Using Visualization Tools to Improve Snow and Ice Control Efficiency

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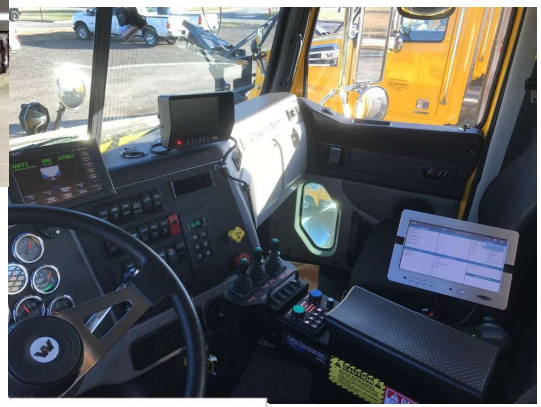
Seriously? Talking about Snow and Ice in April / May?

Key Challenges

- Public Demand for High Level of Services
- Winter Maintenance Budgets Do Not Correlate with Increasing Public Expectations
- Need Cost-Effective Solutions to Include Operations Efficiency

Winter Maintenance Operations: Technologies and Innovations

- Deicing Materials
- Expandable, Wing, and Tow Plows
- Spreaders
- Automatic Vehicle Location (AVL)
- RWIS and Mobile Sensors
- Maintenance Decision Support System (MDSS)
- Plow Route Optimization
- Performance Metrics and Dashboards



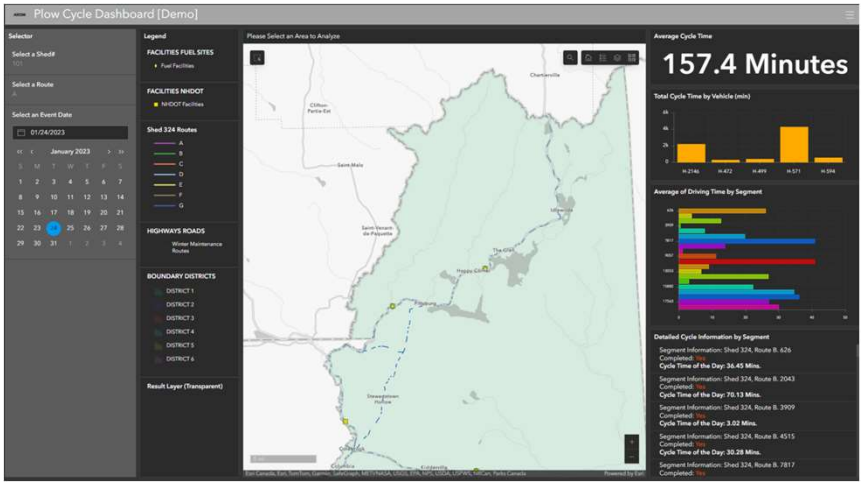
Plow / Treatment Cycle Times

- Cycle Time: The Time It Takes a Snowplow to Complete a Single Cycle to Service a Route or an Area
- Calculating and Estimating Cycle Times Helps Resources Planning and Allocation
- Factors Affecting Cycle Times
  - Equipment Availability
  - Operator Availability
  - Snowplow Capacity
  - Roadway Characteristics
  - Traffic Characteristics
  - Weather / Environmental Factors

Many of those factors are dynamic in nature, making cycle time calculation challenging.

Study Objectives

- Identification of variables that impact cycle times
- Methodology for determining cycle times
- User stories conveying the benefits and challenges of a visualization tool for cycle times
- A framework for a map-based online visualization tool
- A prototype of a visualization tool / dashboards
- An implementation plan for tool development and deployment



State of the Practice

- 24 agencies provided information
- 20 have or are currently deploying GPS/AVL systems
- 6 agencies currently track cycle times
- 7 agencies use AVL data to validate current routes
- 19 agencies have AVL raw data readily available

70% have different cycle time goals based on the classification of the route

Top Five Variables Affecting Cycle Times

- Type of Storm
- Number of Operational Trucks
- Available Truck Operators
- Peak Hour Traffic
- Type of Treatment

Ranking of Platforms

- ArcGIS/AGOL (9)
- Unknown (6)
- PowerBI (5)
- Vendor/AVL specific (4)
- Tableau (2)

