# Co-Optimization of Vehicles and Routes (CoVaR)

## To Improve Commercial Transportation System Efficiency

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PACCAR Inc.

June 5th, 2024

Project ID eems108

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# Overview

## Timeline:

- Start: October 2020
- End: June 2024
- 100% Complete

## Budget:

- Total project funding: $2.5M
  - DOE: $2M
  - Cost Share: $0.5M
- FY2021 Funding: $1.2M
- FY2022 Funding: $0.79M
- FY2023 Funding: $0.5M
- FY2024 Funding: $0.0M

## Barriers:

- Business Incentives for OEMs and Fleets to use Cloud Services
- Vehicle to Cloud Architecture Technologies
- Network Bandwidth

## Partners:

# Relevance

## Objectives:

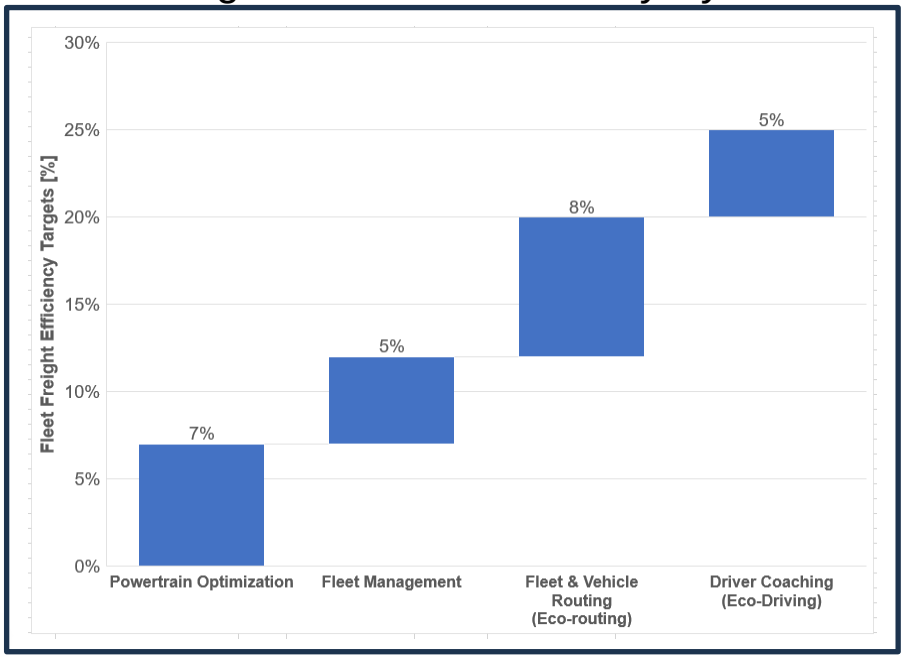
- 25% Fleet Freight Efficiency Improvement
- Develop, Implement, & Validate Advanced Connected Transportation Systems
- Powertrain Agnostic:

  Diesel and e-Powertrain



## Impact:

- Improve Fleet Freight Efficiency Through Various Connectivity Systems:



# Program Outline

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| | | 2020 | 2021 | | | | 2022 | | | | 2023 | | | | 2024 (Ext.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| **Fleet Partner Selection** | | | | | | | | | | | | | | | | |
| **Telematics** | | | | | | | | | | | | | | | | |
| | Development | | | | | | | | | | | | | | | |
| **Eco-Routing** | | | | | | | | | | | | | | | | |
| | Development | | | | | | | | | | | | | | | |
| | Integration | | | | | | | | | | | | | | | |
| | Simulated Impact Assessment | | | | | | | | | | | | | | | |
| **Powertrain Recommendation** | | | | | | | | | | | | | | | | |
| | Development | | | | | | | | | | | | | | | |
| | BEV Model Development | | | | | | | | | | | | | | | |
| | Simulated Impact Assessment | | | | | | | | | | | | | | | |
| **Fleet Management System** | | | | | | | | | | | | | | | | |
| | Development | | | | | | | | | | | | | | | |
| | Integration | | | | | | | | | | | | | | | |
| | Simulated Impact Assessment | | | | | | | | | | | | | | | |
| **Cloud Infrastructure** | Development | | | | | | | | | | | | | | | |
| **Deployment** | | | | | | | | | | | | | | | | |
| | Deploy Telematics Loggers | | | | | | | | | | | | | | | |
| | Deploy Eco-Routing | | | | | | | | | | | | | | | |
| | Deploy FMS | | | | | | | | | | | | | | | |
| | Deploy Powertrain Recommendation | | | | | | | | | | | | | | | |
| **Data Analysis** | Energy Efficiency Assessment | | | | | | | | | | | | | | | |

