RESEARCH

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Utah Department of Transportation - Research Division
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ESRI INSIGHTS PHASE II: THE WAR ROOM

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16. Abstract

UDOT is developing a dashboard that can display information for winter storm events. This project is focused on creating a one-stop shop for decision-making tools and will serve to inform operations managers, who will be making decisions based on feedback from the dashboards. The recommendations this report makes will help the Maintenance Operations management team understand their options for snowplow data management. Literature support and data collection methods had already been established in previous efforts, so this project focused on extending current knowledge into better and more integrated analysis tools.

Challenges remain for parsing large-scale data, such as big data collection issues and platform instability. Currently, the snowplow dashboard offers a simple view of the cost of operations. Other tools (such as letter grade, duration, and maximum intensity) will be integrated when the platform is adequately stable and as other data enhancements are made. One of the biggest challenges UDOT is facing is the large volume of snowplow locations, which makes it difficult to prepare and visually display all the data points. The ArcGIS GeoEvent Server being used for the dashboard crashes often, and the entire workflow is complex and somewhat fragile. The web map also becomes slow and cluttered if it tries to display all the snowplow locations for a given snowstorm, which detracts from the user's experience and ability to use the dashboard.

Before the dashboard can be fully implemented, these challenges will need to be addressed. UDOT is currently investigating a possible alternative for processing the location points in a way that will avoid the current technical challenges, at least until a stable installation is achieved.

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LIST OF ACRONYMS

FHWA	Federal Highway Administration
UDOT	Utah Department of Transportation
RWIS	Road Weather Information System
AVL	Automatic Vehicle Location
TOC	Traffic Operations Center
FY21	Fiscal Year 2021

EXECUTIVE SUMMARY

The collection, processing, and visualization of existing big data sets are becoming critical issues. Using the data that UDOT is generating from its operations will provide critical feedback that can support better decision making both in real time and in post analysis. However, unique challenges exist in parsing large-scale data. Size issues stemming from server management systems and dashboard/visualization tools have created stumbling blocks to implementation.

This report focuses on collecting, coordinating, and visualizing big data from two UDOT sources: Road Weather Information Systems (RWIS) and Automatic Vehicle Location (AVL). However, the methodologies, opportunities, and challenges presented here will hold true for other forms of big data-oriented projects. Recommendations for moving forward will help the Maintenance Operations management team understand their options for snowplow data management and will allow others looking for big data management tools to more quickly find actionable tools and methods to reach their desired output.

Because technology support in this area is quickly growing, the implementation of this tool from conception to its current state and the planned features for future dashboards have not been a static or linear effort. Instead, the evolution of this tool from concept to usable data display evolves from both sides. Behind the scenes, the data management tools and methods continue to be refined; similarly, the end-user interface (the dashboard itself) continues to be reconceptualized both to suit management's needs and due to the constraints with the tools. Currently, the War Room dashboard offers a simple view of the cost of operations. With the core infrastructure behind this dashboard's current iteration in place, it can continue to be extended to meet the desired needs and outputs identified in the goals section of this report.

1.0 INTRODUCTION

1.1 Problem Statement

In the proposal document for this research project, titled *ESRI Insights Phase II: The War Room*, the authors state the problem as follows:

> *UDOT's ESRI ArcGIS Online platform, UPlan, is the web interface for the organization and display of the Department's spatial data, enabling data-sharing between divisions and Regions, and supporting transparency by making information available to the public. With this project we would like to build upon the 2017 UTRAC project entitled "ESRI Insights: Leveraging Spatial Data to Empower Decisions" to create a War Room-type dashboard that would enable mid to senior leadership to be able to see the performance of the maintenance crews regarding snow and ice removal during and after a specific snow event. This War Room-type dashboard would be built off of the existing ESRI-based dashboard that has been created with the previous 2017 UTRAC project but would now include the following information in a "one stop shop" based off of specific Roadway Weather Information System (RWIS) stations: 1) Letter grade for snow removal efforts, 2) Duration of the storm, 3) Maximum Intensity of storm and When it occurred, 4) and the Cost associated with each storm event.*
>
> *This project's intent is to blend the already existing dashboards of ESRI Insights Snow Plow Dashboard and the Snow & Ice Performance Dashboard into a single platform: The War Room Dashboard. The War Room Dashboard would exist in both a desktop computer platform and also in a mobile app platform.*
>
> *This War Room Dashboard would empower mid and senior level leadership to be able to visualize and comprehend the actual effect that the snow removal crews are having on the roadways during and after winter storm events so that*