Variables

Variable	Purpose	Source
Latitude	North-South location of truck. To determine when truck is on a route.	Truck AVL
Longitude	East-West location of truck. To determine when truck is on a route.	Truck AVL
Date and Timestamp	To timestamp when a truck starts and ends on a route.	Truck AVL
Treatment Data (Optional)	If available, to provide more accurate data of when treatment is occurring. Spreader on/off, plow up/down, spinner speed, and other settings that contribute to a change in a truck's treatment width are other optional data to include.	Truck AVL
Truck Identification Number	To determine the capacity of the truck while treating a road.	Truck AVL
Plow and/or Treatment Width	To determine the roadway width was treated per pass.	Truck/Equipment Dataset
Spatial Road Segment (Ideally segmented between turnaround / cross over intersections)	To determine when the truck starts and ends on a road segment.	Spatial GIS Road Data
Snow and Ice Routes	Tool will be able to drill down to a road segment but should be able to drill up to provide insights by pre-determined routes as well.	Spatial GIS Road Data
Number of Lanes or Roadway Width (or passes till considered complete; may include shoulders or median)	To provide information on the require number of lanes or effective roadway width. If needed, include the passes or extra width for shoulder or median treatment.	Spatial GIS Road Data
Weather Data – precipitation, wind and temperature (Optional)	To determine when an event has started. Also, may be used for cycle time vs. storm severity analyses.	National Weather Service, Third-Party or RWIS

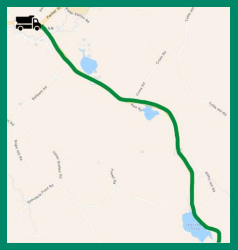
Cycle Time Calculation

Step 1:

Identify that a truck has started on a segment of road via latitude/longitude. Optional treatment data - check if **spreader/sprayer is ON**, if TRUE, the following process that will occur when:

- Start Date and Timestamp, t_{si} for the Cycle
- Start Date and Timestamp, t_{sij} for the individual pass
- Based on truck's ID and optional treatment data - query truck's plow and treatment width/Capacity, C_T

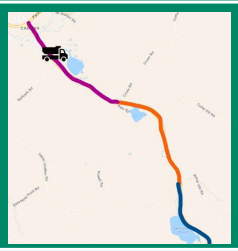
where, i = road segment and j = individual pass along the road segment.



Step 2:

Compare C_T to the road segment lane count or width, w_i to get a cycle ratio.

$$\text{Cycle Ratio}, \theta_j = \frac{C_T}{w_i}$$

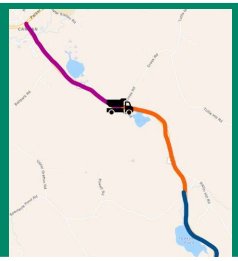


Step 3:

Calculate duration to treat an individual pass along the segment.

End Date and Timestamp, t_{eij}

$$\text{Duration}, D_j = t_{eij} - t_{sij}$$



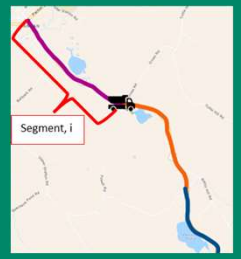
Step 4:

Calculate Results

$$\text{Total Duration to Clear Segment}, T_i = \sum_{\theta_j}^{\theta_j=>1} D_j$$

When $\sum \theta_j = 1$; End Date and Timestamp, t_{ei} for Cycle

$$\text{Cycle Time}_i = t_{ei} - t_{si}$$



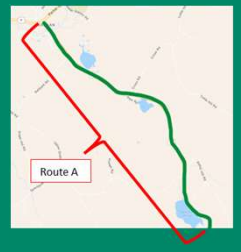
Step 5:

Drill up to review multiple segment (total route) Cycle Time

$$\text{Total Time to Clear Segment}, T_{selected} = \sum T_i$$

For Cycle Time

$$\text{Cycle Time} = \text{Latest}(t_{si}) - \text{Earliest}(t_{ei})$$



User Stories

- 7 User Stories Developed
  - Heavy Traffic Congestion During a Major Snow Event
  - Reduced Fleet Size Due to Availability Issues
  - A Snow Event with Extreme Temperatures
  - Mountainous Terrain (Planning and Calibrating Routes)
  - Traffic Operation Center
  - Post Storm Analysis – Route Modifications
  - Post Storm Analysis for Disaster-Level Readiness
  - Enhanced MDSS Recommendations

