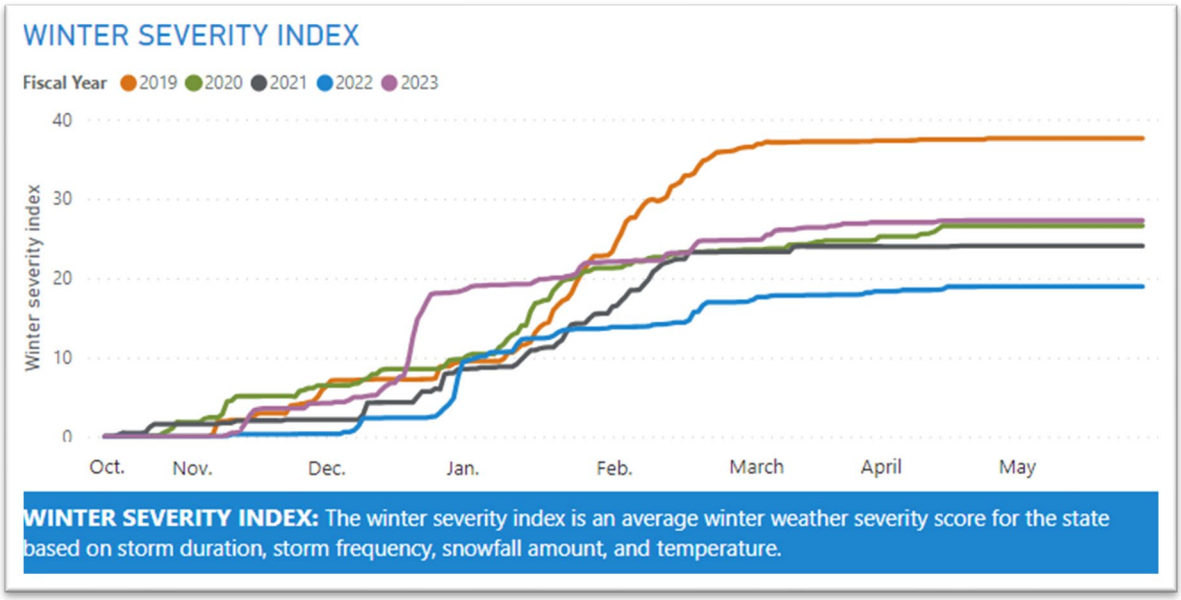
Date Range Selector (Be Sure to Match With FY Controller): 10/22/2013 11/9/2023

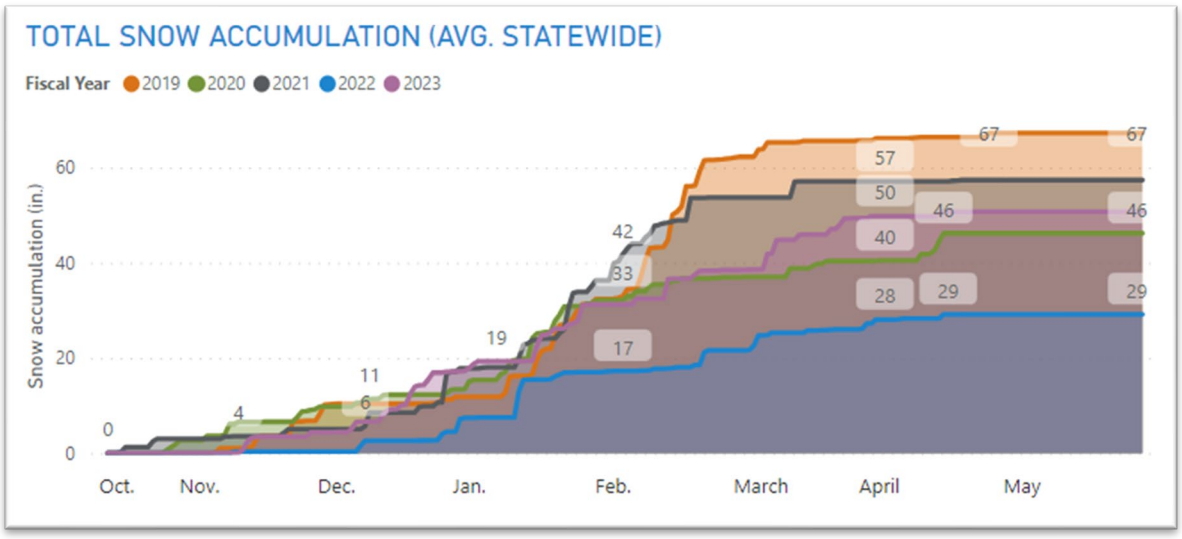
Public Dashboard - Salt Usage Chart, Salt Accumulation, & Weather Severity Index

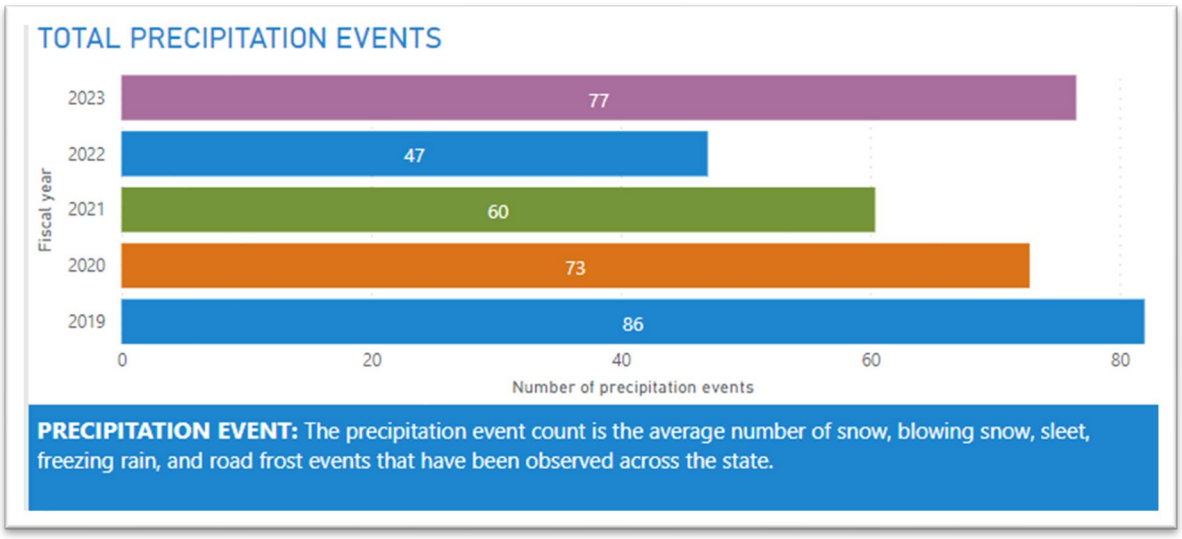
https://iowadot.gov/performance/winter-operations

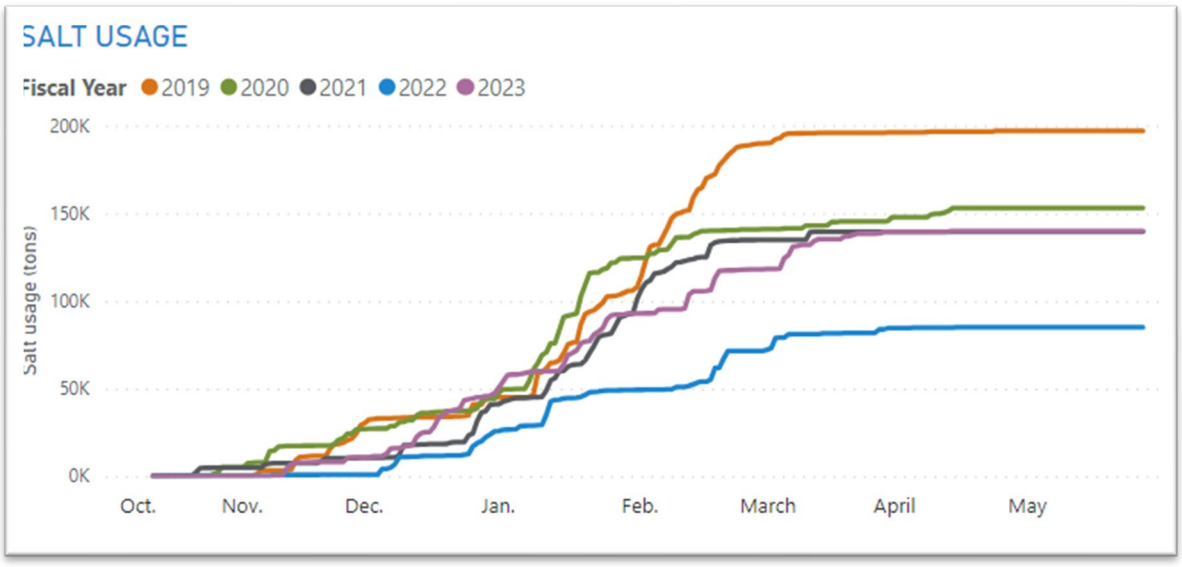
Public Dashboard Overview

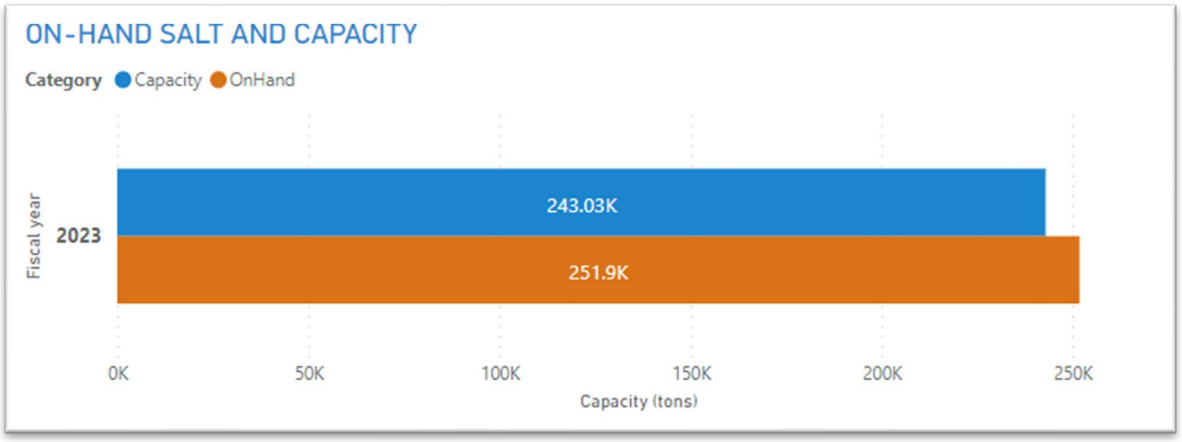
Purpose	To present the public with Iowa DOT's performance. Helpful for discussions with management and legislators, especially mid-season when projections show that more salt is needed.
Performance Measures	Weather severity index, total snow accumulation, precipitation events, salt usage, and valuable salt and capacity. Year to year comparisons for all but the on-hand salt and capacity. Statewide review.
Data Sources	Field staff reports salt usage manually and will review their AVL data to report salt usage. Garage managers and field staff can edit if salt usage gathered by the AVL seems incorrect. Field staff report weather information manually as well. Data are added and pulled from Iowa DOT's MMS, RMS.
Refresh Rate	Daily refresh
Users/Access	Public
Platform/Software	Microsoft PowerBI Widgets




TOTAL SNOW ACCUMULATION (AVG. STATEWIDE)
Fiscal Year 2019 2020 2021 2022 2023
Snow accumulation (in.)
60
40
20
0
Oct.
Nov.
Dec.
Jan.
Feb.
March
April
May
0
4
11
6
19
17
42
33
67
57
67
50
46
46
40
28
29
29


TOTAL PRECIPITATION EVENTS
Fiscal year
2023
2022
2021
2020
2019
77
47
60
73
86
0
20
40
60
80
Number of precipitation events
PRECIPITATION EVENT: The precipitation event count is the average number of snow, blowing snow, sleet, freezing rain, and road frost events that have been observed across the state.





Salt Budget Dashboard

Salt Budget Dashboard Overview

Purpose	This dashboard is used to track the status of our $15 million salt budget. Salt budget is heavily monitored for potential to use in other places. This helps manage expectations for what is "available" in this line item. The average amount of salt is used to set the upcoming salt contract amounts, so this dashboard helps with understanding these historical averages. Used for end of season re-fill to help use up budget and get this done in winter season.
Performance Measures	Cost broken down to garage level. Track orders, paid, delivered, administration fees, along with an estimated range to get to the end of the winter season (based on a 5-year average). Provides previous average, minimum, and maximum costs.

Data Sources	Salt data usage is added and pulled from Iowa DOT's MMS, RMS. RMS has data on shed salt capacity. Includes all materials.
Refresh Rate	Daily refresh
Users/Access	Winter Operations Administrator; Internal and administrative users only
Platform/Software	Microsoft PowerBI

Note that there is a winter operations budget dashboard for all areas in winter operations, like snow fence, office, third party weather data, AVL, equipment, temp-advertising, office winter administration, etc. They do not track labor and fuel at this level.

Development of Dashboards

The Winter Operations Administrator along with the Data Management Analyst are the main people to drive the development of new dashboards. Dashboards typically developed based on requests from other management, field operations, and/or public requesting the same data insights; leading the development of a dashboard to manage these requests. Rare for any field personnel to specifically request a dashboard but might wish to review data in an easy manner, which leads to a dashboard. During development, the team may reach out to end users for feedback and share draft dashboards. If the dashboard is for garage management, they will include all district managers in this feedback. When necessary, a steering committee may be implemented during the design phase but not very often.

The lead developers of these dashboards are the Winter Operations Administrator and the Data Management Analyst. Once developed, IT maintains the dashboard. IT will assist with the cleaning processes for the data loaded into the dashboard. All data are stored in a Structured Query Language (SQL) database and many of the analytics are done within the SQL database, not in the dashboard platform.

The data source for these dashboards is the MMS, RMS, which is a legal log. No formal process is required to verify accuracy. The dashboard does allow for field personnel to review data quickly and determine if there was a data entry error in RMS, which can then be mitigated. The data within the dashboards are developed to present the previous five years or just the current seasonal year.

Challenges during development involved limitations arising from calculations and data constraints, leading to ongoing refinements as user interaction increased. Technical issues led to the exclusion of a speed dashboard due to data processing challenges, and RWIS sensor unreliability prevented its inclusion in analyses.

The best advice for developing a dashboard is to have a complete understanding of the data being used and to know the audience that is going to be using the dashboard.

System Operations and Maintenance

The hosting of these dashboards for viewing occurs through three distinct methods:

- Publicly accessible sites on the website
- Technically public but not openly shared
- Those requiring a PowerBI pro license for viewing, allocated to a small group.

While technically publicly accessible, the material usage and weather dashboards are not advertised but can be accessed via DOT email links. This removes the need for password access to dashboards that are shared with partner agencies.

The Data Management Analyst maintains the frontend of the dashboards and IT maintains the database side of the dashboards. Data updates are varied, with the RMS updated manually while the dashboards refresh automatically.

The costs and resources involved in the development, implementation, maintenance, and enhancement of these dashboards are not meticulously tracked, but minimal efforts are needed for ongoing maintenance, especially for updates in new seasons. The costs primarily lie in the development phase, with ongoing maintenance and storage costs being comparatively lower and less rigorously tracked.

The initial development involves more significant efforts, requiring collaboration with IT and users, prioritizing these operations over others due to their significance. The Winter Operations Administrator and the Data Management Analyst focus on refining analytic methodologies within SQL, aligning with policies and guidelines such as salt prediction, and any policy changes prompt collaboration between Data Management Analyst and IT to recalibrate calculations within SQL.

Benefits / Lessons Learned

The winter dashboards are beneficial resources that enable everyone from the management to the garage level to understand and measure how resources are being used during winter maintenance operations. The dashboards also create a form of healthy competition between garages as they can compare, but also work together to meet target resource usage.

One lesson learned from the development of these winter dashboards was that it is best to keep them simple and easy to understand for users. The data should start out small and grow over time. The staff should not be forced to use it and the data should be presented as it is to start. Difficulties that had to be overcome when developing the dashboards included the cost it would take to develop the first dashboard. However, with the pressure to save money on salt expenses, the benefits far outweighed the costs.

Future / Enhancements

Iowa DOT is currently developing a tool for comparing individual storms as projected and what occurred. At this time there are no other plans for future dashboard enhancements besides the possibility of adding more dashboards based on future questions or needs.

Potential dashboards that would be useful for development include a speed-based data dashboard, a dashboard using friction sensors, using weather information to compute road conditions, and image analysis using dashcam data.

Overall, there are numerous ideas for potential dashboards in the future, but it is difficult to see the benefits of them if the use cases are not fully understood and outweigh the cost of development.