> *intelligent decisions can be made regarding altering operations if it is needed to streamline and optimize the process.*
>
> *This project will help UDOT reach its goals of Transparency, Fiscal Responsibility, and Optimizing Mobility.* ***Transparency*** *will be achieved by having an interactive dashboard that the Public can access to see how their tax dollars are being spent regarding keeping the roadways clear of snow and ice.* ***Fiscal Responsibility*** *will be achieved by UDOT continuing to strive to conduct snow removal operations in the most cost effective and efficient manner with this dashboard being a prime indicator on the effectiveness of the operations.* ***Optimizing Mobility*** *will be achieved as UDOT becomes finer tuned in their snow removal efforts based on feedback that the dashboard will provide during and after the storm event. This will lead to higher Levels Of Service (LOS) on the roadways and thus will help optimize the mobility of the traveling Public in the State. (Ferrin, p. 1)*

While providing guidance, this problem statement has evolved through the course of developing this research project as new challenges were identified.

1.2 Objectives

In the original problem statement, the authors desire "to build a War Room-type dashboard that can display the following information for winter storm events: 1) Letter Grade, 2) Duration, 3) Maximum Intensity and When, and 4) Cost." Because of the difficulties in establishing the big data architecture, the cost dashboard was created first, along with locations of snowfall. The other tools will be integrated when the platform is adequately stable and as other data enhancements are made. While the infrastructure behind the current dashboard will soon be able to support the desired items, the focus of the dashboard's current interface has been the costs, both estimated prior to official reporting and actual once official reporting of quantities are complete, as the metric of interest. From this foundation, the remaining items can be integrated.

1.3 Scope

By building on work performed in previous years, management was able to assess the performance of UDOT's snow removal efforts in real time. This research project focused on creating a one-stop shop for decision-making tools that could offer insights in real time as well as assessing prior efforts with the goal of improving future efforts in an adaptive management framework. Spatially, the scope includes the snowplow shed management areas. Temporally, the data is collected and updated in real time for the state fiscal year units.

The primary audience of the dashboard are the operations managers who will be making real-time decisions based on feedback from the dashboards. However, because this is also an effort to steward state resources and ensure transparency, the actual audience may expand to include executive and legislative state leadership, UDOT executive management, and members of the public with an interest in government transparency.

1.4 Outline of Report

This report is divided into seven chapters:

- Introduction
- Research Methods
- Data Collection
- Dashboard Development
- Conclusions
- Recommendations and Implementation

2.0 RESEARCH METHODS

2.1 Overview

Approaching this project, it was clear that literature support and data collection methods had already been established in previous efforts. Therefore, the methods involved in this specific project were intended to extend current knowledge into better and more integrated analysis tools, rather than create an entirely new foundation for this project. To this end, the main tasks to be accomplished included:

1. **Coordinate the sharing of existing datasets** between the UDOT Traffic Operations Center (TOC) and the selected consultant performing the work to be fed into the War Room-type dashboard;
2. **Create two prototype War Room Dashboards** (a desktop application and a mobile application) complete with actual datasets based on the objectives that have already been given;
3. **Conduct a proof-of-concept presentation** for UDOT senior leadership in order to get feedback to further refine the two versions of the dashboard to meet the needs of the Department.

The timeline of developments of this project followed three basic milestones. Through the first quarter of the year, an Esri ArcGIS GeoEvent Server was set up through Amazon servers to collect the data and FME was used to coordinate the data into a useable format. By August, the process was refined enough to begin construction of a dashboard interface using Esri Operations Dashboard, which functions in both a mobile and desktop interface. By October, the data for plowed locations and storm locations were being aligned with three aspects of cost (employee hours, salt, and equipment) to create the desired dashboard output. While ongoing efforts may increase the dashboard's capacity, the current project is expected to complete at least the cost aspect by the end of January 2021.