User Story 8: Enhanced MDSS Recommendations

Story

Multiple agencies that were a part of the Federal Highway Administration's (FHWA) MDSS Pooled Fund program have started utilizing a Cycle Time Dashboard. Currently, the MDSS algorithm uses one cycle time variable for the routes within the system. Through using the data from the Cycle Time Dashboards, it was clear the cycle time ranges based on the time of day (peak vs off-peak), resources available, and weather severity.

At a recent conference, these agencies began to discuss utilizing the cycle time data within the MDSS to continue to enhance the system for better recommendations. The agencies reached out to FHWA to work on another pooled fund program project to further enhance the MDSS by utilizing the Cycle Time Dashboard. One of the goals of the enhancement project is to include cycle time data based on time of day and weather severity, and the software will provide insight to expected cycle time if resources are not increased. The project moved forward and was successful in linking the Cycle Time Dashboard data into MDSS for better recommendations. These enhanced insights are beneficial for storm planning and communicating timeframes, as well as overall winter maintenance resource and budget planning.

Assumptions

- FHWA agrees to update MDSS
- Cycle time data are collected at agencies using MDSS
- Cycle time data will enhance recommendations

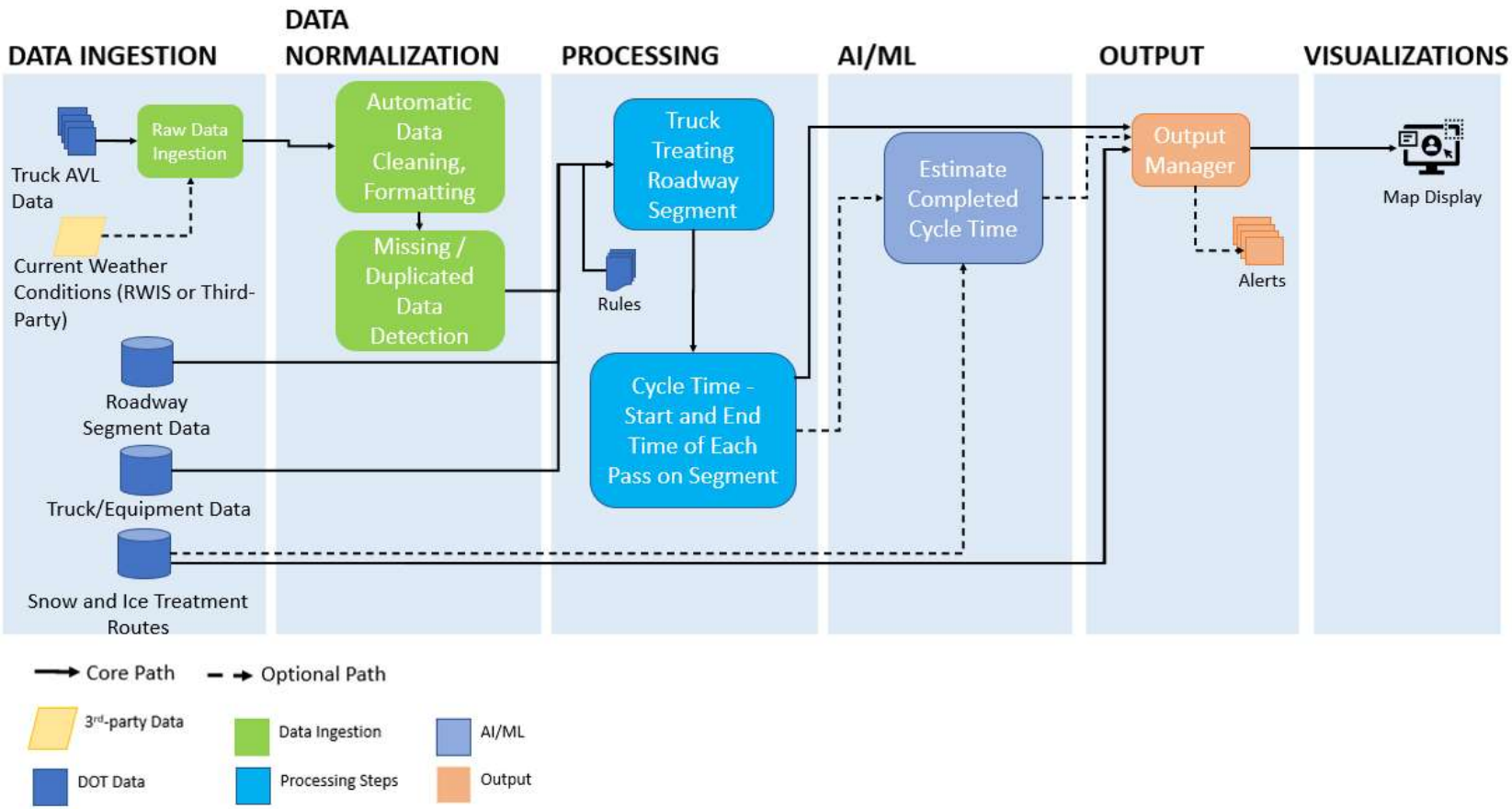
Scenario Outcome and Comments

- Better recommendations for MDSS

Operational System

- AVL System
- Cycle Time Real-time Tracking Dashboard/Tool
- MDSS

Visualization Tool High-Level Architecture



Tool Framework

- Requirements
  - Data Ingestion, Normalization (Cleaning, Formatting, Missing/Duplicate Data Detection), Processing, Estimation, Output, and Map Display
- Database Design
  - Extract, Transform and Load (ETL) Process and Options
  - Database details and variables
- Storage options
- Dashboard and Tool Platform and Hosting Options
- Development and Testing Stage Needs