Appendix C – Case Study Interview Summary: Kentucky Transportation Cabinet

Overview

Virtual interviews were conducted by Ming-Shiun Lee and Mallory Crow of AECOM and coordinated with the assistance of Chris Lambert and Randi Feltner with the Kentucky Transportation Cabinet (KYTC) on Thursday December 21st, 2023, at 9 AM CST.

KYTC Staff Interviews

Meeting attendees on Thursday, December 21st included the following individuals:

1. Chris Lambert
2. Randi Feltner

Introduction

Development began for winter dashboards in 2012 when salt began to run out during winter maintenance and so the KYTC wanted a better way to track material usage to prevent issues like this from occurring again. Geographic information system (GIS) data was used to understand historical analyses to figure out why this happened. In 2014, the KYTC formed a deal with Waze to obtain real time traffic data. Eventually, KYTC wanted to blend weather information from the National Weather Service (NWS), Waze, and alerts, so the department began collaborating with developers in 2015 to create winter dashboards.

GoKY Dashboard

GoKY Dashboard Overview

Purpose	Used to view live traffic data and contains information such as locations of congestion, crashes, hazards, weather conditions, traffic cameras, and more.
Performance Measures	Availability, scalability, and can support one million concurrent users
Data Sources	HERE traffic speeds, Waze reports, TMC reports, maintenance weather reports, traffic cameras, DMS messages
Refresh Rate	Every 2 minutes
Users/Access	The public
Platform/Software	Google Cloud

The KYTC GoKY Dashboard serves as a central hub for real-time roadway information, catering to both public and agency needs. Functioning as an advanced 511 system, it empowers travelers with up-to-date road conditions while aiding KYTC and partner agencies in making informed decisions.

Kentucky's GoKY dashboard transitioned from ESRI to Google Maps not just for a fresh look, but for critical performance improvements. The original platform struggled with user surges, leading to inaccurate information and frustrating delays. Google Maps, with its robust scalability and faster refresh rates, ensured reliable access and real-time data even during peak periods. Additionally, Google Cloud

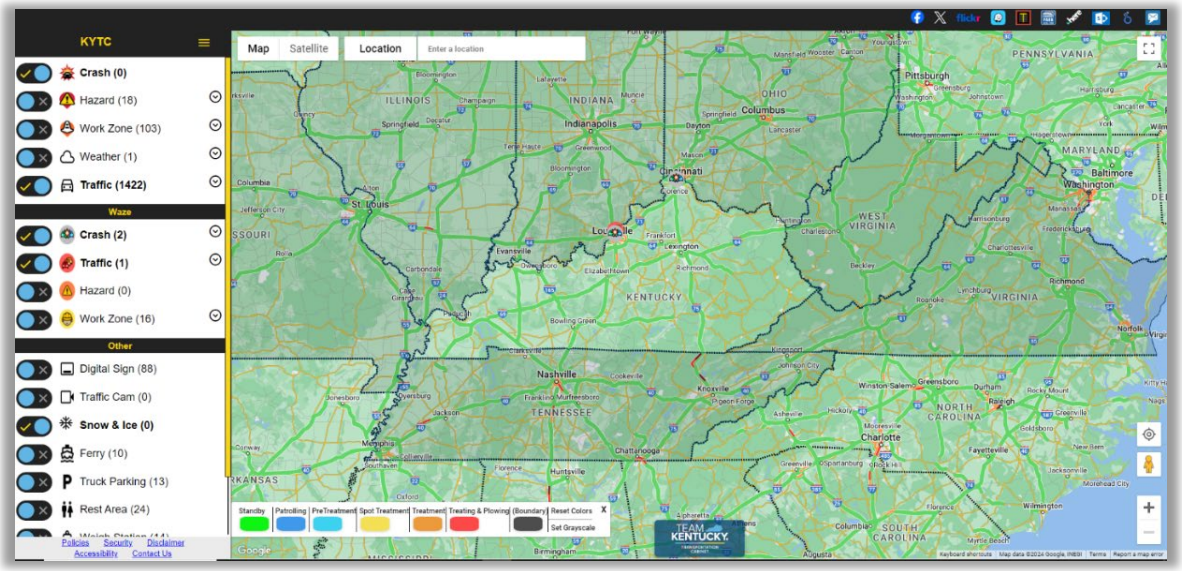
offered cost-effectiveness and access to advanced features like traffic layer integration and data streaming, significantly enhancing the dashboard's functionality. This may clarify the difference between traffic layer viewing and data availability from Google.

Real-Time Data:
The dashboard leverages a multitude of data sources, including HERE traffic speeds, verified by other Waze users (not necessarily by KYTC), TMC updates, maintenance weather responses, traffic cameras, and DMS messages. This comprehensive data pool refreshes every two minutes, ensuring users have the most current picture of Kentucky's roadways. Additionally, traffic cameras and DMS message displays provide visual aids for enhanced situational awareness.

Scalability and Reliability:
Built on Google Cloud's robust platform, GoKY boasts exceptional scalability, seamlessly managing even peak user volumes. This ensures consistent and reliable access to critical information, even during unforeseen circumstances like emergencies or natural disasters.

Data-Driven Decision Making:
Beyond public information, GoKY empowers KYTC staff and partner agencies with valuable data-driven insights. This intelligence informs crucial decisions regarding resource allocation, response strategies, and overall transportation management. Notably, GoKY played a significant role in coordinating road closures and recovery efforts during past natural disasters.

Continuous Improvement:
While the current user interface is undergoing mobile optimization, the GoKY dashboard remains committed to ongoing development. Future iterations promise exciting new features, potentially including static data layers like rest areas, truck parking locations, and weather radar integration. Additionally, the exploration of Road Weather Information System (RWIS) data and outward-facing dashcam views hold promise for further enhancements.



The GoKY dashboard stands as a dynamic and valuable resource, continuously evolving to meet the diverse needs of Kentucky's transportation landscape. By providing real-time, comprehensive information to both the public and transportation agencies, GoKY fosters informed decision-making, promotes safety, and contributes to a more efficient and well-managed transportation system.

However, limitations exist. Snow and ice data currently rely on manual entry, which can be less accurate and timely compared to real-time information. Additionally, not all winter operations vehicles have global positioning system (GPS) integration, hindering real-time tracking. Recognizing these limitations, KYTC is actively working on mobile optimization and exploring advancements like static data layers for rest areas and truck parking, weather radar integration.

KYTC Roadway Weather Decision Support System (DSS) Dashboard

KYTC Roadway Weather Decision Support System (DSS) Dashboard Overview

Purpose	Provides real-time decision-making data that includes salt, automatic vehicle location (AVL) data, cameras, and storm severity index
Performance Measures	Salt usage, vehicle location, camera access for visualization, and storm severity index. All in one spot joined to roadway segment.
Data Sources	AVL, cameras
Refresh Rate	Every 2 minutes
Users/Access	District and central office staff
Platform/Software	Google Cloud, ESRI

The KYTC Roadway Weather DSS Dashboard is a real-time decision support tool designed primarily for internal staff use. It provides a wealth of data, including AVL, and is updated every two minutes. The data is pulled together from various sources, including a roadway weather table, and is stored on Google Cloud. The system tracks a variety of metrics, including salt passes, line segments, camera feeds, and a storm severity index, all of which are updated at half-mile intervals.

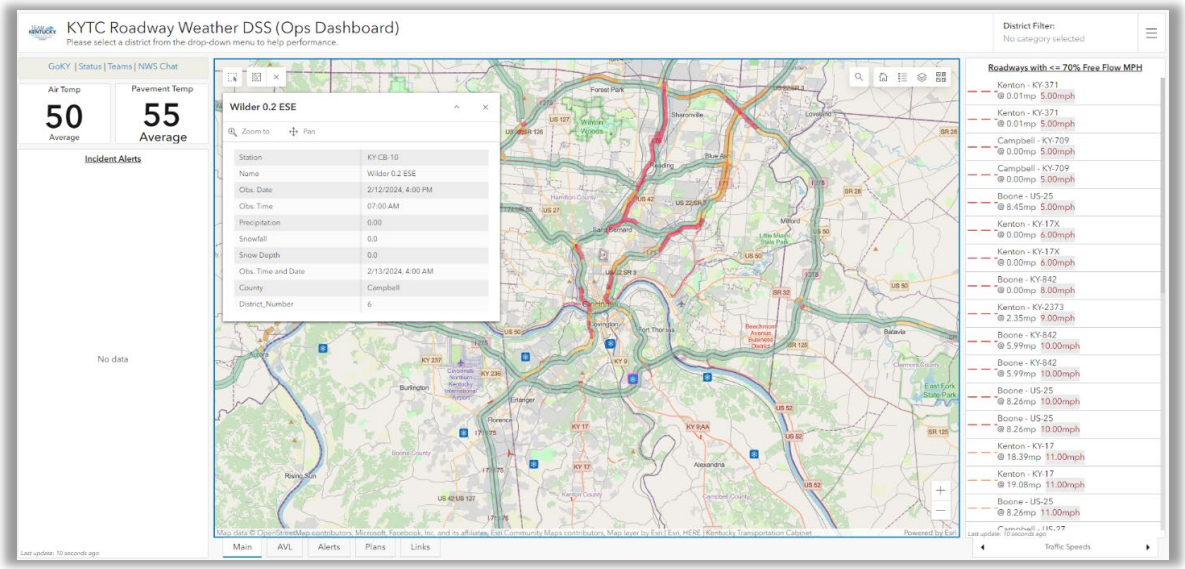
While the system is available to the public, it is not actively promoted. Despite this, it has proven to be a valuable resource for Public Information Officers (PIOs), who use it to respond to public inquiries about traffic conditions. For example, if a member of the public calls to complain about traffic, the PIO can pull up the relevant section of roadway and provide real-time information about the situation.

The system overwrites the data every two minutes, and updates for passes and salt are pulled from a Google Sheet until an end date is added. However, it is important to note that the system does not store historical data; it is purely a real-time tool. But according to DOT personal, this process is currently under review to become more automated.

The system has more detailed information than its public version. Although the link is public, it is not widely publicized and is mostly shared with partner agencies. This approach eliminates the need for password sharing. Additionally, this was effective in eliminating any issues related to authentication that may come up during off-hours.

The network is broken down into half-mile segments, which are updated every two minutes. Users can click on these segments to view important data points, such as pavement and air temperature. The storm severity index is also available for each segment.

Looking ahead, the next iteration of this tool will include a trend-tracking feature. However, it is worth noting that the current system may become obsolete and could be retired in a year or so once the updated version is developed. One of the limitations of the current system is that none of the real-time speed data providers they have worked with can provide volume data, which could help determine the reasons for slowdowns. Currently there exists a confusion on which platform needs to be used for the next generation of the system. It was noted that since ESRI is limited on historical view of data and Looker Studio is limited on layering (visualizations), both of these are currently used.



GoKY: ITS Real-Time Information Dashboard / Real Time ITS Data Studio Dashboard

GoKY: ITS Real-Time Information Dashboard / ITS Data Studio Dashboard Overview

Purpose	To show short-term trends and help facilitate decision support
Performance Measures	Uptime and scalable to report on millions of records
Data Sources	TMC, Waze, HERE, AVL, RWIS, KYMesonet, CoCoRahs, First Look
Refresh Rate	Every 2 minutes on most feeds and every 2-3 for AVL
Users/Access	The public
Platform/Software	Looker Studio + Google Cloud

The GoKY: ITS Real-Time Information Dashboard, also known as ITS Data Studio, is an innovative solution developed by the KYTC. The primary function is to facilitate decision-making by visualizing short-term trends. The dashboard is designed to be robust, with performance measures focusing on uptime and scalability, capable of reporting on millions of records.

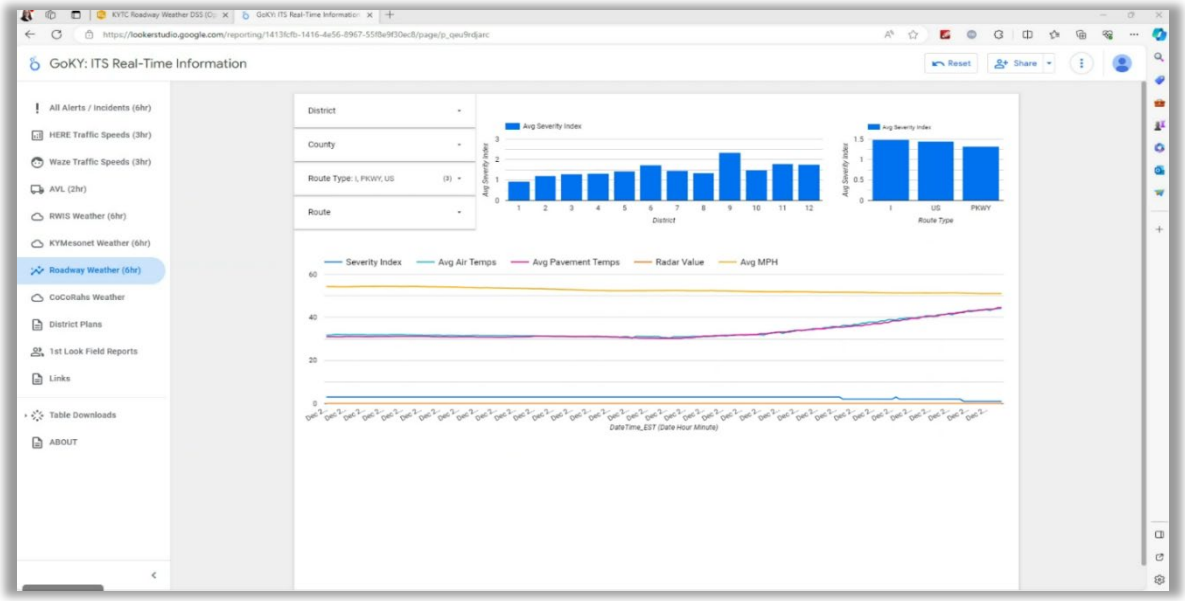
The data for the dashboard is sourced from a diverse range of platforms including TMC, Waze, HERE, AVL, RWIS, KYMesonet, CoCoRahs, an in-house mobile application developed by the KYTC. The refresh

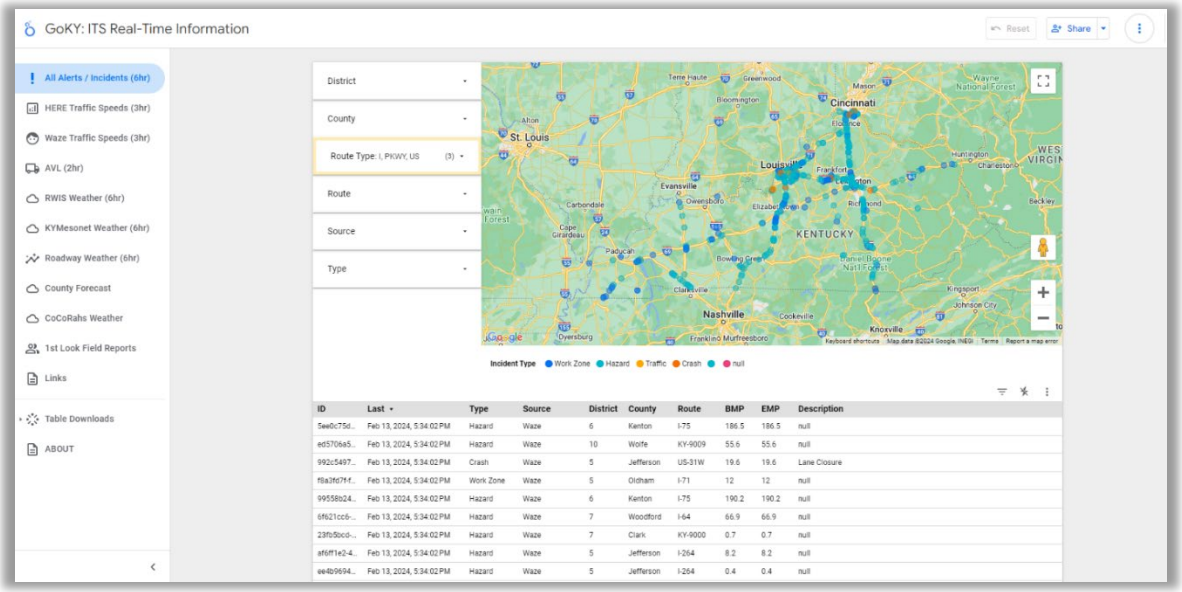
rate is optimized for real-time updates, connecting directly to the data warehouse every 2 minutes for most feeds and every 2-3 seconds for AVL data.

Despite being accessible to the public, the dashboard is primarily used for internal purposes. It is built on the Looker Studio and Google Cloud platforms. The dashboard is utilized to monitor short-term traffic and weather trends. However, due to the volume of data it processes, some users have reported performance issues. The dashboard aggregates nearly 41.5 million records of real-time data within a six-hour timeframe, processing a total of 166 million records every 24 hours.