2.2 Background/Methodology Item 1: Coordinate the Sharing of Existing Datasets

In 2017, the UDOT maintenance team initiated a research project that would allow them to 1) understand how Esri Insights can add value and complement existing data management tools already used at UDOT, 2) prove the application's ability to add value to UDOT's existing spatial data by offering new opportunities to analyze and report on spatial data, and 3) integrate aspatial and spatial data. This research led to the first integrated system using AVL data alongside RWIS information, however, limitations such as "walls" between data sets have made automation and integration of further data sets difficult. Since that time, UDOT and the consultant have identified better tools for data integration. Furthermore, Esri's dashboard capabilities of the tools have progressed. As a result, the dashboards that were established in the 2017 project have now been extended into an integrated War Room Dashboard. This involved the following steps: identifying processing tools and developing processing steps for coordinating data.

2.2.1 Identifying Processing Tools

In 2019, FME was identified as a potential tool that would facilitate the simple coordination of massive data from multiple sources, creating a structured output that could be queried and output to applications. FME is a software product by Safe Software that allows users to customize workflows, automating work efforts like collecting, converting, and compiling data according to a schedule.

From the workflow, the data is saved to an Amazon-hosted ArcGIS GeoEvent Server that integrates with Esri products, including the dashboard tools that will create the final version of the snowplow dashboard.

2.2.2 Developing Processing Steps

The FME workflows relied on Python scripts to connect and transform data. Eight distinct scripts were created for integration into the FME workflow for the following data items: snowplow locations, costs (divided into personnel, salt, and equipment), preparation of RWIS points from Oracle database query, recombined RWIS and cost table, assignment of event ID to cost table so storm and cost can be related, compilation of the massive quantity of points into a

smaller number of multi-point features for faster display, and finally, the last script which pulls the actual cost to date of UDOT's snow plowing activities.

2.3 Create Two Prototype War Room Dashboards

Due to the unpredictable nature of winter storm conditions, storm response must be mobile and flexible. To this end, the War Room features needed to be presented in online formats that could accommodate review for future decision making, as well as in a mobile (cellphone-based) format that could give information to decision makers away from the office. These prototypes were developed by August of 2020 but continue to be updated to better meet UDOT management needs and to better operate from the data storage systems.

2.4 Conduct a Proof-of-Concept Presentation

Because the tool developed in response to many unforeseen constraints, the proof-of-concept presentation was more like a series of presentations and iterative feedback. Throughout the one-year development period, meetings were held when milestones were achieved, including the establishment of the ArcGIS GeoEvent Server and the various design stages of the dashboard itself. The following table shows the dates that the authors of this report met with the client for proof-of-concept development and briefly highlights the meetings' themes.

Table 1: Date and Theme of Proof-of-Concept Presentations

Date	Theme(s)
5/18/2020	• Follow-up on architecture setup • Discuss data move and connections
5/28/2020	• Follow-up on architecture setup • Review data move and connections
6/1/2020	• Follow-up on architecture setup • Review data move and connections
7/6/2020	• Review schedule and tasks • Discuss server performance • Report on data move and connections • Discuss data questions

7/20/2020	• Review action items • Discuss server performance • Report on data connections • Discuss draft cost calculation methods and associated data questions
7/27/2020	• Review action items • Discuss server performance • Report on data connections • Discuss draft cost calculation methods and associated data questions
8/3/2020	• Review action items • Discuss server performance • Report on data connections • Discuss draft cost calculation methods and associated data questions
8/10/2020	• Review action items (CSVs to right folder for daily export) • Report on data connections
8/17/2020	• Review action items (resolve errors for database save) • Report on data connections
9/9/2020	• Review equipment pricing details • Check in on database progress • Discuss schedule
9/14/2020	• Check in on data services progress
9/23/2020	• Discuss progress and items needed
10/5/2020	• Review draft dashboard
10/19/2020	• Review draft dashboard
11/2/2020	• Review draft dashboard
11/9/2020	• Kick-off on Time and Cost-Benefits Effort • Follow up on other dashboard items
11/23/2020	• Discuss baseline for travel time with snow • Discuss baseline for crashes with snow
11/30/2020	• Identify and make a plan to resolve the issues with the services and the ArcGIS GeoEvent Server
12/7/2020	• Review analysis completed and determine use
1/11/2021	• Review literature review completed and determine use for future elements • Follow up on server performance issues

The arc of the conversation presented in the table above highlights the challenges discovered throughout the process. However, the cost dashboard itself is currently in a useful format and can begin to be implemented at a management level with some additional architectural stability.

2.5 Summary

The methodology explored above resulted in a functional dashboard with features that are usable as a post-assessment of maintenance performance on both mobile and desktop formats. Subsequent chapters will discuss the foundation, design, and usability of the dashboard itself.