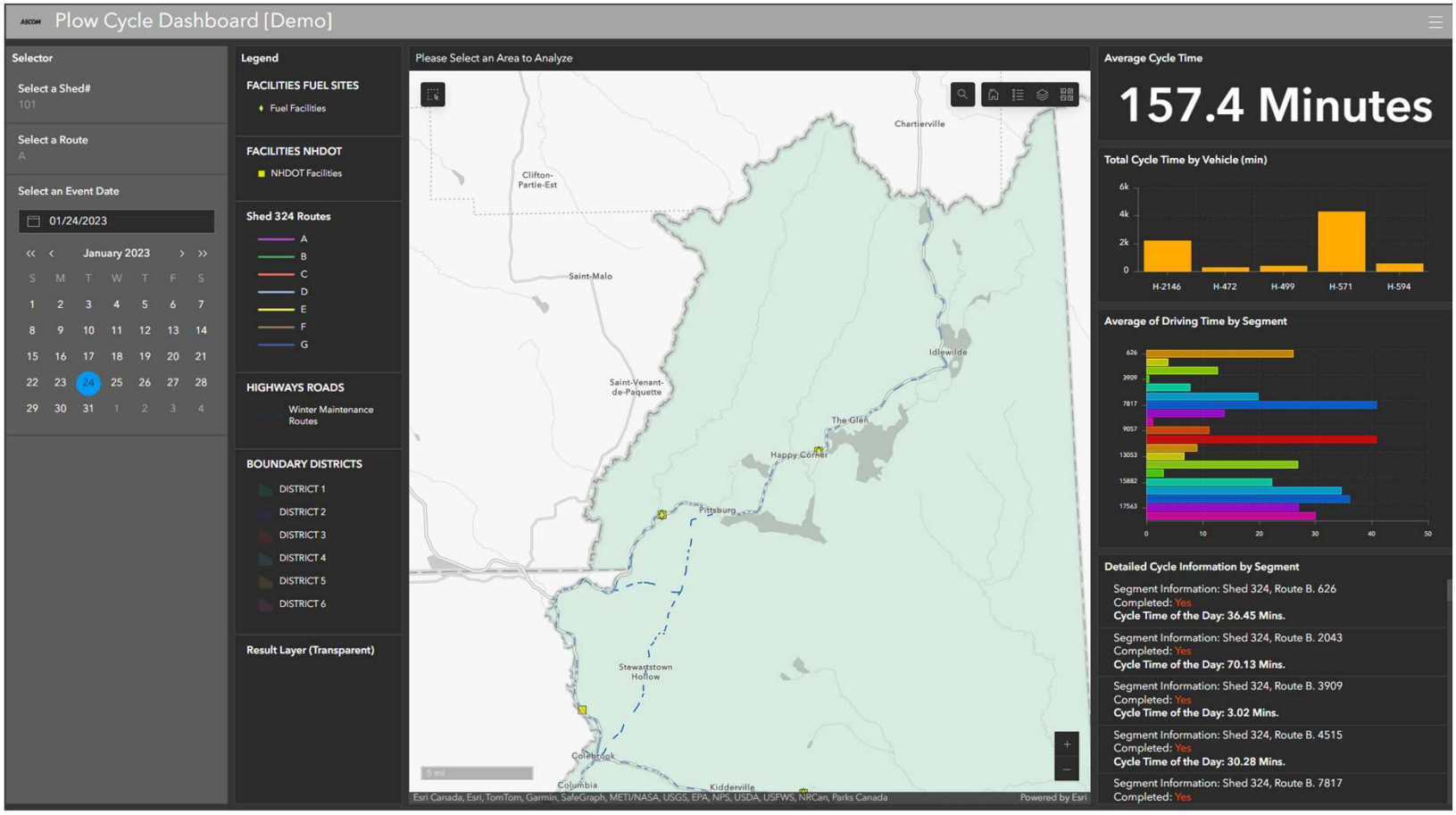
ETL Options

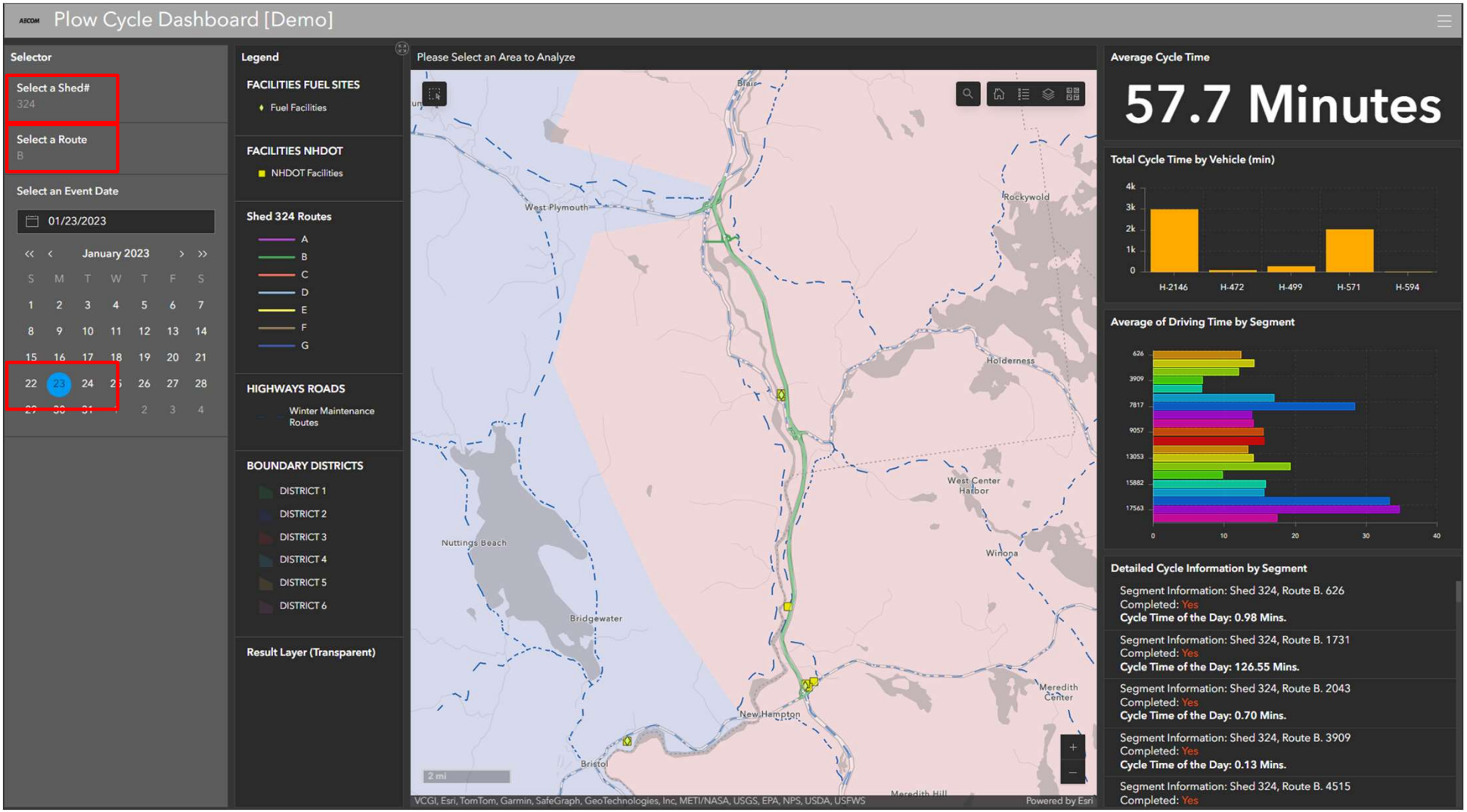
ETL Options	Description	Pros	Cons
Custom ETL Scripts/Code	Writing custom scripts or code in programming languages like Python, Java, or Ruby to perform ETL tasks. This approach offers maximum flexibility but can be time-consuming and requires development expertise.	Maximum flexibility can be tailored to specific needs.	Time-consuming, and requires development expertise.
ETL Tools	There are many ETL tools available, both open-source and commercial, that provide a graphical interface for designing ETL workflows.	Provides a graphical interface, may have pre-built functionalities.	May have a learning curve, may be costlier depending on the tool.
Cloud-Based ETL Services	Many cloud providers offer ETL services that are fully managed and scalable.	Fully managed, scalable, often integrated with cloud platforms	Might involve ongoing costs, dependency on the cloud provider.
Open-Source ETL Frameworks	Build ETL processes using open-source frameworks and libraries. These frameworks provide flexibility and can be customized as needed.	Flexible, customizable, and often community supported.	Required expertise, potential integration challenges.
Data Integration Platforms	Some platforms offer comprehensive data integration capabilities, including ETL, data transformation, and data quality.	Comprehensive solution, covers ETL, transformation, and quality,	Potentially higher cost, may be complex to implement.
Data Integration as a Service	There are SaaS solutions that provide ETL and data integration capabilities, often with pre-built connectors to popular data sources.	SaaS model, pre-built connectors for data sources.	Subscription based-cost, dependency on service-provider.
Serverless ETL	ETL processes using serverless computing platforms, which can be cost-effective and scalable.	Cost-effective, scalable, event-driven model.	May require adaptation to serverless paradigm, potential integration challenges.