The dashboard was developed as a response to frequent queries from leadership, providing valuable decision support. It allows users to monitor average and minimum speeds, mile points, and routes. It also tracks recovery movements and downward progressions.

One of the unique features of the dashboard is the Severity Index, a scoring system developed by KYTC (similar to the Purdue method). This index scores air temperature, wind, and radar values per segment, with color values indicating intensity. A leading GIS Developer developed a python script to analyze radar data at 1/10th mile segments, offering granular weather impact insights.





In summary, this dashboard is a comprehensive tool that combines weather, speed, and severity data to provide real-time or trending insights. It should be noted that the uniqueness of this view is the time-depth. Despite some limitations, it is an example of data visualization for facilitating informed decision-making. The KYTC plans to continue improving the dashboard and addressing its limitations in future iterations.

Material Usage Dashboard

Material Usage Dashboard Overview

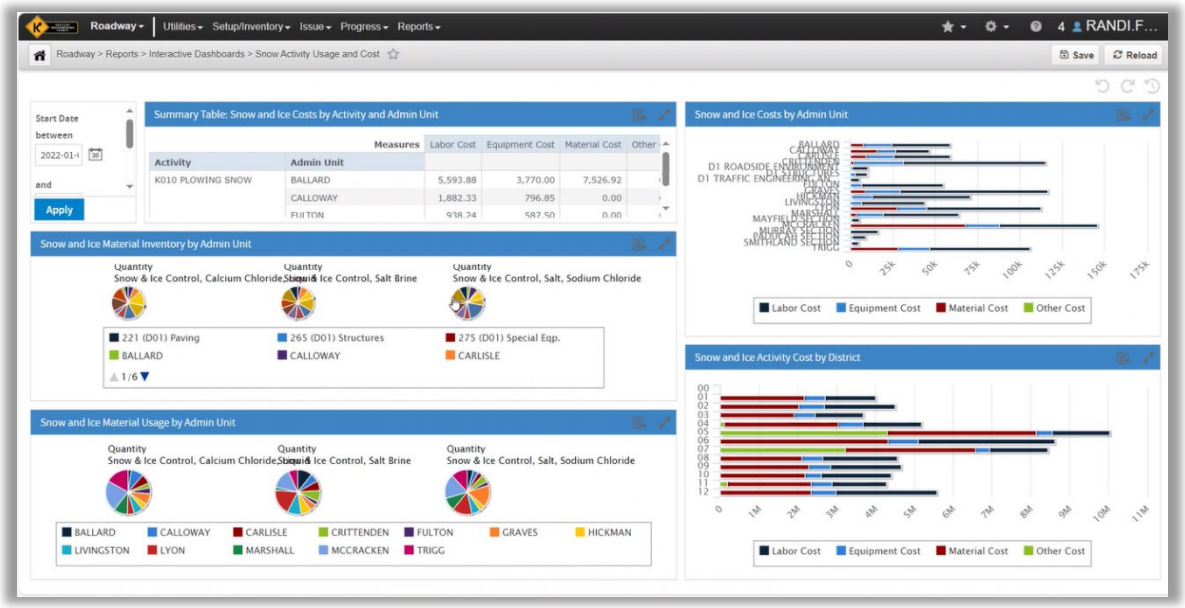
Purpose	Serves as a material usage dashboard that summarizes inventory information
Performance Measures	Material usage, safety, labor cost, equipment cost
Data Sources	OS Information (Manual Entry via Trimble)
Refresh Rate	Daily
Users/Access	Internal
Platform/Software	OMS by Trimble (formerly Agile Assets)

Material Usage Dashboard leverages GeoTab assets to analyze manually entered inventory data. This dashboard is not open to the public and remains as an internal tool during development. While GPS coverage reaches 100%, AVL data currently sits at 85-90%, with daily card integration in development.

Beyond tracking material use, the dashboard expands into the realm of safety, pulling metrics like seatbelt usage, speeding, and harsh braking from GeoTab's onboard systems. GeoTab's diverse functionalities also offer potential for camera integration, temporary work zone identification, and more. On the other hand, the Geotab Safety Scorecard feature is a separate product, only available within the Geotab platform.

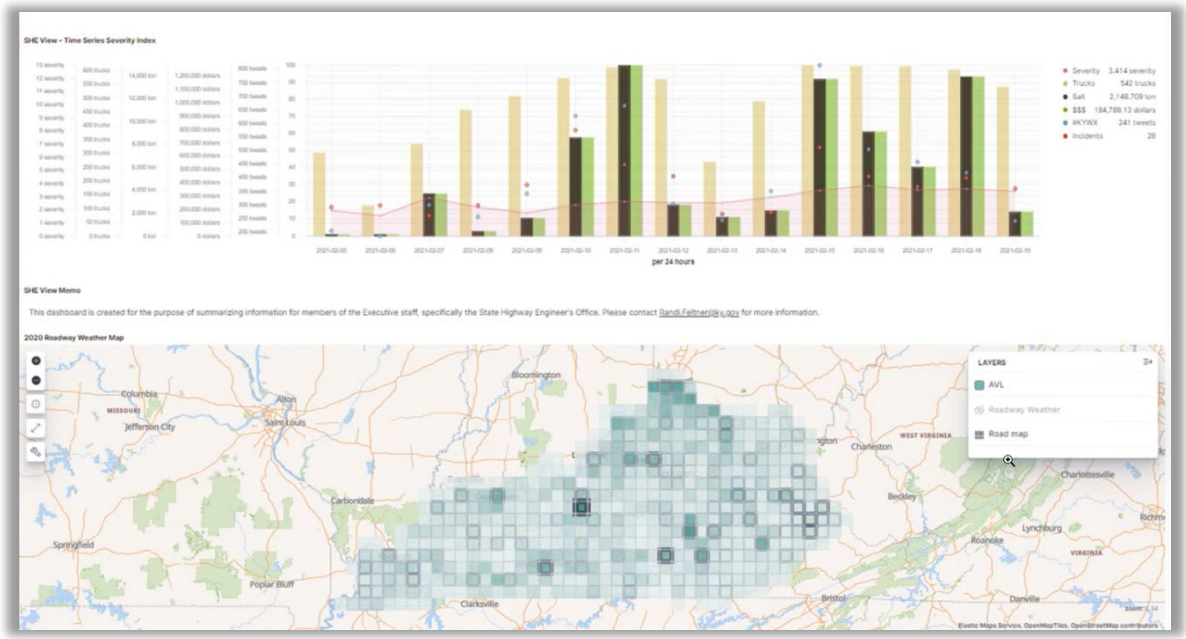
Initially focused on salt usage, the dashboard's scope has broadened to encompass overall asset management, aiming to enhance resource efficiency, particularly in contract-heavy areas. Its

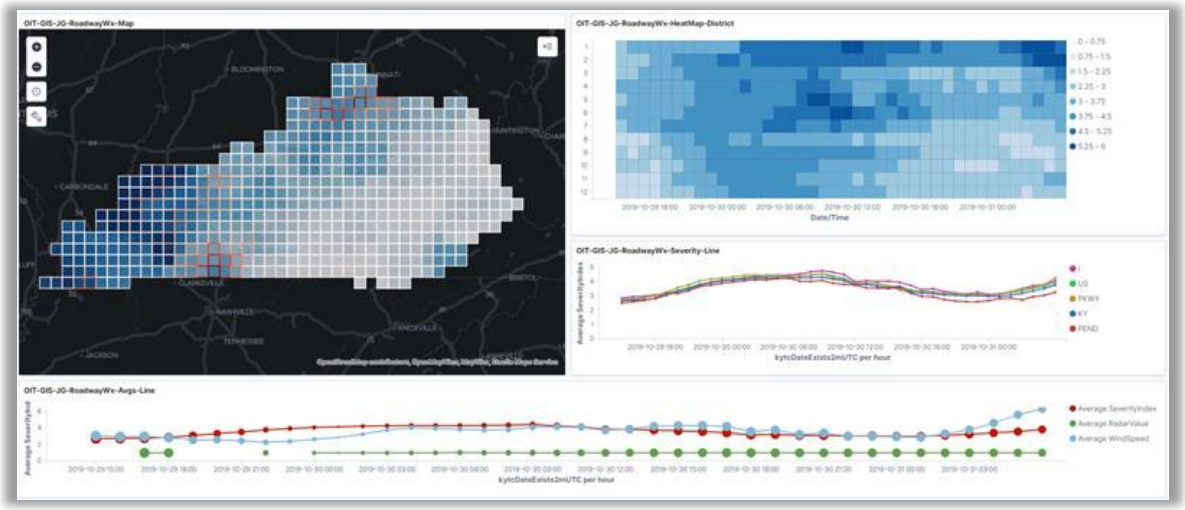
adaptability allows for future enhancements and creation of additional dashboards. Although the team do not yet have the AVL automated integration complete, they actively explore utilizing GeoTab's AVL data more effectively. While material usage currently relies on manual updates, integration with Trimble's AVL enhancements promises automation.

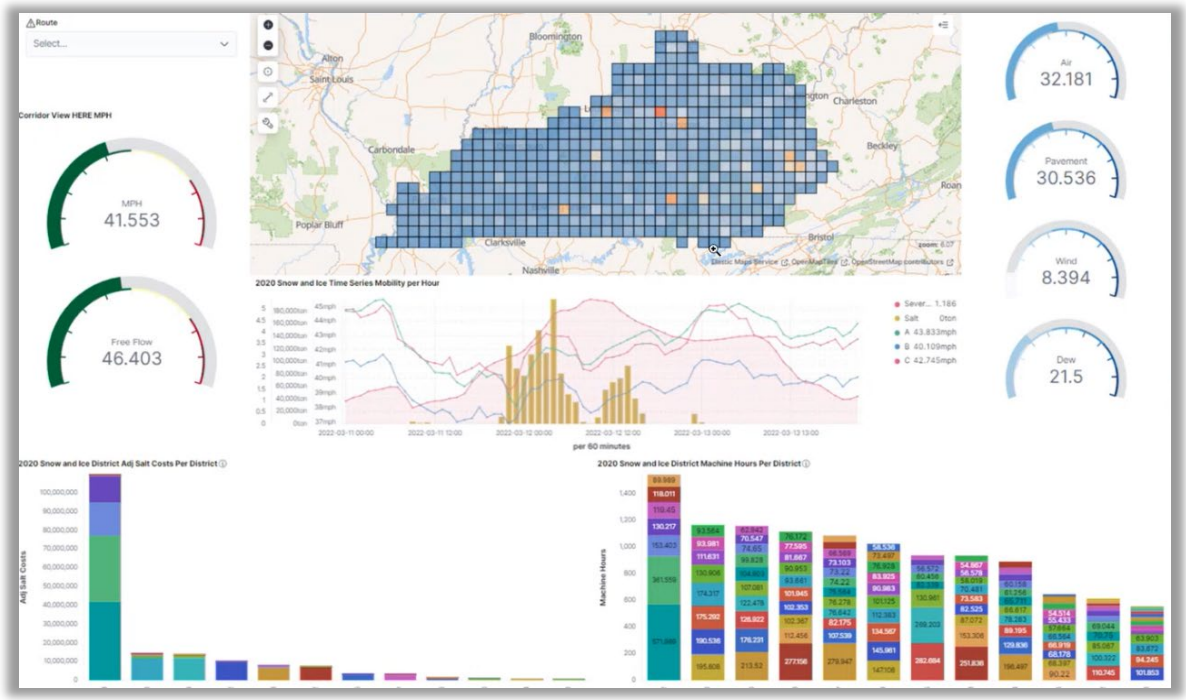


Previous Dashboards

A migration from the former Elastic Search platform to Google Cloud/Data Studio caused changes in dashboard layouts, making previous user – interfaces inaccessible. One lesson learned from the development of this dashboard is that switching vendors may result in the loss of some dashboard views, requiring manual recreation.







Development of Dashboards

Dashboards were developed to help with requests KYTC was receiving and can be used to create strategic plans. As the dashboards became more implemented, more requests were being made that required additional dashboards to be made. A request is received and then the development team comes together to build upon it and decide what data is needed and how the dashboard should be made.

An internal team of developers and stakeholders helped develop the dashboards. There are no formal processes that have been made to verify the accuracy of performance measures, however, if an error occurs, they will be notified. They are still learning where data is coming from and what unique issues can occur with the equipment they use. The data is stored in Data Looker Studio as well as Google Cloud.

The data stored can be queried back to 6 hours but a query for data from further back on previously deployed dashboards is being worked on.

System Operations and Maintenance

These dashboards are hosted for viewing on Looker Studio and Google Cloud. A team of system IT consultants maintains the dashboard system. Looker Studio and Google Cloud maintain and store the data for these dashboards and update the data. The costs and resources needed to maintain and develop these dashboards are not directly tracked.

Benefits / Lessons Learned

Benefits and lessons learned are below:

1. **Data Quality:**
   - AVL data is more prone to errors in winter conditions, so it is important to be aware of this when using it for winter dashboarding.
   - It is important to understand your data sources and data quality to create accurate and reliable dashboards.
2. **Vendor Management:**
   - Switching vendors can change dashboards and affect data, so it is important to be prepared for this and to have a plan in place for testing and updating dashboards after a vendor change.
   - Not all vendors will notify you of updates that could affect your dashboards, so it is important to stay up to date on vendor changes and test your dashboards regularly.
3. **Data Selection and Filtering:**
   - It is important to use relevant data for your dashboards and to filter out irrelevant information.
   - For example, when using speed or Waze data, it is important to test out different filters to determine what works.
4. **Project Management:**
   - Be specific with the scope of your project and keep the team small.
   - Use team members who are knowledgeable of both operations and technology.
5. **Additional Findings:**
   - It is important to find the right platform for real-time and historical data.
   - There is a need for a small, knowledgeable team to work on winter dashboards.
   - Team members should be knowledgeable of both operations and technology.

Future / Enhancements

The KYTC has identified five areas for potential future enhancements of their current dashboards:

1. **Mobile Optimization**
   - The current user interface is undergoing optimization for mobile devices to improve accessibility and user experience.
2. **Static Data Layers**
   - Future versions of the dashboard may include static data layers such as rest areas, and truck parking locations, which would provide additional useful information to the users.
3. **Weather Radar Integration**
   - There is a possibility of integrating weather radar to provide real-time weather updates, which could be crucial for travelers.

4. **RWIS Data**
    - The exploration of RWIS data is being considered. This could provide more detailed and location-specific weather information.
5. **Outward-Facing Dashcam View**
    - This feature could provide real-time visual information from the roads, enhancing situational awareness for both the public and KYTC staff.

These enhancements aim to improve the functionality, user experience, and the range of information provided by the GoKY dashboard. However, please note that these are potential future enhancements and may be subject to change based on several factors.

Appendix D – Case Study Interview Summary: North Dakota DOT

Overview

Virtual interviews were conducted by Ming-Shiun Lee and Mallory Crow of AECOM and coordinated with the assistance of Steeg (Miles) Nelson with the North Dakota Department of Transportation (NDDOT) on Monday December 4th, 2023, at 1 PM CST.

NDDOT Staff Interviews

Meeting attendees on Monday, December 4th included the following individuals:

1. Brandon Beise
2. Steeg (Miles) Nelson
3. Brad W. Darr

Introduction

In 2020, the NDDOT initiated the development of dashboards with the primary objective of determining speed recovery performance measures. This initiative was driven by an increasing necessity for quantifying performance metrics that were beyond manual computation capabilities.

Subsequently, the state awarded a grant to NDDOT in the same year, facilitating the creation of data-driven dashboards. This development was conducted in collaboration with North Dakota State University (NDSU).

In recent endeavors, NDDOT and NDSU have been working together to consolidate manual snow and ice cost data from various sources. The goal is to integrate this data into a dashboard that is updated monthly. This effort exemplifies the continuous strive for improvement and efficiency in their operations.