3.0 DATA COLLECTION

3.1 Overview

This research project does not generate any new data; rather, the goal is to create a more usable output for the data that is already collected by UDOT. The following sections contain descriptions that mostly concern the adaptation of these existing sources into a usable output.

3.2 Snowplow Location

When snowplows are running, location information is periodically recorded and made available via Verizon's NetworkFleet API. ESRI's ArcGIS GeoEvent Server automatically receives the location information, converts it into GIS points, and saves the data in a Spatiotemporal Big Data Store database. The data is pushed out as an ESRI Feature Service named "AVL_Storage". The data is then filtered into a view named "FY21_Snowplow" that contains only snowplow locations during the fiscal year 2021 (FY21).

3.3 Supporting Data

Supporting data was gathered, prepped, and published as a Feature Service named "Support_Data". This data contains RWIS station locations, maintenance shed information, snowplow components, and equipment rates.

4.0 DASHBOARD DEVELOPMENT

4.1 Overview

This chapter is divided into two parts: the preprocessing steps required to set up the dashboard and the configuration of that dashboard.

4.2 Preprocessing the Data

All the data needed to run the dashboard is in a Feature Service named "FY21_Data". The data is updated via eight python scripts. These python scripts were embedded in an FME project named "update_snowplow_cost_dashboard." This FME project is scheduled to run once a day, thus updating the dashboard's data daily.

4.2.1 Python Scripts

The purpose of the eight python scripts within the FME project are described below, and corresponding numbers are on the workflow diagram for reference.

Script #1 uses the snowplow location data to identify the days that snowplows were active and adds a row for each snowplow and day in the cost table.

Script #2 uses the supporting data to estimate personnel, salt, and equipment costs and adds these estimates to the corresponding cost table rows.

Script #3 uses RWIS data from an Oracle database (#3a) and from the supporting data (#3b) to prepare RWIS points to show snow intensity on the dashboard map.

Script #4 uses RWIS data now in the RWIS prepped table and the snowplow active days now in the cost table to determine storm events and save the storm events in a table named "Storms."

Script #5 assigns the storm event ID to the cost table thereby relating the data together.

Script #6 assigns the storm event ID to the RWIS prepped data thereby relating the data together.

Script #7 uses the FY21 snowplow points and combines all the points for each snowplow per day into a multipoint feature. The multipoint feature draws better on the dashboard map than single-point features.

Script #8 uses UDOT's accounting data to calculate the actual cost to date of UDOT's snowplowing activities.

The following diagram shows how these scripts relate the data to each other, showing how the output gets to the Esri Dashboard tool.