Tool Platform and Hosting Options

Hosting Platform	Power BI	Tableau	ESRI	QlikView	Google Data Studio
Data Visualization	✓	✓	✓	✓	✓
Mapping & Spatial Analysis	✗	✗	✓	✗	✗
Data Source Types	Various (CSV, Excel, SQL)	Various (files, databases, cloud)	Geospatial data formats, GIS databases	Various (files, databases, cloud)	Various (Google Sheets, BigQuery, etc.)
Integration Capabilities	Good integration with Microsoft products, REST APIs, SDKs	Connectors, APIs, third-party integrations	Integration with ArcGIS Online, ArcGIS Enterprise	APIs, connectors, and custom integrations	Integration with Google products, connectors
Collaboration & Sharing	Collaboration features, sharing with Power BI Pro license	Collaboration features with Tableau Creator license	Collaboration features with ArcGIS Online	Collaboration features, sharing capabilities	Collaboration features, sharing capabilities
Cost	Varies based on licensing plan (e.g., Power BI Pro, Premium)	Varies based on licensing plan (e.g., Creator, Explorer)	Varies based on licensing plan (e.g., ArcGIS Online, Enterprise)	Varies based on licensing plan	Free for basic usage, additional costs for advanced features
System Requirements	Internet connectivity, compatible web browser	Internet connectivity, compatible web browser	Internet connectivity, compatible web browser	Internet connectivity, compatible web browser	Internet connectivity, compatible web browser