Maintenance Dashboard

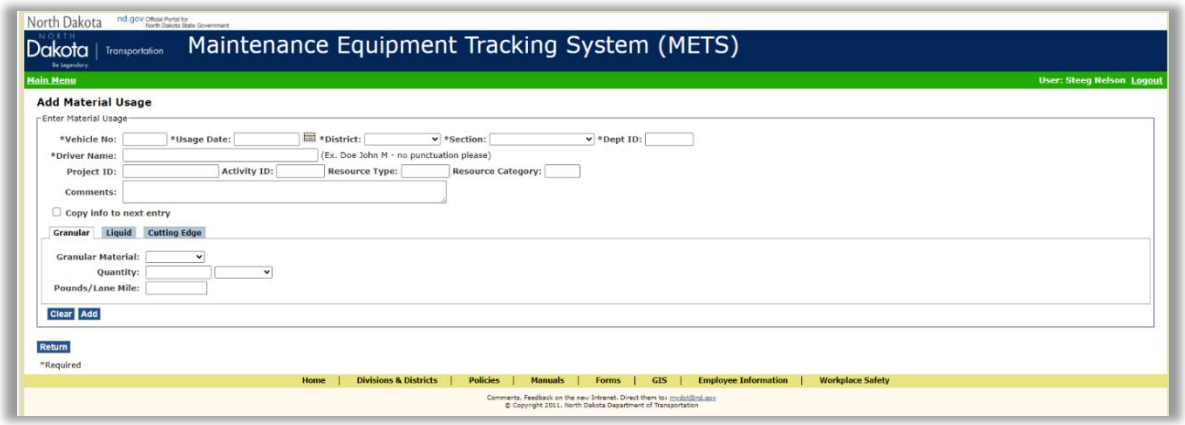
Maintenance Dashboard Overview

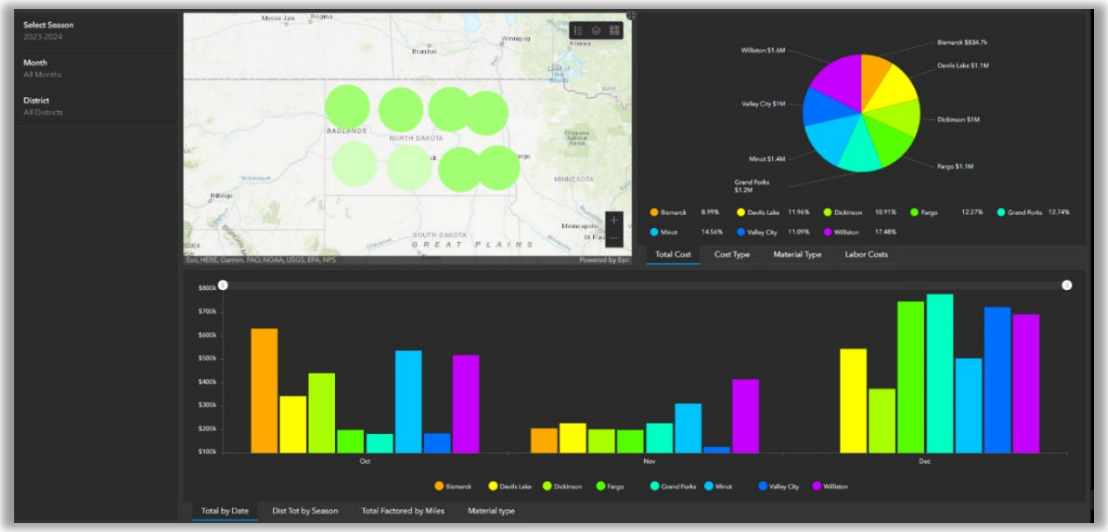
Purpose	This dashboard is still being developed; however, the goal is for it to be able to track the cost of snow and ice control.
Performance Measures	Cost of snow and ice control
Data Sources	Maintenance Equipment Tracking System (METS), Finance Data (via People Soft), & Automatic Vehicle Location (AVL)
Refresh Rate	Updated monthly
Users/Access	Decision makers and districts have access
Platform/Software	ESRI

The Maintenance Dashboard is an internal tool under development by NDDOT. The goal for this dashboard is to seamlessly integrate their in-house material usage inventory and finance data from People Soft. The current policy reflects a monthly update of both data sources; however, all historical data throughout the month is dated manually upon creation. The dashboard currently filters by garage

level and is primarily used by the maintenance crew, management, and district representatives to track costs of snow and ice maintenance.

Future implementation includes connecting AVL data that would be updated in real time. The dashboard filter would be setup at the route level and would be used to compare material usage, performance, and road conditions.





Maintenance Speed Recovery Dashboard

Maintenance Speed Recovery Dashboard Overview

Purpose	Tracks how long vehicle speeds return to normal travel speed due to snowstorm events
Performance Measures	Snowstorm travel speed
Data Sources	Data is provided by Maintenance Decision Support System (MDSS), roadway sensors in the form of Automatic Traffic Recorders (ATR), radar sensors on Roadside Weather Information System (RWIS) towers (10-12 locations)
Refresh Rate	24 hours
Users/Access	Districts
Platform/Software	ESRI

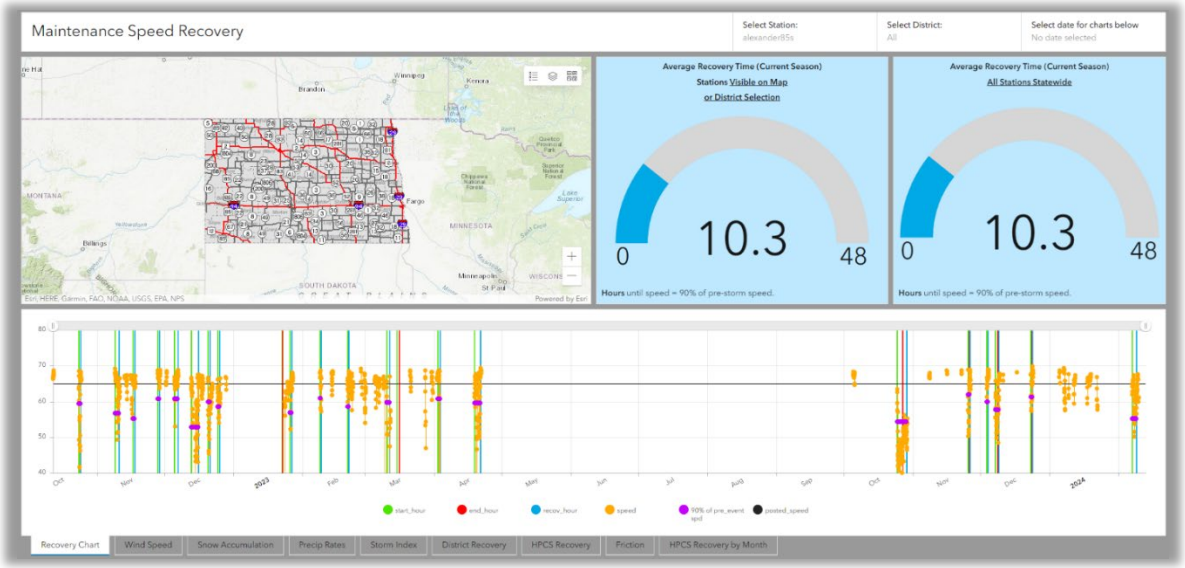
Speed sensors, ATRs, and radar sensors are deployed across various locations within the state to gather data during storm events. This data is analyzed to measure the duration required for traffic speeds to return to pre-storm conditions. A recovery rate of 90% of the pre-storm speed is deemed as a return to normalcy. The dashboard can be used to view historical data of up to one year.

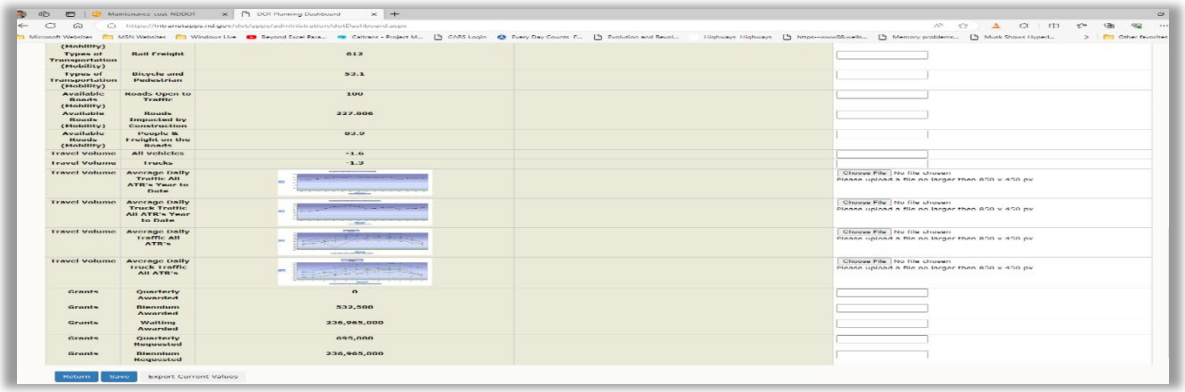
While there is potential for the integration of newer speed data sources, the rural characteristics of North Dakota limit the availability of highly dense areas. The Maintenance Speed Recovery Dashboard, which is automated, serves as the primary source of data for the public-facing NDDOT dashboard. Manual data extraction from the internal dashboard is necessary to populate the NDDOT dashboard.

An intermediate step in this process involves completing a DOT dashboard tool questionnaire form, which ensures that only the necessary data is pulled for the NDDOT dashboard. The primary function of this dashboard is to monitor the performance of speed recovery rates at the district level, thereby facilitating the allocation of resources to areas where recovery rates are suboptimal.

The dashboard provides a range of metrics, including snow recovery, friction, and speeds. Future enhancements to the dashboard may include the incorporation of correlations between decreases in friction and speed readings.


Maintenance Speed Recovery
Select Station:
alexander85s
Select District:
All
Select date for charts below
No date selected
Average Recovery Time (Current Season)
Stations Visible on Map
or District Selection
5.5
0
48
Hours until speed = 90% of pre-storm speed.
Average Recovery Time (Current Season)
All Stations Statewide
10.3
0
48
Hours until speed = 90% of pre-storm speed.
Snow Accumulation (inches)
Recovery Chart
Wind Speed
Snow Accumulation
Precip Rates
Storm Index
District Recovery
HPCS Recovery
Friction
HPCS Recovery by Month


Maintenance Speed Recovery
Select Station:
alexander85s
Select District:
All
Select date for charts below
No date selected
Average Recovery Time (Current Season)
Stations Visible on Map
or District Selection
10.3
0
48
Hours until speed = 90% of pre-storm speed.
Average Recovery Time (Current Season)
All Stations Statewide
10.3
0
48
Hours until speed = 90% of pre-storm speed.
Recovery Chart
Wind Speed
Snow Accumulation
Precip Rates
Storm Index
District Recovery
HPCS Recovery
Friction
HPCS Recovery by Month



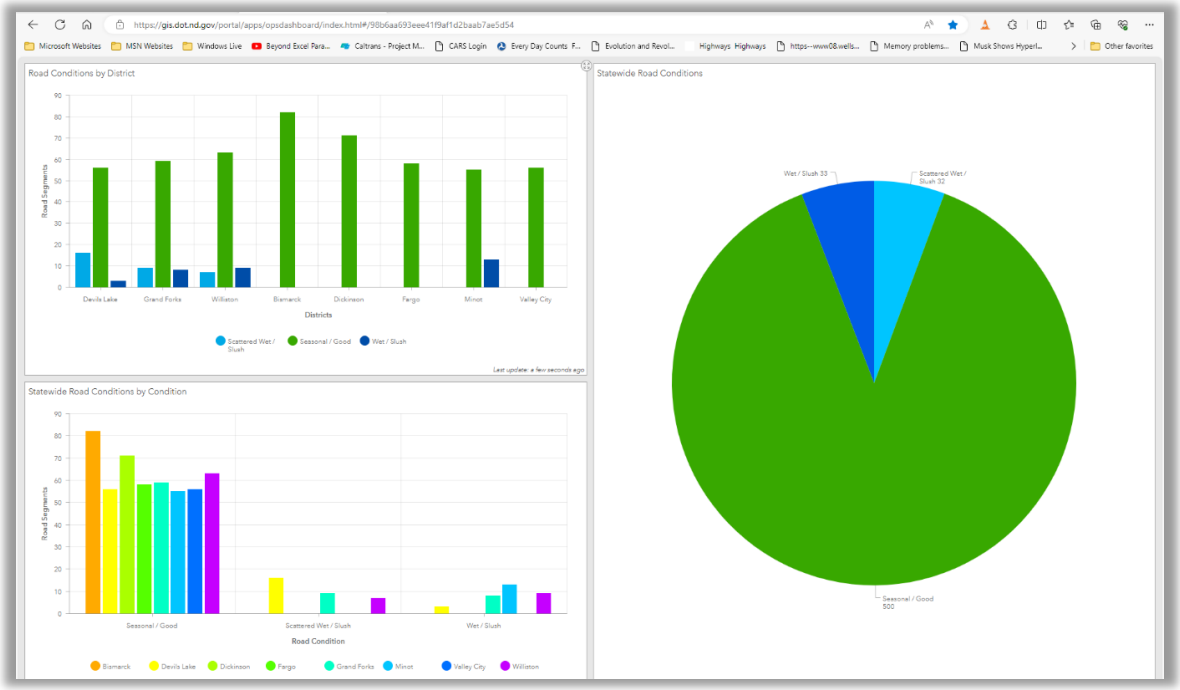
Road Condition Dashboard

Road Condition Dashboard Overview

Purpose	Provide real time data of road conditions
Performance Measures	Mobility, weather, road condition
Data Sources	Road Condition Reporting System (RCRS)
Refresh Rate	Real time
Users/Access	Internal, field operators, maintenance, patrol
Platform/Software	ESRI

The Road Condition Dashboard, developed by the Information Technology department in 2023, offers real-time data, effectively presenting a snapshot of the prevailing road conditions. This data is derived from 511 maps, which in turn source their information from the RCRS.

The RCRS serves as a tool for field operators and snowplow drivers, facilitating the manual input of road condition data. This includes parameters such as visibility, visibility density, weather conditions, and the state of the roads themselves. The integration of these data sources ensures that the Road Condition Dashboard provides a comprehensive and up-to-date overview of road conditions. At the garage level you can compare neighboring road conditions to see how a storm is progressing across the state.

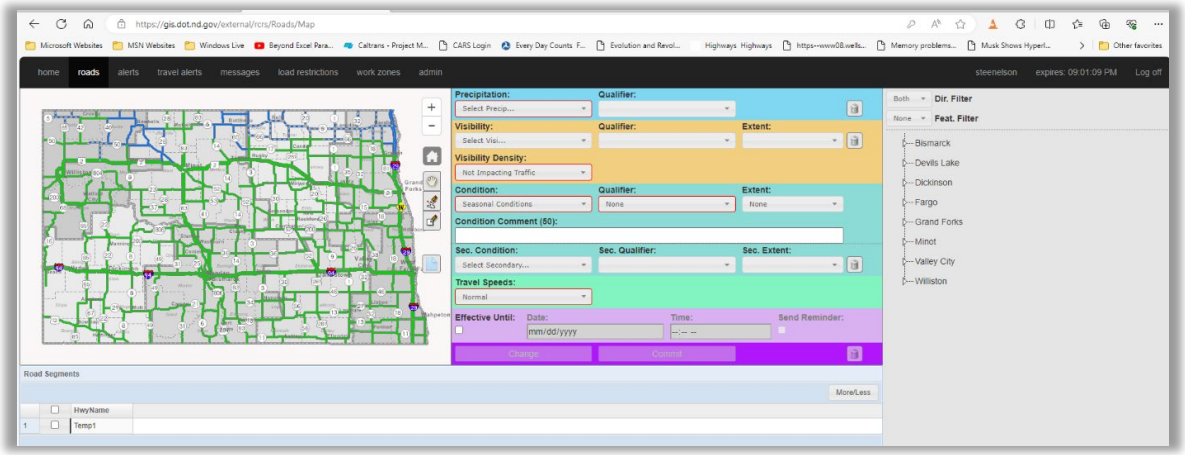


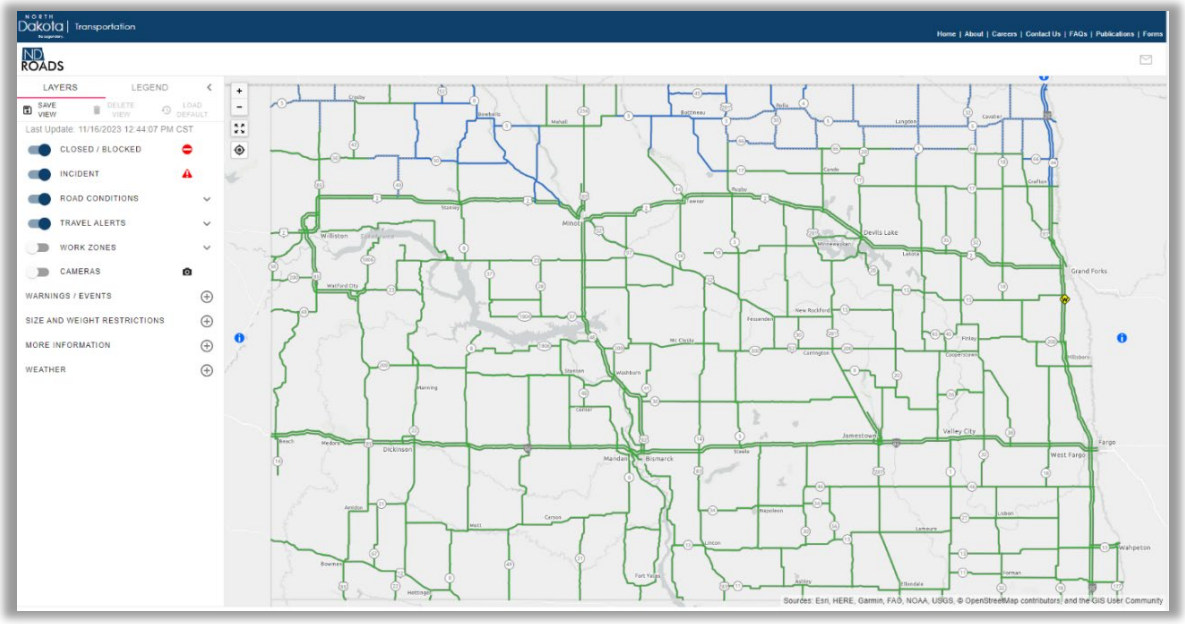
North Dakota Roads Dashboard

North Dakota Roads Dashboard Overview

Purpose	Tracks incidents and feed into the Road Condition Dashboard
Performance Measures	Road conditions, incidents, weather
Data Sources	RCRS, state radios, highway patrol
Refresh Rate	Manual input
Users/Access	Public access
Platform/Software	ESRI

The North Dakota Roads Dashboard utilizes data from the RCRS and occasionally incident reports from local state and highway patrol. The main goal for this dashboard is to visualize current road conditions as there is not a state TMC in place at the time the interview was conducted. This dashboard also serves as source for the newly developed Road Conditions Dashboard.