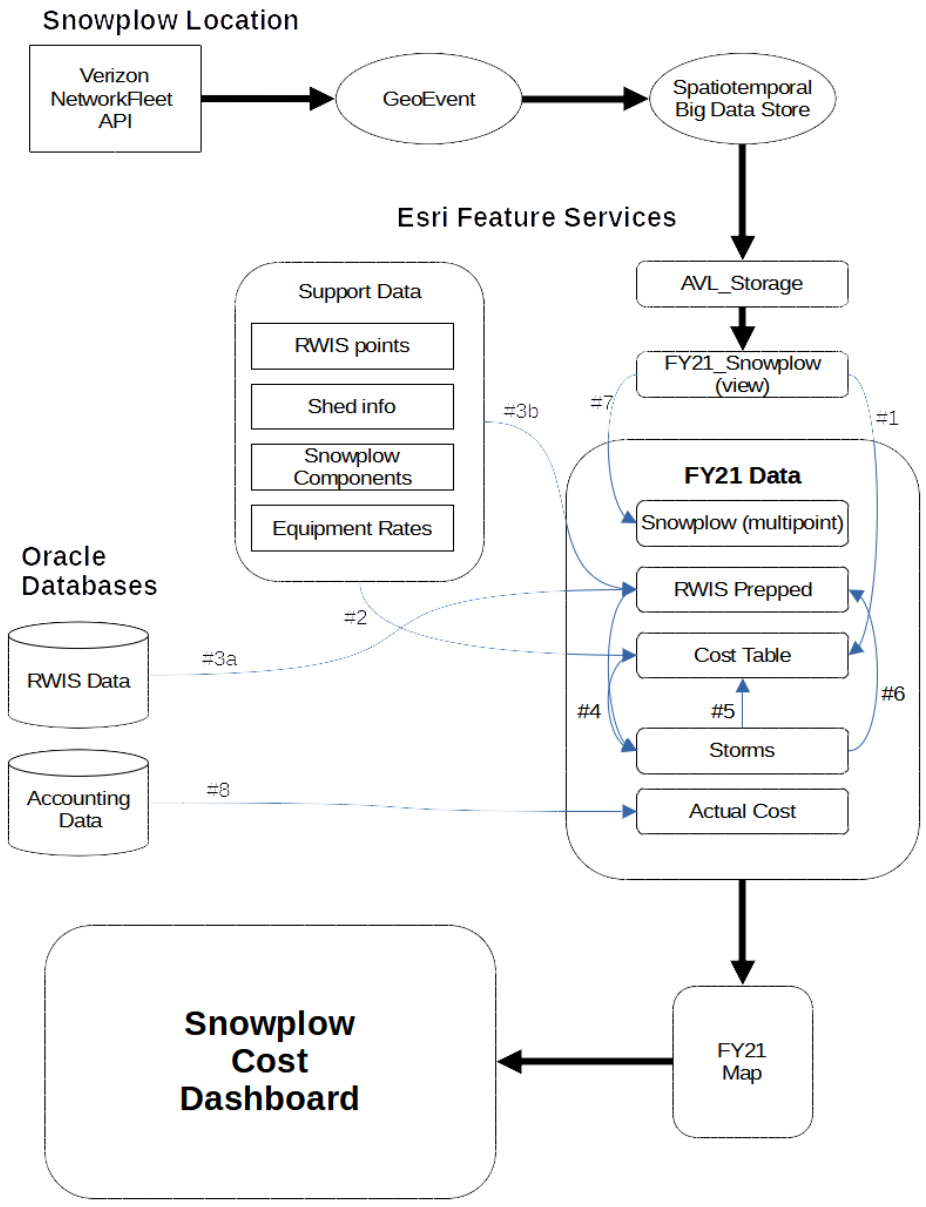


Figure 4.2 Workflow for Preprocessing Dashboard Data

4.3 Configuring Dashboards

A FY21 map was created that contains the FY21 Data Feature Service. This map "drives" the dashboard, meaning the map is the primary connection to the data that is summarized as statistics in other frames within the application. When using the snowplow cost dashboard, a user can select a storm event to view the estimated personnel costs, salt costs, and equipment costs in their respective frames along the left-hand side of the page. Below that, the three costs are summed into a total cost which is the estimated snowplowing costs for that storm. The map updates to show the snowplow locations for the selected storm, and it gives an overview of snowfall intensity as a map overlay. Finally, the bottom-most frame shows the official year-to-date cost of snowplow operations given by UDOT's Comptroller's office.