Prototype Tool

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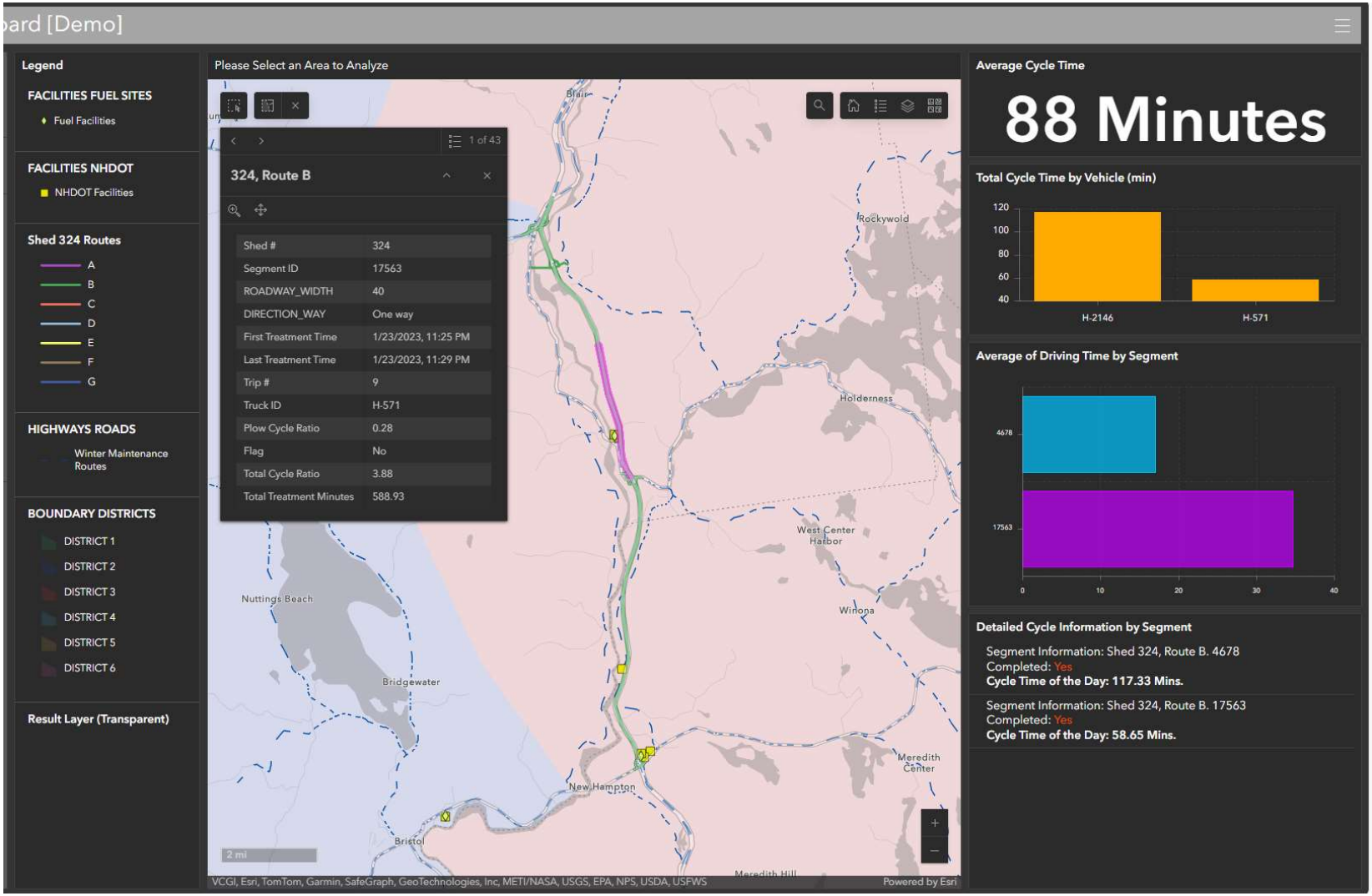
Plow Cycle Dashboard [Demo]
Selector
Select a Shed#
324
Select a Route
B
Select an Event Date
01/23/2023
January 2023
S M T W T F S
1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
2 3 4
Legend
FACILITIES FUEL SITES
Fuel Facilities
FACILITIES NHDOT
NHDOT Facilities
Shed 324 Routes
A
B
C
D
E
F
G
HIGHWAYS ROADS
Winter Maintenance Routes
BOUNDARY DISTRICTS
DISTRICT 1
DISTRICT 2
DISTRICT 3
DISTRICT 4
DISTRICT 5
DISTRICT 6
Result Layer (Transparent)
Please Select an Area to Analyze
Blair
West Plymouth
Rockywold
Holderness
West Center Harbor
Winona
Nuttings Beach
Bridgewater
New Hampton
Meredith Center
Bristol
Meredith Hill
2 mi
VCGI, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, USFWS
Powered by Esri
Average Cycle Time
57.7 Minutes
Total Cycle Time by Vehicle (min)
4k
3k
2k
1k
0
H-2146
H-472
H-499
H-571
H-594
Average of Driving Time by Segment
626
3909
7817
9057
13053
15882
17563
0
10
20
30
40
Detailed Cycle Information by Segment
Segment Information: Shed 324, Route B. 626
Completed: Yes
Cycle Time of the Day: 0.98 Mins.
Segment Information: Shed 324, Route B. 1731
Completed: Yes
Cycle Time of the Day: 126.55 Mins.
Segment Information: Shed 324, Route B. 2043
Completed: Yes
Cycle Time of the Day: 0.70 Mins.
Segment Information: Shed 324, Route B. 3909
Completed: Yes
Cycle Time of the Day: 0.13 Mins.
Segment Information: Shed 324, Route B. 4515
Completed: Yes