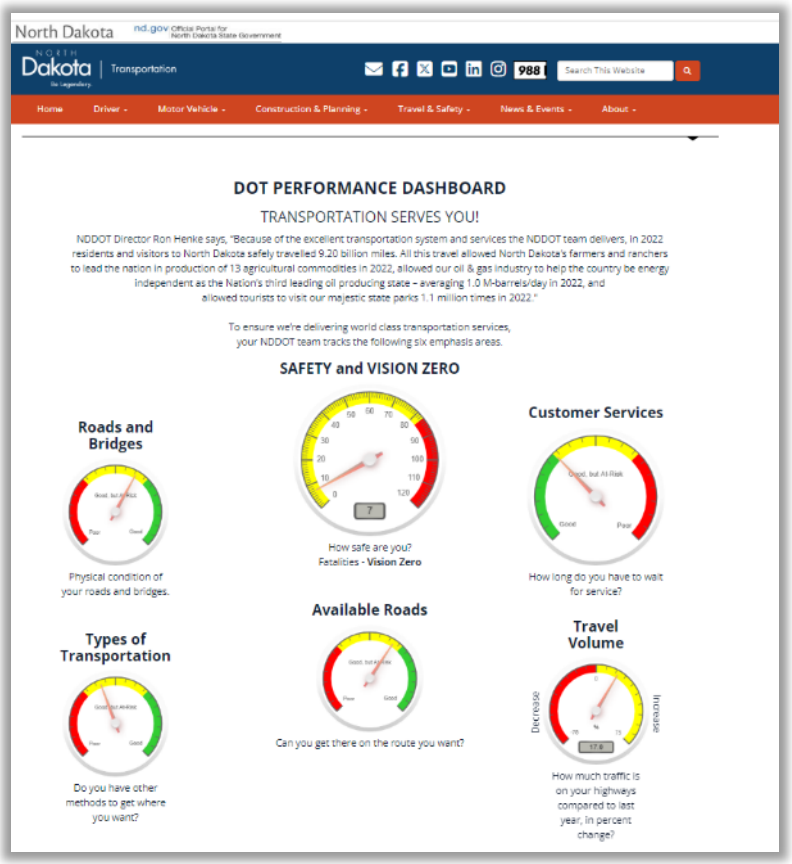
NDDOT Dashboard

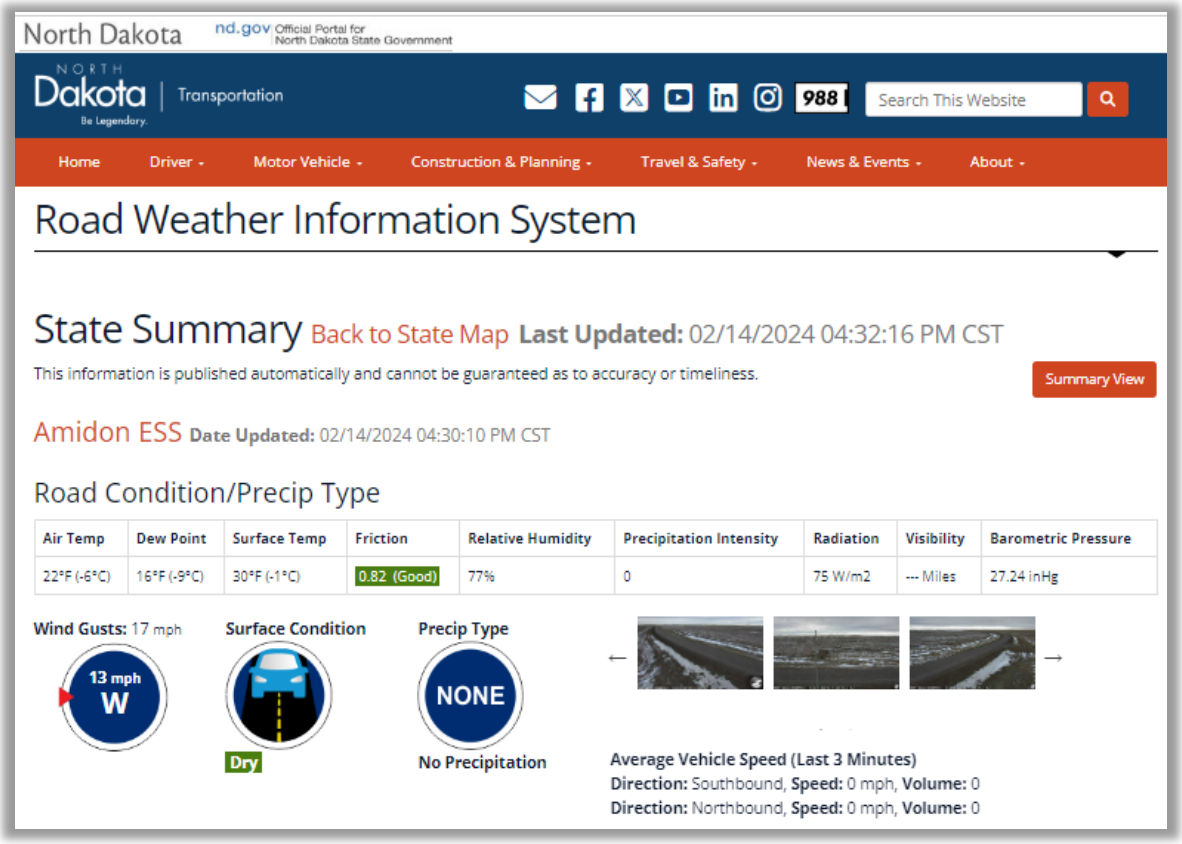
NDDOT Dashboard Overview

Purpose	Thorough understanding of the current state of NDDOT transportation infrastructure
Performance Measures	Average travel speed recovery time for the current season, weather, mobility
Data Sources	Dashboard datasheet, live data feed
Refresh Rate	Updated daily
Users/Access	Public access
Platform/Software	ESRI

The NDDOT Dashboard was developed in-house by the Information Technology department and the planning division, with parameters established internally. The dashboard presents a range of metrics, including the condition of roads and bridges, safety and Vision Zero metrics, customer service indicators, types of transportation, available roads, and traffic volumes.

The dashboard also enables the analysis of road conditions using road imagery and a variety of performance metrics. These include temperature, wind, precipitation levels, friction, and visibility. This approach ensures a thorough understanding of the state's transportation infrastructure and its performance.


North Dakota
nd.gov Official Portal for North Dakota State Government
Dakota | Transportation
988
Search This Website
Home
Driver
Motor Vehicle
Construction & Planning
Travel & Safety
News & Events
About
DOT PERFORMANCE DASHBOARD
TRANSPORTATION SERVES YOU!
NDDOT Director Ron Henke says, "Because of the excellent transportation system and services the NDDOT team delivers, in 2022 residents and visitors to North Dakota safely travelled 9.20 billion miles. All this travel allowed North Dakota's farmers and ranchers to lead the nation in production of 13 agricultural commodities in 2022, allowed our oil & gas industry to help the country be energy independent as the Nation's third leading oil producing state – averaging 1.0 M-barrels/day in 2022, and allowed tourists to visit our majestic state parks 1.1 million times in 2022."
To ensure we're delivering world class transportation services, your NDDOT team tracks the following six emphasis areas.
SAFETY and VISION ZERO
How safe are you?
Fatalities - Vision Zero
Roads and Bridges
Physical condition of your roads and bridges.
Customer Services
How long do you have to wait for service?
Available Roads
Can you get there on the route you want?
Types of Transportation
Do you have other methods to get where you want?
Travel Volume
Decrease
Increase
How much traffic is on your highways compared to last year, in percent change?



Development of Dashboards

The decision to develop maintenance dashboards was a collaborative effort between a team of state maintenance engineers and NDSU. This initiative was driven by the NDDOT planning division's interest in speed data. During the COVID-19 pandemic, the prioritization of speed recovery data was emphasized. Subsequently, a state grant was secured to facilitate this process.

System Operations and Maintenance

The development, implementation, maintenance, and enhancement of sixteen sites were funded through a grant, with costs ranging between $100,000 and $120,000. An additional seventy-three sites were incorporated into the contract in the following year. The finance group was actively involved in the cost management of the dashboards to ensure that staff hours were allocated within the confines of internal policies.

Benefits / Lessons Learned

The implementation of these dashboards has led to an increase in the Level of Service (LOS) across roads that utilize dashboard data. They aid in resource allocation decisions, provide valuable training, enable real-time monitoring of roadway conditions, and track material usage and labor costs.

Additional benefits include the automation of certain processes, saving time, and the ability to view and extract data at any time. This allows for the tracking of the impact of decisions made by state decision-

makers. The National Cooperative Highway Research Program (NCHRP) utilized data from the dashboards for a snow and ice control measure study, which was subsequently presented to the state.

Future / Enhancements

NDDOT has expressed interest in several future enhancements for its winter dashboards. These include the ability to track weather severity alongside speed for normalization, track salt usage for winter maintenance roads, implement more predictive and proactive measures, and expand Automatic Vehicle Location (AVL) controller information and AVL pavement temperature data.

NDDOT also plans to develop new data sources and dashboards in the future. This includes the development of a TMC to monitor traffic conditions throughout the area and deploy traffic management strategies as needed. Additionally, they aim to develop smart corridors, which are sections of roadway equipped with dynamic signs that change based on roadway conditions.

Appendix E – Case Study Interview Summary: Ohio DOT

Overview

Virtual interviews were conducted by Ming-Shiun Lee, Allison Balogh, and Mallory Crow of AECOM and coordinated with the assistance of Dean Alatsis with the Ohio Department of Transportation (ODOT) on Wednesday January 24th, 2024, at 12 PM EST.

ODOT Staff Interviews

Meeting attendees on Wednesday, January 24th included the following individuals:

- Dean Alatsis
- Ryan Lowe, PE
- Tim Filla
- Stephanie Marik, PE
- Joshua Thieman

Introduction

The ODOT started dashboarding with a goal to transform the data on spreadsheets into user friendly dashboards. While they have not developed dedicated dashboards for Global Positioning System (GPS)/Automatic Vehicle Location (AVL) data, they recognize the potential. They offer a mobile-friendly GPS/AVL dashboard and are piloting a "real-time evaluator" tool. The real-time evaluator tool or in other words the real-time snow & ice dashboard visualizes current conditions like speed and weather. Additionally, separate after analysis dashboards show the route recovery based on snow & ice performance evaluator using performance metric aiding managers in evaluating staffing and operational efficiency. In short, ODOT is actively weaving data visualization into their decision-making, and GPS/AVL integration is likely on the horizon.

Real-Time Snow and Ice Dashboard

Real-Time Snow and Ice Dashboard Overview

Purpose	Checks if winter maintenance goals are being met during a snowstorm. Evaluates snow and ice data in real time and allows users to view probe data and Road Weather Information System (RWIS) data. Helps aid in the allocation of resources.
Performance Measures	Speed conditions, weather conditions
Data Sources	Speed data (via INRIX), weather data (via RWIS)
Refresh Rate	Real time/ every few minutes
Users/Access	County managers
Platform/Software	ESRI

During winter storms, ensuring efficient snow and ice removal is crucial for public safety and smooth operations. To achieve this, county managers rely on a specialized tool, the real-time snow and ice web map. This interactive map, not a traditional dashboard, provides crucial insights into road conditions and weather in real-time.

Fueled by data from two sources, the map displays both speed and weather information. Speed data, gathered through the INRIX API, allows for comparison with expected speeds on each road segment. Deviations are highlighted in orange and red, indicating potential slowdowns and areas requiring intervention. Additionally, internal RWIS data provides real-time updates on weather conditions, allowing managers to anticipate further challenges.

With data refreshed every few minutes, the map acts as a dynamic command center. County managers can monitor performance against set goals, allocate resources strategically, and make informed decisions based on the latest conditions. This empowers them to respond proactively to storm events, ensuring efficient snow and ice removal and maintaining public safety. While currently limited to internal access, the real-time snow and ice web map plays a vital role in keeping the county moving during winter storms.

Snow and Ice Performance Evaluator Tool Dashboard

Snow and Ice Performance Evaluator Tool Dashboard Overview

Purpose	Determine if recovery goals are being hit after a snowstorm and organizes it by district and county.
Performance Measures	Storm start, storm end, recovery goal, time recovered
Data Sources	RWIS, INRIX
Refresh Rate	Monthly
Users/Access	District highway managers and county. Results are used by leadership.
Platform/Software	Python/SQL, TSMO data warehouse

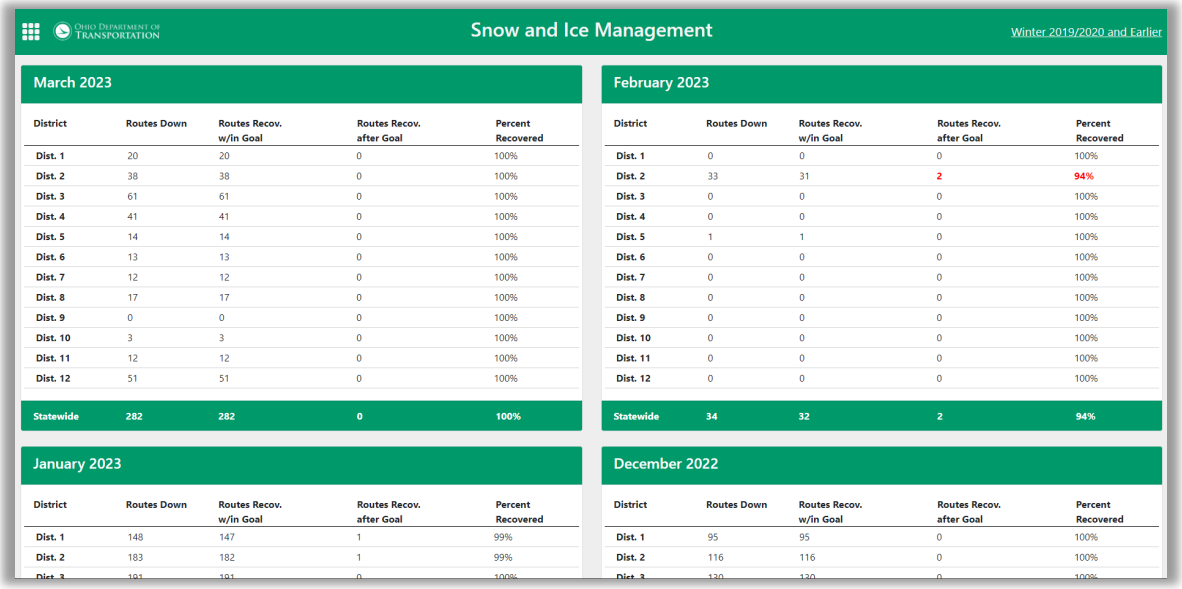
The Snow and Ice Performance Evaluator Tool Dashboard is a comprehensive solution for analyzing post-storm snow and ice removal performance across districts and the entire county. It is designed to identify routes that have not met recovery goals, with a benchmark set at 96% recovery. This tool allows for a detailed exploration of these routes.