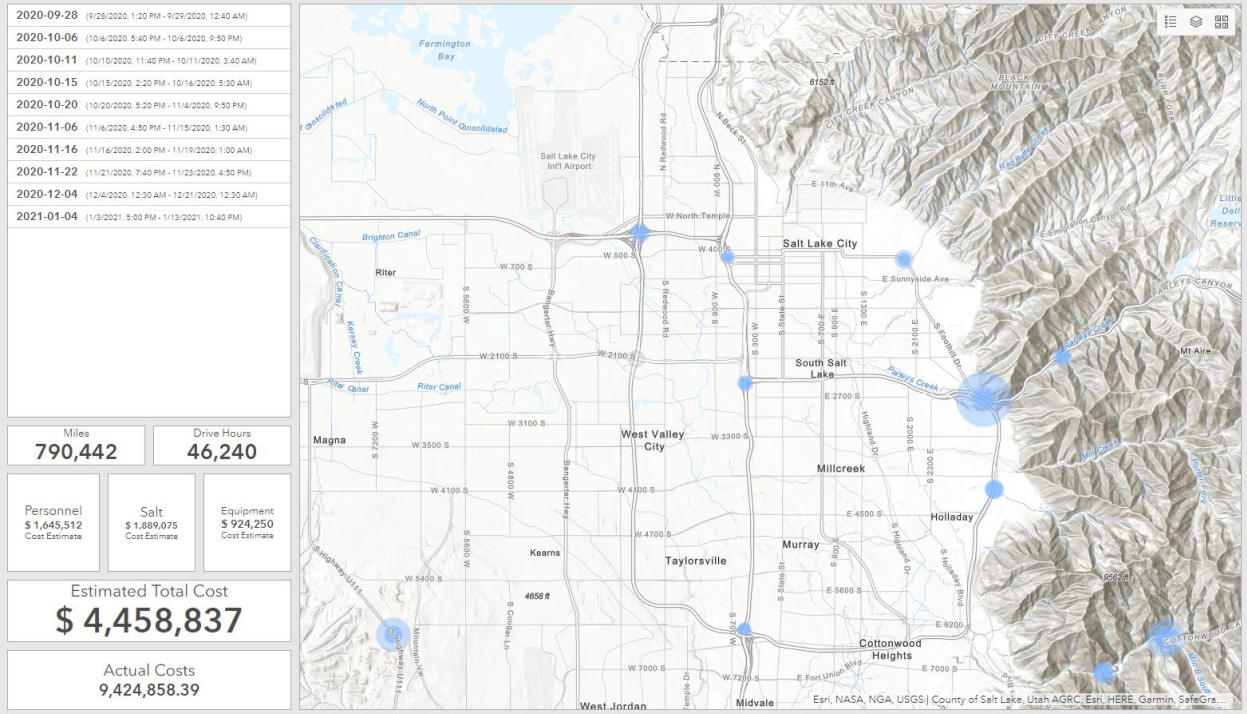


Figure 4.3 Dashboard Overview

5.0 CONCLUSIONS

5.1 Summary

The snowplow dashboard concept holds promise for management at all levels within UDOT and for transparency purposes outside of UDOT. However, challenges remain, such as big data collection issues and platform instability. These are discussed in detail below.

5.2 Findings

The current snowplow dashboard helps to identify where costs are being accrued relative to storm locations and plowing operations. The dashboard also has the potential to align the costs with the performance analysis, establishing a cost-benefit ratio that could help improve overall effectiveness of winter maintenance activities. By rolling this cost analysis into the War Room concept, the general data infrastructure can be leveraged into the big-picture perspective the Department desires.

5.3 Limitations and Challenges

The very large volume of snowplow location points causes difficulties for the dashboard, both in data preparation and in display. Many hours and attempts were required to set up an ArcGIS GeoEvent Server to receive, process, and store the storm locations. Still to this day, the ArcGIS GeoEvent Server crashes often, bringing the Feature Services and dashboard down. Because GeoEvent uses UDOT's Esri Portal hosting, whenever the ArcGIS GeoEvent Server goes down, any hosted Feature Service also goes down, even if it is not connected to the ArcGIS GeoEvent Server. Even after many hours and attempts at solving this problem, the reality is that the hosting ability of Esri Portal under the current architecture and configuration simply does not work.

It took many months to identify, locate, and connect all the data pieces needed for the dashboard. Once the connections were established, the next challenge was the difficulty involved in establishing an automatic daily update. The solution is the eight python scripts embedded in

one FME project, which is scheduled to run once a day. However, UDOT's current FME server does not support projects with the latest version of ArcGIS python scripts. Because of this, the FME project must be run manually each day until UDOT updates their FME Server.

The entire workflow is complex and appears to be somewhat fragile. If the ArcGIS GeoEvent Server will run consistently without crashing, and if UDOT could publish the FME project to run daily, then perhaps the data would smoothly update as desired. At the writing of this report, this has not happened, and manual "tweaks" and updates are required to keep the dashboard running.

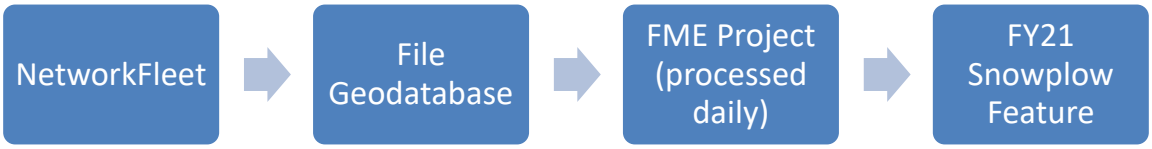
Finally, the large volume of snowplow location points hinders the user's experience. Because Esri's products only display a certain number of points (usually 1000) on a web map, the user cannot look at the entire state and see all the snowplow location points for a given storm. The map just "bogs down" and doesn't show all the points. This also causes the dashboard to be sluggish which is not very user friendly. While this limitation is the current reality, an alternative solution may exist, and is explored in the next section. It is important to note that this alternative is in the conceptual phase and has not been proven yet.