ard [Demo]
Legend
FACILITIES FUEL SITES
Fuel Facilities
FACILITIES NHDOT
NHDOT Facilities
Shed 324 Routes
A
B
C
D
E
F
G
HIGHWAYS ROADS
Winter Maintenance Routes
BOUNDARY DISTRICTS
DISTRICT 1
DISTRICT 2
DISTRICT 3
DISTRICT 4
DISTRICT 5
DISTRICT 6
Result Layer (Transparent)
Please Select an Area to Analyze
1 of 43
324, Route B
Shed # 324
Segment ID 17563
ROADWAY_WIDTH 40
DIRECTION_WAY One way
First Treatment Time 1/23/2023, 11:25 PM
Last Treatment Time 1/23/2023, 11:29 PM
Trip # 9
Truck ID H-571
Plow Cycle Ratio 0.28
Flag No
Total Cycle Ratio 3.88
Total Treatment Minutes 588.93
Rockywold
Holderness
West Center Harbor
Winona
Nuttings Beach
Bridgewater
New Hampton
Meredith Center
Bristol
2 mi
VCGI, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, USFWS
Powered by Esri
Average Cycle Time
88 Minutes
Total Cycle Time by Vehicle (min)
120
100
80
60
40
H-2146
H-571
Average of Driving Time by Segment
4678
17563
0
10
20
30
40
Detailed Cycle Information by Segment
Segment Information: Shed 324, Route B. 4678
Completed: Yes
Cycle Time of the Day: 117.33 Mins.
Segment Information: Shed 324, Route B. 17563
Completed: Yes
Cycle Time of the Day: 58.65 Mins.

Tool Development Steps

- Step 1. Identify Stakeholders
- Step 2. Determine Needs
- Step 3. Review AVL Data
- Step 4. Review Internal Data Required for the Tool
- Step 5. Establish Proper Expectations of the Tool's Outputs
- Step 6. Work with Stakeholders on Platform and Hosting Needs for the Tool and Data
- Step 7. Determine Data Extract, Transform, and Load Workflow
- Step 8. Develop Algorithm
- Step 9. Develop Dashboard or Graphical User Interface (GUI)
- Step 10. Validate and Test
- Step 11. Develop User Reference/Guide
- Step 12. Utilize and Maintain Tools

Benefits

- A Better Understanding of the Cycle Time Needs for Road Segments
- Resource Planning and Allocation
- Reliable Information to Disseminate on Situational Awareness. Increase Awareness to the Public of Conditions to Increase Safety
- Improved Readiness and Decision-making for Disaster-level Snow and Ice events, Emergency Closures and Reopening
- Data for Route Optimization
- Recommendations for MDSS

Thank you.

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