The performance measures within the dashboard are multifaceted. It tracks recovery goals and times for different priority routes, with a 2-hour goal for P1 routes and a 4-hour goal for P2 routes. The tool measures the downtime for each route based on real-time speed data provided by INRIX. It also defines the start of a storm based on a combination of RWIS and INRIX data and to end a storm, only RWIS data is considered. The INRIX data is then utilized to determine the route recovery which account for both weather conditions and speed impact. The success of recovery is measured by how quickly after the end of a storm routes return to speeds that are within 10mph of the historical average speed Recovery is achieved when a route is within 10 mph of the historical speed for at least one consecutive hour.

The dashboard utilizes multiple data sources. INRIX provides real-time speed data for tracking downtime, while RWIS triggers the start and end of a storm and helps define recovery periods. The TSMO data warehouse houses historical speed data, which is used to measure recovery success.

The functionality of the dashboard is designed to be user-friendly and informative. A Statewide/District view allows leaders, HMAs, and Roadway Service Managers to analyze performance within their areas, while a county-wide view offers managers an overview of the effectiveness of the storm response. Route details are available for a more granular analysis, particularly for specific routes that have not met recovery goals. Managers can provide feedback to be incorporated into the dashboard about incidents that may impact recovery.

From a technical standpoint, this dashboard is powered by Python and SQL scripts that process data and drive analysis. The results are displayed on a website that allows for interaction. After each storm, a manual trigger is activated for analysis and reporting. To keep leadership informed, quarterly reports summarizing overall performance are sent out.



Ohio Department of Transportation

Snow and Ice Management

Winter 2019/2020 and Earlier

March 2023

District	Routes Down	Routes Recov. w/in Goal	Routes Recov. after Goal	Percent Recovered
Dist. 1	20	20	0	100%
Dist. 2	38	38	0	100%
Dist. 3	61	61	0	100%
Dist. 4	41	41	0	100%
Dist. 5	14	14	0	100%
Dist. 6	13	13	0	100%
Dist. 7	12	12	0	100%
Dist. 8	17	17	0	100%
Dist. 9	0	0	0	100%
Dist. 10	3	3	0	100%
Dist. 11	12	12	0	100%
Dist. 12	51	51	0	100%
Statewide	282	282	0	100%

February 2023

District	Routes Down	Routes Recov. w/in Goal	Routes Recov. after Goal	Percent Recovered
Dist. 1	0	0	0	100%
Dist. 2	33	31	2	94%
Dist. 3	0	0	0	100%
Dist. 4	0	0	0	100%
Dist. 5	1	1	0	100%
Dist. 6	0	0	0	100%
Dist. 7	0	0	0	100%
Dist. 8	0	0	0	100%
Dist. 9	0	0	0	100%
Dist. 10	0	0	0	100%
Dist. 11	0	0	0	100%
Dist. 12	0	0	0	100%
Statewide	34	32	2	94%

January 2023

District	Routes Down	Routes Recov. w/in Goal	Routes Recov. after Goal	Percent Recovered
Dist. 1	148	147	1	99%
Dist. 2	183	182	1	99%

December 2022

District	Routes Down	Routes Recov. w/in Goal	Routes Recov. after Goal	Percent Recovered
Dist. 1	95	95	0	100%
Dist. 2	116	116	0	100%

Snow and Ice Dashboard

Snow and Ice Resources Reporting Dashboards Overview

Purpose	Provides overview of materials and costs for each season
Performance Measures	How much material was used in the season, totals per year, labor hours, truck miles, total cost, historical records, current inventory, average salt usage
Data Sources	Inventory Management System (via EIMS)
Refresh Rate	Daily
Users/Access	District level, Highway Maintenance Administration (HMA)
Platform/Software	PowerBI

The Snow and Ice Resources Reporting Dashboards are a crucial tool for maintaining efficient snow and ice removal throughout the season. They require strategic planning and resource allocation, serving as an essential resource for both district-level managers and the HMA.

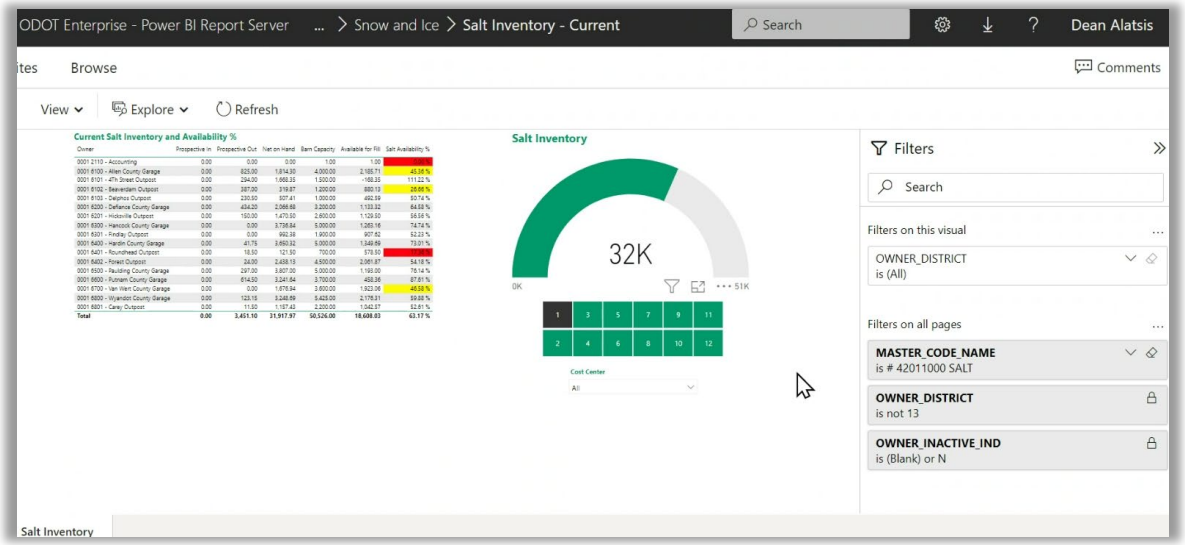
The dashboards track the usage of materials such as salt and other materials like de-icers and liquids, throughout the season, presenting yearly totals and historical snapshots dating back to 2015. They also update material in the system of record withing the next business day. As materials are entered into EIMS providing nearly real-time insight into the current material inventory across all garages, ensuring preparedness for upcoming storms. Additionally, they allow for the analysis of labor hours, truck miles, and total costs associated with snow and ice removal efforts, offering valuable insights into operational efficiency.

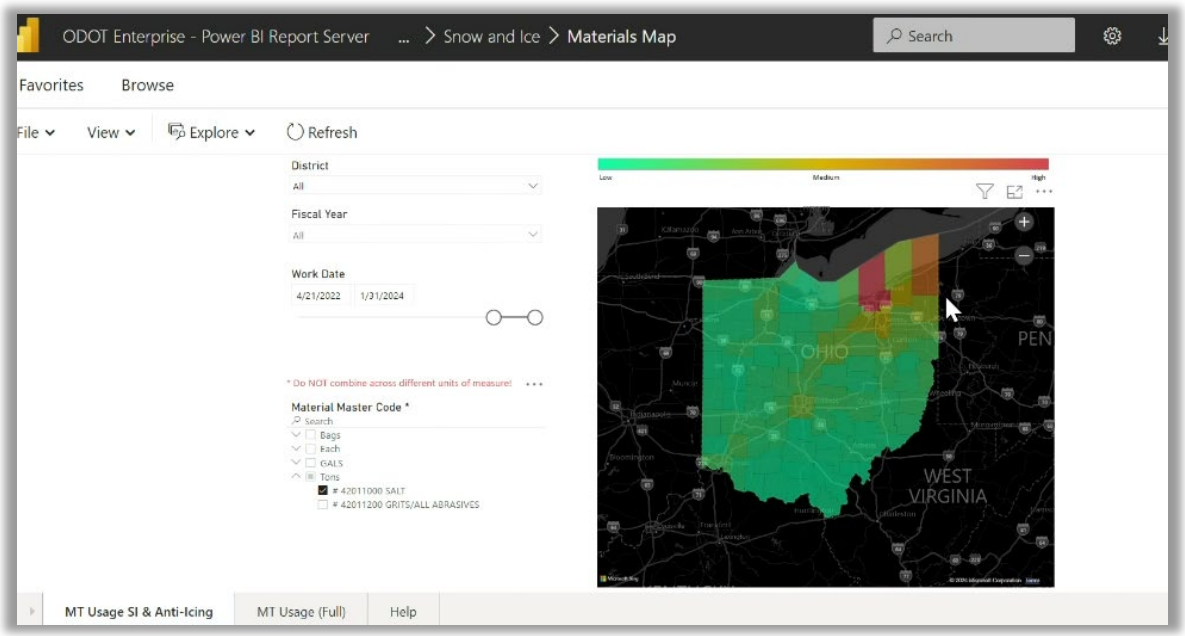
All information displayed on the dashboards are directly pulled from the EIMS inventory management system, ensuring data accuracy and consistency. Updates occur daily at midnight, reflecting any changes made within the EIMS system. However, delays may occur if garages experience high workloads and have not updated the system promptly.

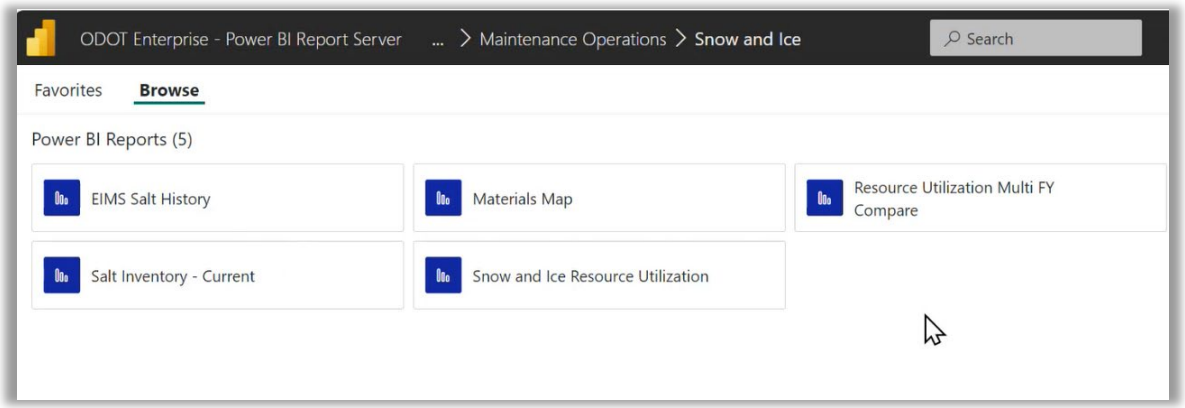
The dashboards offer several benefits to their users. District managers gain instant visibility into material usage across their respective districts, enabling proactive monitoring and resource allocation. The HMA can eliminate the need for daily inquiries to individual districts, improving overall communication and operational efficiency.

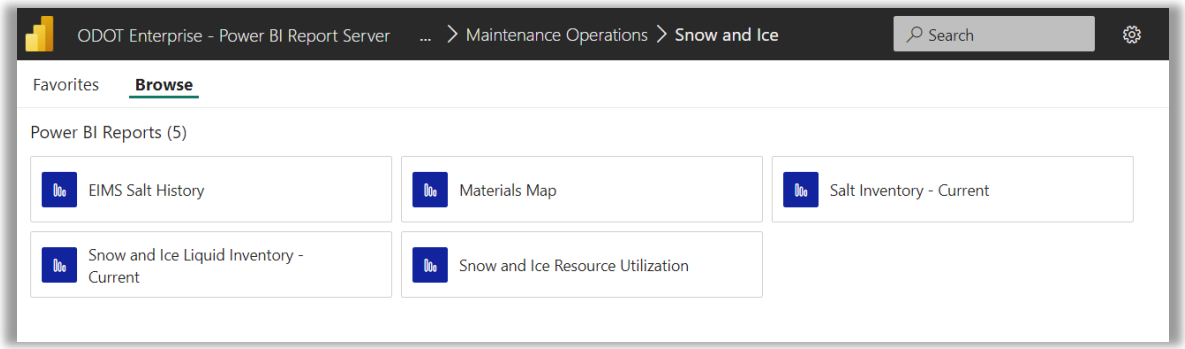
From a technical standpoint, the dashboards use PowerBI as a platform, providing a user-friendly interface for data visualization and interaction. They allow users to track salt and other material usage, monitor salt shed capacity and inventory, and access daily snapshots of resource utilization.

Several enhancements are planned for these dashboards. These include integrating data from the salt usage dashboard with a separate ordering system, offering a more comprehensive view of resource management. A similar dashboard dedicated to tracking liquid de-icing materials is also under development, further expanding the scope of winter resource monitoring.









Mobile AVL Dashboard

Mobile AVL Dashboard Overview

Purpose	To view number of trucks available in a district, compared to how many being used. Can also view salt application rate and speed based on district. Used to view AVL data quickly on mobile devices.
Performance Measures	Application rate, speed, and miles driven
Data Sources	AVL, manual winter truck reporting
Refresh Rate	Real time
Users/Access	Public and leadership
Platform/Software	AVL website

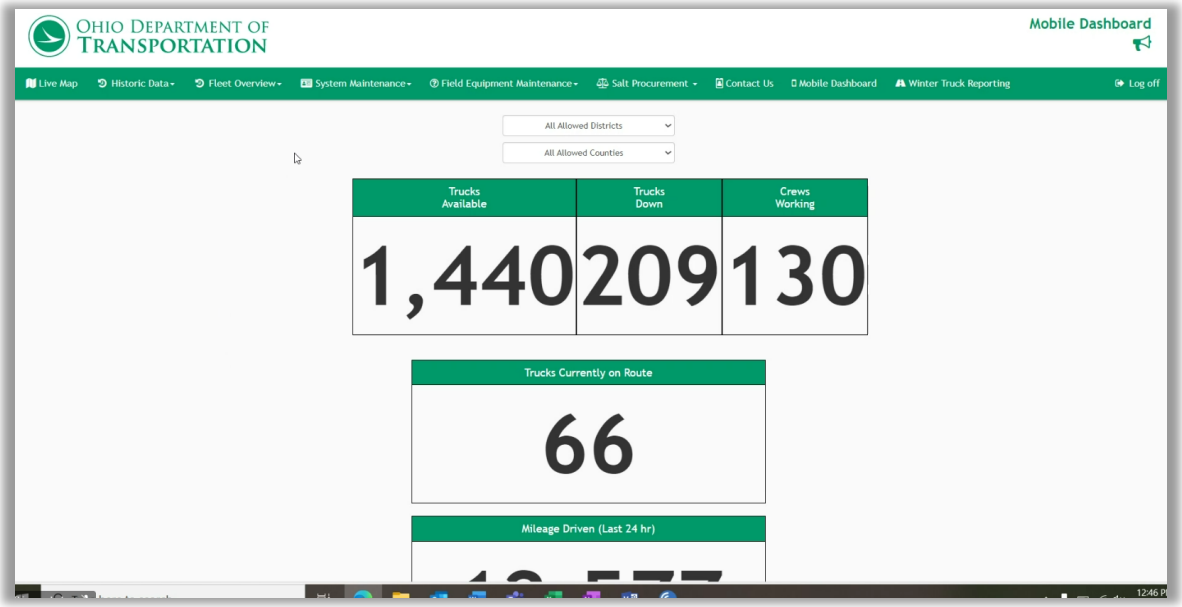
The Mobile AVL Dashboard has been developed to load easily on a mobile phone, providing a user-friendly interface for real-time spot checks. Although the map may take a little longer to load, it provides a comprehensive view of all trucks available in a district and how many are out on the routes.

The dashboards utilize GPS/AVL data to track trucks currently on route, specifically those outside of the geofence of the garage. They also include a Truck Usage History Dashboard and a Winter Truck Reporting feature. The latter requires manual updates every morning by daily morning entry, every 2 hours during storms, shift changes. These updates populate the dashboard with the latest truck availability information.

The primary purpose of the dashboards is to serve as an AVL/GPS - hydraulic/salt treatment dashboard. Users can select a district and pull all truck data from the last 30 minutes, including salt application rate and speed. Despite some issues with the accuracy of the hydraulics data systems, the mobile dashboards provide valuable insights into AVL on the fly, allowing users to see trucks available and crews working on snow and ice.

Performance measures include tracking trucks up/down, crews working on snow and ice, and miles driven (both 24 hours and 2 hours). The data sources for these dashboards include AVL and manually entered data from county managers or timekeepers, reported every morning and every two hours during an active event.

The dashboards refresh in real-time, providing up-to-date information for users. They are particularly useful for communication, allowing the public and leadership to stay informed about ongoing operations. The dashboards are hosted on the AVL website, ensuring easy access for all users.



Development of Dashboards

Dashboards are constructed based on specific needs. Requests for development funding are submitted to the IT department, which then evaluates the most suitable tools and options based on the intended use of the dashboard. This discussion continues until the foundational structure of the dashboard is established. The traffic management team oversees the performance of these dashboards. While there is no formal process for evaluating the performance of these dashboards, familiarity with the software and data can aid in identifying potential inaccuracies or areas for improvement. The PowerBI team has been instrumental in the development of the dashboards and assists in managing the servers on the backend.