5.3.1 Alternative

There is a possible alternative for processing the location points. UDOT stores all of the NetworkFleet location data in monthly tables in a file geodatabase. So perhaps the workflow could bypass GeoEvent and not use it at all.

Instead of:

An alternative workflow is:



This alternative workflow would still have the following difficulties, but with potential workarounds:

1. FME Server will still need to be updated to use projects with current python scripts.
2. The display of massive volumes of points on the web map (unless scale thresholds are set).
3. If ArcGIS GeoEvent Server crashes, both the Esri Portal hosted services and the dashboard go down. Even though the dashboard workflow would not use the ArcGIS GeoEvent Server, UDOT still uses the ArcGIS GeoEvent Server for other purposes and the current configuration connects this with Esri Portal. This could be solved by publishing services to Esri Portal without using the hosting ability.

6.0 RECOMMENDATIONS AND IMPLEMENTATION

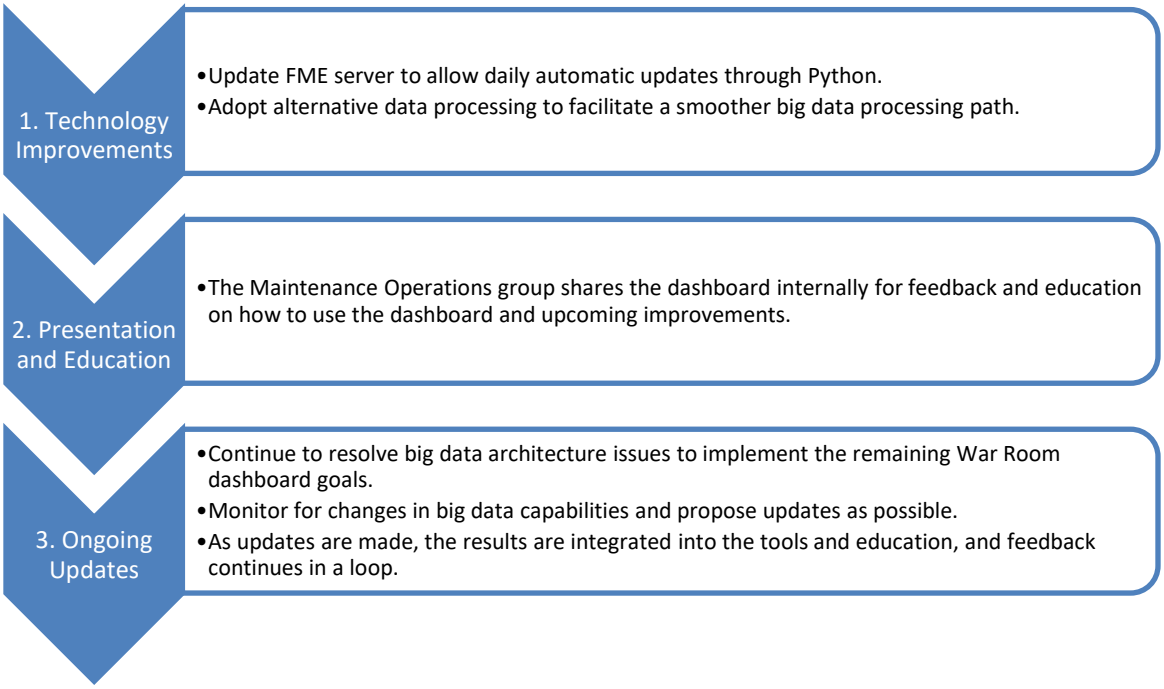
6.1 Recommendations

Continue to explore ways to make the dashboard more stable:

- Use the alternative method for processing the massive amounts of snowplow location points. Bypass GeoEvent, at least until a stable installation is achieved.
- Avoid hosted Feature Services. Instead, store the data on UDOT servers and publish the services to Portal using data stores.
- Use collated lines to show snowplow locations instead of individual data points unless scale thresholds are set for points.

6.2 Implementation Plan

Before the dashboard can be fully implemented, the challenges addressed in previous sections of this report would need to be addressed. The current proposed implementation could proceed as follows:



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