During the development process, several challenges were encountered, including the creation of scripts for goal calculations due to their complexity. The assistance of a senior developer was invaluable in addressing these issues and redesigning the scripts. Data quality has also been an issue and must be

checked to ensure the most accurate readings are being used. These checks are performed manually and have quality thresholds in place to ensure standard procedures are followed.

Benefits / Lessons Learned

The implementation of these dashboards has yielded numerous benefits. Districts now have access to vital, relevant data at any time. The use of GPS/AVL data allows for real-time tracking of truck locations. Districts can utilize the available data to make informed decisions, and the impact of these decisions on routes can be measured. Leadership can use the information provided by the dashboards to make strategic decisions, and the communication division can use the data to highlight ODOT's efforts to assist the public and promote its work.

Future / Enhancements:

Several enhancements are planned for the future. These include adding liquids to the dashboards, merging salt ordering data in the Services and Support section, and enhancing the front end of the dashboard that displays the financial year summary. ODOT is exploring new data sources and may potentially create additional dashboards related to weather data.

Appendix F – Case Study Interview Summary: Virginia DOT

Overview

Virtual interviews were conducted by Ming-Shiun Lee, Allison Balogh, and Mallory Crow of AECOM and coordinated with the assistance of Bryan Wade and AJ Younes with the Virginia Department of Transportation (VDOT) on Tuesday January 23rd, 2024, at 11 AM EST.

VDOT Staff Interviews

Meeting attendees on Tuesday, January 23rd included the following individuals:

- Bryan Wade
- AJ Younes

Introduction

The VDOT started dashboarding with a goal to streamline the process of analyzing hired equipment data for statewide and ice contractors.

Winter Preparedness Dashboard

Winter Preparedness Dashboard Overview

Purpose	Visualize statewide data clearly which includes equipment and vendor details broken down by district, type, and salt available
Performance Measures	Material and equipment usage, location, and status
Data Sources	Districts self-report, salt is updated by garage personnel, Severe Weather Application Systems (SWAS)
Refresh Rate	30 minutes
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	Power BI

At its core, the dashboard displays equipment and vendor details, including multi-year and yearly agreements. This information is broken down by district and equipment type, providing a picture of VDOT's resources across the state. Additionally, the dashboard tracks material and equipment usage, location, and status, offering performance measures during critical winter events.

Data for the dashboard originates from multiple sources. Information on hired equipment vendors is collected through SWAS. VDOT equipment details are self-reported by individual districts. Importantly, salt availability data is currently entered manually by area headquarters' personnel, though it is linked to other materials and equipment at any selected location. Other crucial information, such as operational hours, is gathered through SWAS and integrated into a central data warehouse.

The dashboard updates automatically every 30 minutes, ensuring near real-time insights for authorized users. Public access is granted to anyone within the state, while primary usage falls on VDOT leadership during winter operations. Power BI serves as the underlying platform for visualization and data presentation.

While offering valuable insights, the dashboard also acknowledges limitations. The current system relies on manual entry for salt availability data, which introduces potential discrepancies. Additionally, not all data sources are fully integrated into a single, unified system of record. Despite these limitations, the winter preparedness dashboard remains a valuable tool for VDOT to assess its readiness, efficiently allocate resources, and make informed decisions throughout the winter season.

Winter Weather Event Dashboard

Winter Weather Event Dashboard Overview

Purpose	Provides weather event information as soon as someone accesses SWAS
Performance Measures	Equipment and material amount only for locations that are in an active event
Data Sources	Fuel system, SWAS
Refresh Rate	30 minutes
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

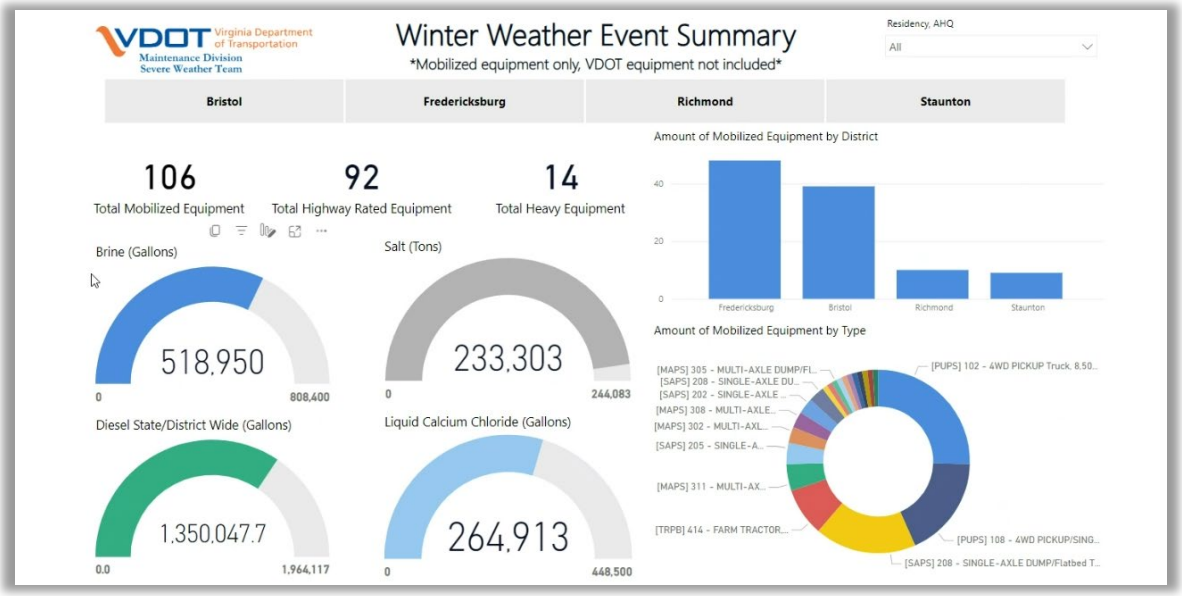
In response to winter weather events, VDOT employs a dedicated dashboard to monitor critical data in real-time. This platform automatically activates as soon as personnel begin mobilizing in the SWAS, offering valuable insights throughout the event's duration. Once the event concludes and SWAS activity ceases, the dashboard returns to a blank state.

Focusing on key performance measures, the dashboard provides an overview of resources deployed during an event. This includes tracking the number of mobilized pieces of equipment, categorized by specific areas within the state. Additionally, it monitors crucial supplies like salt, brine, and fuel, ensuring informed decision-making during critical response phases.

Data for the dashboard is gathered from various sources. Fuel level information is automatically updated daily from the designated fuel system. Similarly, real-time activity within SWAS feeds directly into the platform. Notably, the dashboard only populates with data once trucks are documented as mobilized within SWAS, ensuring a direct correlation between displayed information and ongoing operations.

Like the Winter Preparedness Dashboard, this platform refreshes every 30 minutes, maintaining near real-time insights for authorized users. Public access is available to anyone within the commonwealth, while VDOT leadership remains the primary user base during active events. Power BI serves as the platform for data visualization and presentation.

By providing a centralized hub for monitoring VINs, resources, and supplies, the winter weather event dashboard empowers VDOT leadership to make informed decisions throughout response efforts. While limited to active events triggered in SWAS, this platform remains a valuable tool for ensuring efficient resource allocation and effective management during critical winter weather situations.



Full Inventory Dashboard

Full Inventory Dashboard Overview

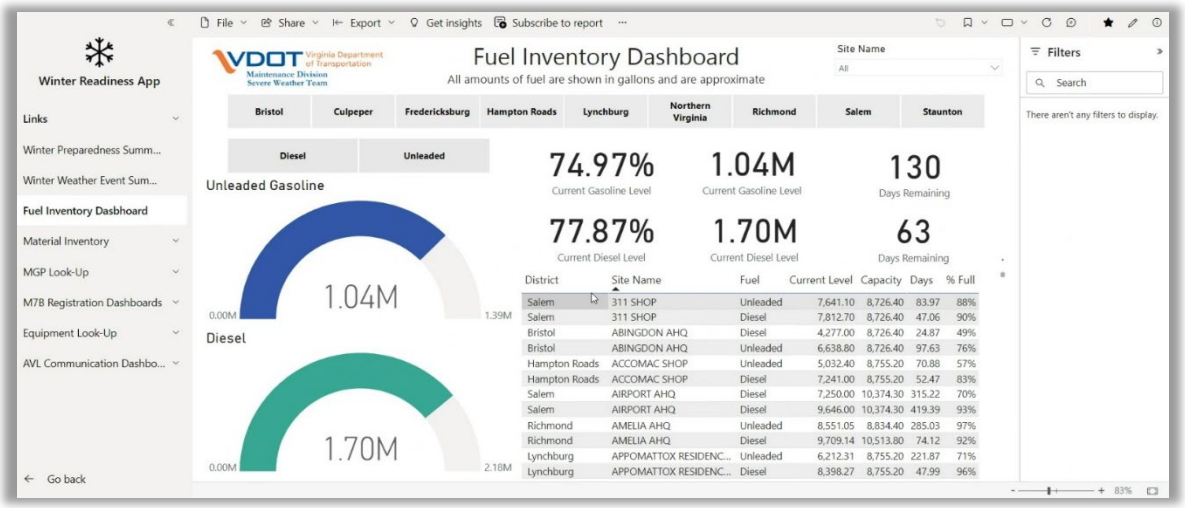
Purpose	To breakdown and summarize fuel data
Performance Measures	Calculate an average burn rate using past data and organize it based on fuel type, districts, and amount of fuel
Data Sources	Fuel System
Refresh Rate	Daily
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

Fuel management plays a crucial role in VDOT's operations. To gain deeper insights into fuel usage and optimize resource allocation, VDOT utilizes a dedicated Fuel Inventory Dashboard. This platform offers a comprehensive breakdown of fuel data, providing valuable information for both leadership and the public.

The dashboard allows users to filter data down to specific sites, enabling a granular view of fuel consumption across VDOT's facilities. Its core functionality lies in calculating burn rates. Leveraging historical data, the dashboard calculates estimated fuel consumption based on fuel type, individual districts, and the state's total fuel inventory. This information helps identify potential inefficiencies and opportunities for improvement.

Data for the dashboard originates directly from VDOT's fuel system, ensuring consistency and accuracy. However, it is important to note that the refresh rate is daily, meaning the displayed information reflects the previous day's data. While not real-time, this daily update offers a valuable snapshot of fuel usage trends.

Like the other dashboards discussed, public access is granted to anyone within the commonwealth, fostering transparency. However, primary usage falls on VDOT leadership, who leverage the insights to make informed decisions regarding fuel procurement, logistics, and resource allocation. Power BI serves as the platform for data visualization and presentation.



Material Inventory Dashboard

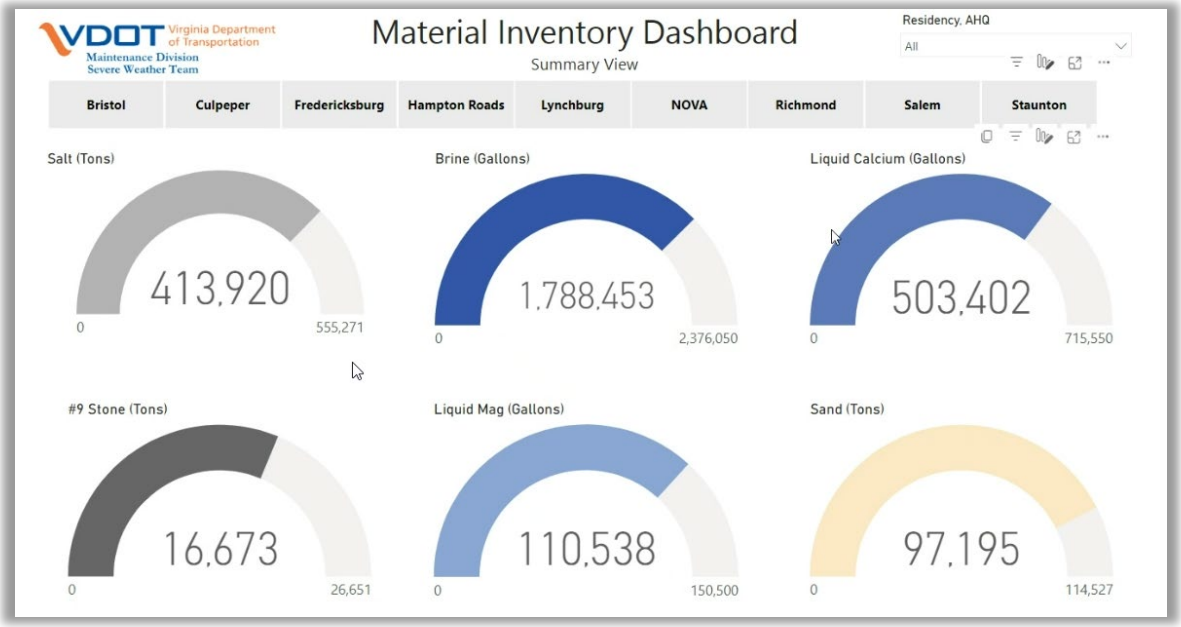
Material Inventory Dashboard Overview

Purpose	Material inventory data
Performance Measures	Material usage, availability, locations, and types
Data Sources	Field staff
Refresh Rate	Daily
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

Ensuring the efficient management of materials is crucial for VDOT operations. To achieve this, VDOT utilizes dedicated material inventory dashboards, offering insights into material usage and inventory levels across the state.

These dashboards primarily cater to two goals: firstly, providing a breakdown of materials used, and secondly, comparing those figures with what is currently ordered and on-hand. This comparison allows for proactive identification of potential shortages or surpluses, enabling informed decision-making regarding material procurement and allocation. The data for the dashboards is manually entered by field staff, ensuring timely updates. While the primary refresh rate is daily, more frequent updates can occur depending on individual garage practices. This approach offers a balance between timeliness and data accuracy.

Public access is available to anyone within the commonwealth, fostering transparency in VDOT's material management practices. However, primary usage falls on VDOT leadership, particularly local leaders and upper management. Garages directly input data, eliminating the need for them to rely on the dashboard itself. Notably, users can customize their view to tailor the information to their specific needs. Additionally, frequently used filters may be incorporated as default settings for all users, enhancing overall user experience.



M7B Registration

M7B Registration Dashboard

Purpose	To visualize and provide insight into the amount of M7B vendor and truck agreements by status and location
Performance Measures	Number of vendors, amount of equipment, status of agreements
Data Sources	SWAS

Refresh Rate	30 minutes
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

This dashboard helps to visualize and provide insight into the amount of M7B vendor and truck agreements by status and location. This centralized platform empowers users to streamline vendor management and troubleshoot any SWAS-related issues faced by vendors.

Secondly, the dashboard tracks key performance measures associated with M7B contractor vehicle registration. It displays the number of vendors, amount of equipment, status of agreements. This information helps VDOT identify potential bottlenecks and inefficiencies, aiming to achieve optimal self-reporting of equipment by contractors.

Data for the dashboard is automatically refreshed every 30 minutes, ensuring near real-time insights. While public access is available to anyone within the commonwealth, primary usage falls on VDOT leadership. Power BI serves as the platform for data visualization and presentation.

MGP Look-Up Dashboard

MGP Look-Up Dashboard Overview

Purpose	Provide VDOT Insight into a vendors minimum guaranteed payment for financial planning purposes
Performance Measures	Table of details from SWAS
Data Sources	SWAS and manual data
Refresh Rate	As needed
Users/Access	District/ Residency/ Area headquarters
Platform/Software	PowerBI

For some winter weather events, VDOT utilizes minimum guaranteed payment (MGP) agreements with contractors. These agreements ensure contractors receive a baseline payment even in low-snow seasons, while VDOT retains flexibility to call upon their services when needed. To manage these agreements effectively, VDOT employs the MGP Look-Up Dashboard.

This dashboard serves two primary purposes. Firstly, it provides a detailed table summarizing data pulled from SWAS. This table offers VDOT insights into contractor activity, enabling informed decisions about who to call upon during specific events. For instance, if a contractor with a minimum payment has not yet fulfilled their work quota, VDOT may prioritize them over other vendors without such agreements.

Secondly, the dashboard acts as a tool for ensuring fair distribution of work and timely payments. With access to individual MGP details, financial personnel within each district can monitor progress towards minimum payments. This allows them to strategically distribute workload throughout the season and ensure all contractors receive their guaranteed payments promptly. Additionally, the dashboard provides end-of-season insights into outstanding payments, facilitating efficient financial management.

It is important to note that the data displayed on the MGP Look-Up Dashboard requires some manual interpretation and manipulation by VDOT staff. Additionally, the refresh rate is not automated, meaning updates occur as needed. Despite these limitations, the dashboard remains a valuable tool for VDOT to manage MGP agreements effectively, ensuring fair treatment of contractors and optimal resource allocation during winter weather events.

The dashboard is primarily used by VDOT's area headquarters, districts and residencies, who leverage the information for decision-making throughout the winter season. Power BI serves as the platform for data visualization and presentation.

Equipment Verification Dashboard

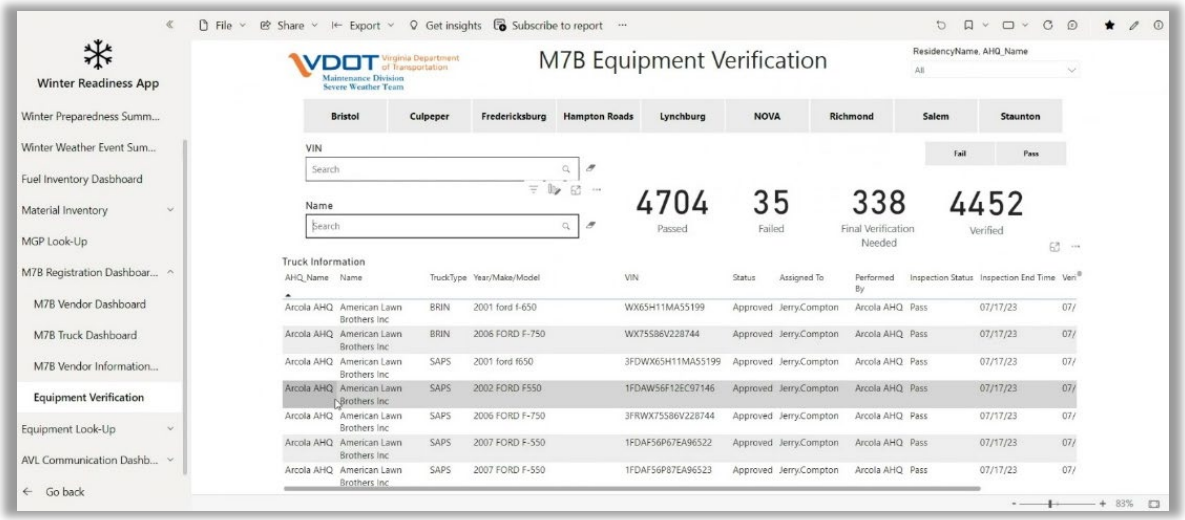
Equipment Verification Dashboard Overview

Purpose	Provides a database of equipment/vendor inspection details that was used to check the readiness of snow and ice removal equipment
Performance Measures	Pass/fail verification of inspection
Data Sources	Inspection System – CAL AMP K-12 (SYNOVIA)
Refresh Rate	Once a day
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

This dashboard offers two core functionalities. Firstly, it acts as a searchable equipment verification hub, drawing data directly from VDOT's SWAS and equipment verification system. This centralized platform empowers users to streamline vendor management and troubleshoot any SWAS-related issues faced by vendors.

Secondly, the dashboard tracks key performance measures associated with M7B contractor vehicle registration. It displays the number of active contracts and tracks the progress of contractor vehicles going through the equipment verification process. This information helps VDOT identify potential bottlenecks and inefficiencies, aiming to achieve optimal self-reporting of equipment by contractors.

Data for the dashboard is automatically refreshed every 30 minutes, ensuring near real-time insights. While public access is available to anyone within the commonwealth, primary usage falls on VDOT leadership. Power BI serves as the platform for data visualization and presentation.



Equipment Look-Up Dashboard

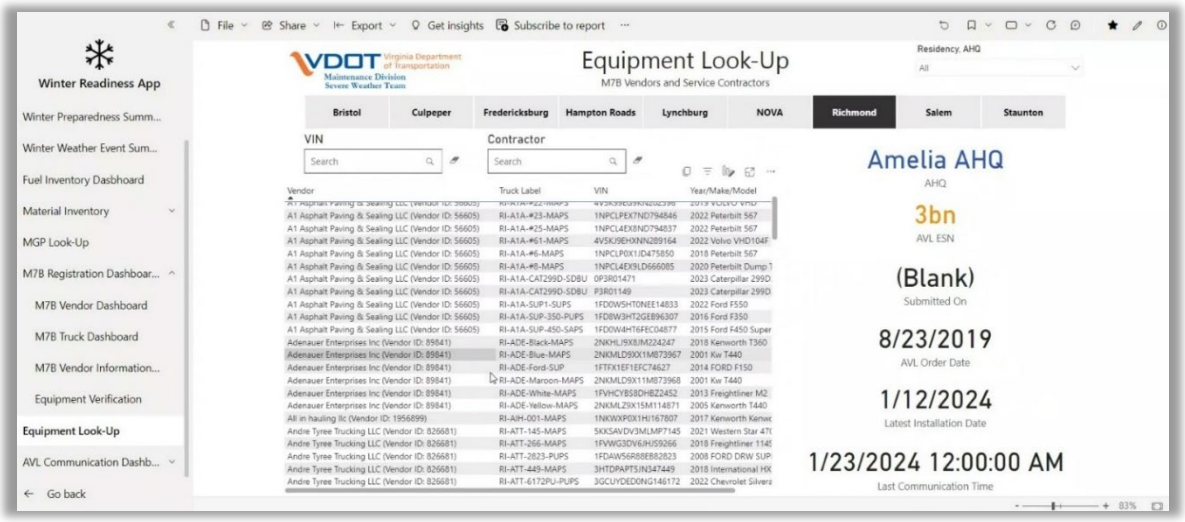
Equipment Look-Up Dashboard Overview

Purpose	To allow users to search all vendors and equipment in the database
Performance Measures	Agreement, Automatic Vehicle Location (AVL) orders, installation, AVL communications last ping
Data Sources	SWAS and AVL
Refresh Rate	Thirty minutes
Users/Access	Anyone in commonwealth but primarily leadership at VDOT
Platform/Software	PowerBI

VDOT relies on a diverse network of vendors and equipment to tackle winter weather events. To ensure efficient management and coordination, VDOT utilizes the Equipment Look-Up Dashboard. This platform offers a comprehensive searchable database, empowering users to locate specific vendors and equipment with ease. Unlike other dashboards limited to M7B program vendors, the Equipment Look-Up Dashboard extends its reach to encompass all VDOT-contracted vendors. This comprehensive approach makes it a valuable tool for verifying equipment details and streamlining communication across the entire winter operations network.

The dashboard goes beyond listing vendors and equipment. It provides key performance measures related to each entry. This includes details regarding active agreements, AVL orders, equipment installations, and the most recent communication ping from AVL systems. This information allows users to assess equipment readiness and identify potential issues promptly.

Data for the Equipment Look-Up Dashboard is gathered from multiple sources. SWAS provides vendor and agreement information, while the AVL order date system and AVL system itself contribute installation and communication data. With a refresh rate of 30 minutes, the dashboard offers near real-time insights. While public access is granted to anyone within the commonwealth, primary users come from VDOT's district and residency levels, directly interacting with vendors on the ground. This ensures that those closest to operations have the information they need to make informed decisions and collaborate effectively. Power BI serves as the underlying platform for data visualization and user interaction.



Emergency Management Center Dashboard

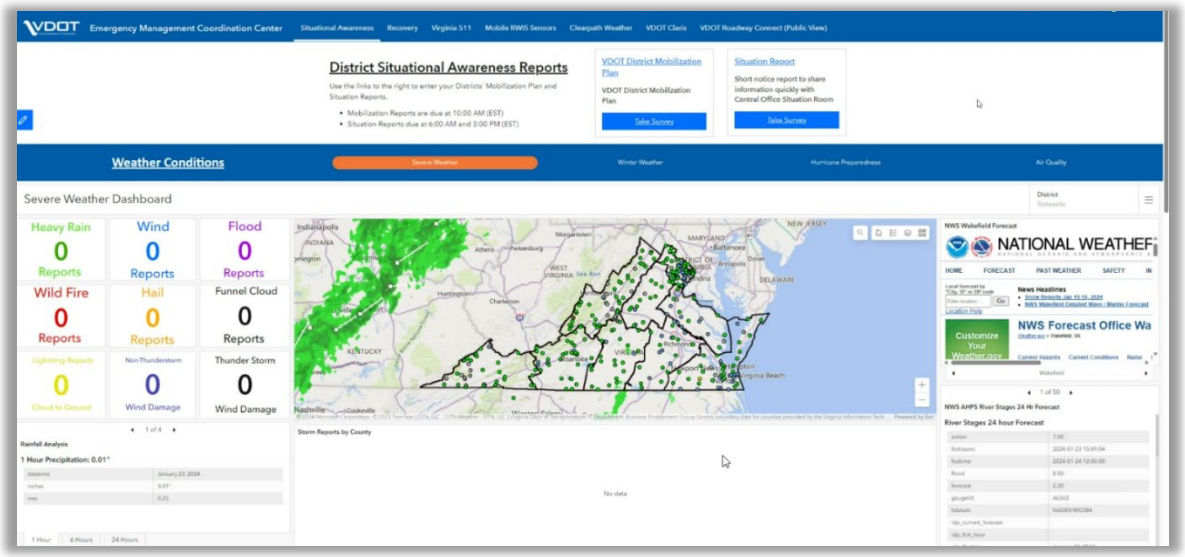
Emergency Management Center Dashboard Overview

Purpose	Provides all weather information
Performance Measures	Snow and radar
Data Sources	Data Transmission Network (DTN) data, local storm reports, radar, National Weather Service (NWS), AVL, Waze, other spatial details
Refresh Rate	Real time
Users/Access	State partners and districts
Platform/Software	ArcGIS Online (AGOL)

The Emergency Management Center Dashboard is a specialized tool that focuses on emergency management. Its primary purpose is to provide comprehensive weather information. This includes data on various weather conditions, with a particular emphasis on snow and radar data. The dashboard's performance is evaluated based on the accuracy and timeliness of this data.

The data used by the dashboard is collected from a variety of sources. These include DTN, local storm reports, radar, the NWS, AVL systems, Waze, and other spatial details such as park and ride locations. This diverse range of data sources allows the center to make informed decisions during emergencies.

One of the key features of the center is its real-time data refresh rate. This ensures that the most current information is always available, which is crucial during emergency situations. The platform is designed to be shared with state partners and districts. It has a flexible permission system that allows for various views on the hub, depending on the access level granted. The center operates on the AGOL software platform.



Damage Assessments Dashboard

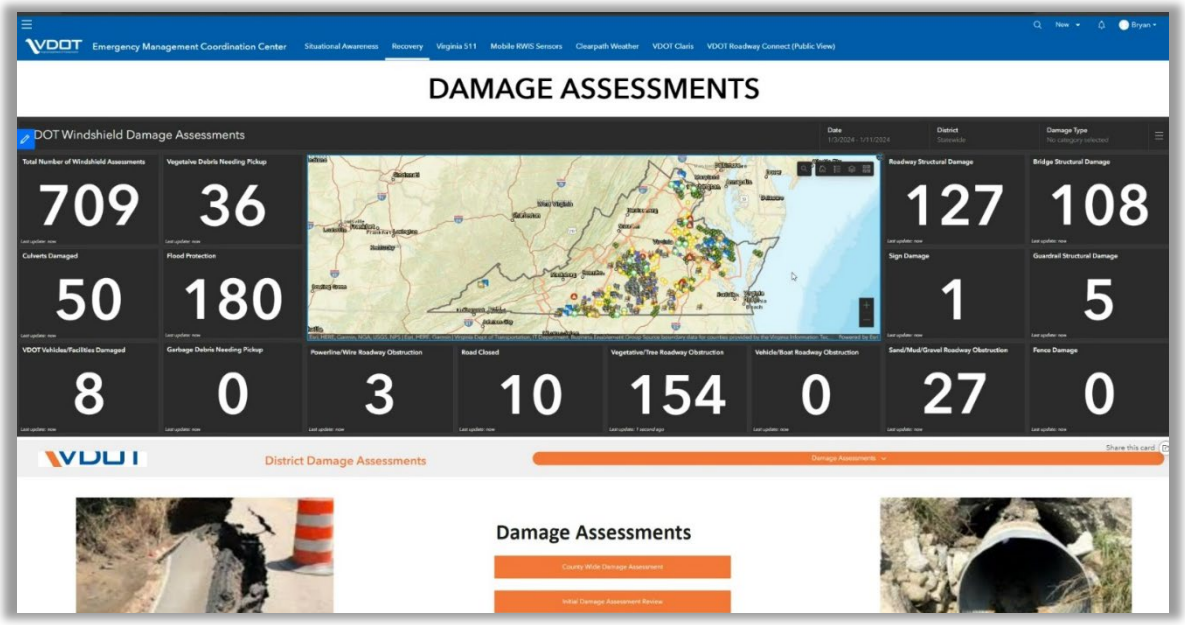
Damage Assessments Dashboard Overview

Purpose	Track, manage, and add value to damages and determine if the Federal Emergency Management Agency (FEMA) or Federal Highway Administration (FHWA) are needed. This dashboard will also track the review/status for the damage reports.
Performance Measures	Status of reports, images of damage, cost of damage
Data Sources	Survey 123 from field crews
Refresh Rate	Real time
Users/Access	State districts
Platform/Software	AGOL

VDOT faces the crucial task of assessing damage and initiating repairs efficiently. To streamline this process and ensure timely recovery, VDOT utilizes a dedicated Damage Assessments Dashboard powered by AGOL. This dashboard serves several key purposes. Firstly, it provides a centralized platform for tracking and managing all reported damages, offering a comprehensive overview of the situation. This allows VDOT to prioritize repairs based on severity and resource availability. Secondly, the dashboard facilitates the process of adding value to damage assessments. By integrating with relevant systems and

procedures, the dashboard can help determine eligibility for federal assistance from FEMA or FHWA, streamlining financial recovery efforts. Thirdly, the dashboard allows VDOT to track the review and approval status of individual damage reports.

Performance measures displayed on the dashboard include the status of each damage report, associated images for visual verification, and estimated repair costs. This information empowers VDOT leadership to make informed decisions regarding resource allocation and prioritize critical repairs. Data for the dashboard originates from Survey123, a mobile data collection app utilized by VDOT field crews. This app streamlines the data collection process, capturing information directly at the damage site and feeding it into the dashboard in real-time. This eliminates manual data entry and significantly reduces processing time. Prior to implementing Survey123 and the AGOL dashboard, damage assessments were a manual and time-consuming process, often taking weeks to complete. The digitalized approach has updated VDOT's response, saving weeks of time and enabling a more efficient and data-driven recovery process.



Development of Dashboards

The process for deciding the development of dashboards for VDOT is based on if there is a manual process that can be automated to save time. By having dashboards that automate work, resource sharing has become easier. With the data platforms VDOT has available, they can make as many dashboards as they need. The more productions and users there are the more enhancements that take place.

A team of Emergency Operations and Management Specialists mostly developed these dashboards. The extract, transform, and load process for the dashboard involved using Power Automate tools and all data was stored in the cloud and exported and shares from ESRI. The accuracy of the data is usually verified by the provider, but when data does have errors from moving it is easily catchable as the team is very familiar in what “normal data” looks like. Most of the data is stored in an IT data warehouse; however, a large-scale data system for PowerBI is in the works. Some of the team use ESRI cloud storage. Data can be queried as far back as 2019 from ESRI’s cloud storage, however PowerBI cannot go back and view older data since there are so many changes made to historical data.

Some issues that were encountered in development of these dashboards include issues with internal connections to PowerBI and collaborating with vendors. No specific issues with ESRI occurred since there were plenty of online resources.

System Operations and Maintenance

The hosting of the dashboards and who is responsible for updating the data varies depending on the dashboard. The same team that developed the dashboards, which is the team of Emergency Operations and Management Specialists, is also responsible for their maintenance if there are any issues or enhancement that needs to be made. The databases for these dashboards are maintained by ESRI and an Emergency Operations Specialist, and IT maintains the data warehouse for PowerBI. The costs to maintain these dashboards and resources are associated with the personal who use and maintain them. VDOT has 700 ESRI licenses with cloud services and weather vendors.

Benefits / Lessons Learned

Some of the benefits gained from having these dashboards include having a faster response time, automating workflow, dealing with less emails, standardizing processes, resource allocation, and managing vendors. Some lessons learned from creating these dashboards were that going to ESRI conferences helped gained a deeper understanding because the team was able to meet other users and gain in-person assistance. By speaking to other DOT's, new dashboards can be inspired. Also, VDOT has a lot of people skilled in software, but they need to communicate more efficiently so that work is not duplicated.

Future / Enhancements

Some future enhancements include adding 511 data involving road closures during the winter into the emergency response dashboards. Also using ArcGIS Velocity for early weather warnings as well as big data analytics with damage assessments and insight for analytics. For PowerBI, the team would like to explore the possibility of using historical data. A new data miner is also in the works to potentially be implemented for situational awareness security.

research for winter highway maintenance

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