Budget Period 1: Technology Development

Budget Period 2: Technology Implementation

Budget Period 3: Testing & Validation

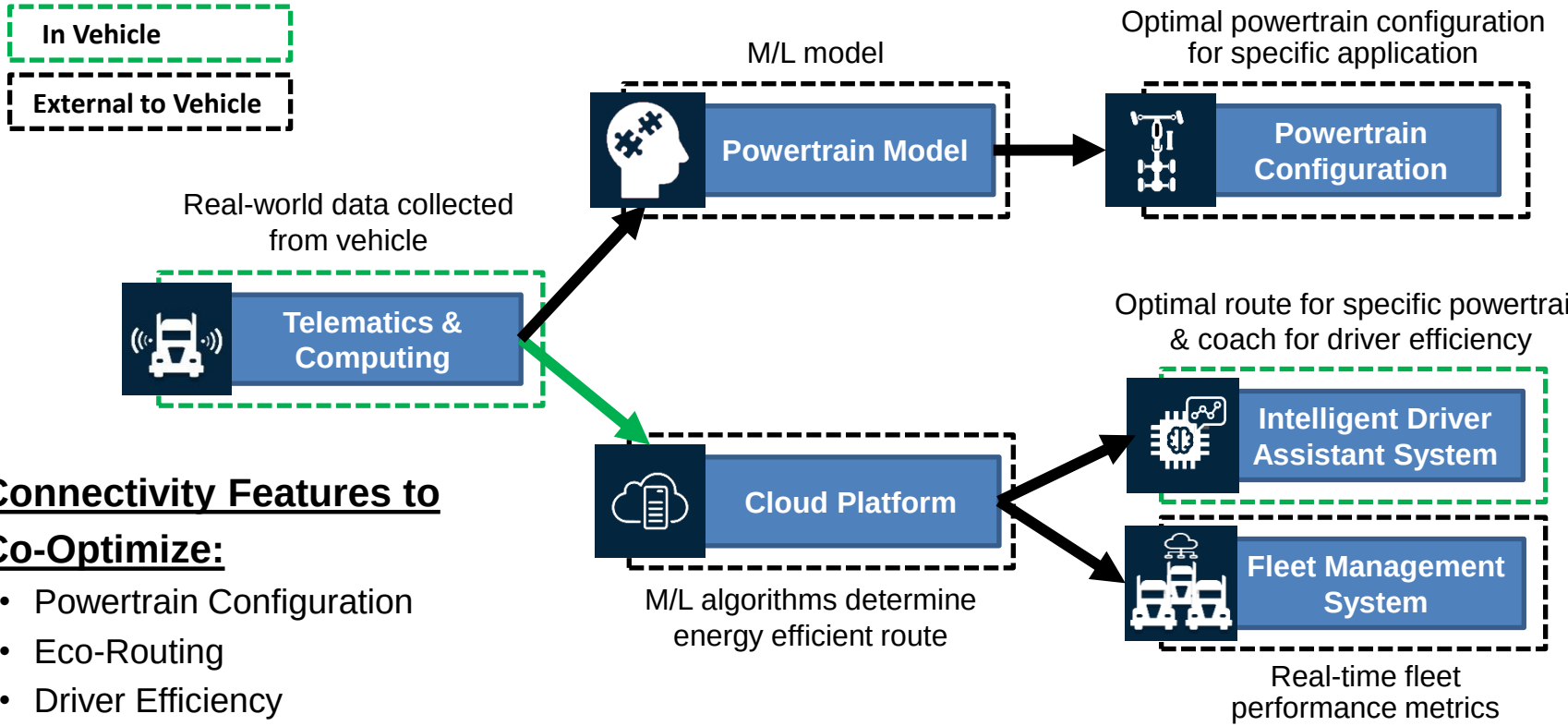
BP3: No-Cost Ext.

# Milestones

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| Milestone | Description | Status |
|---|---|---|
| **Baseline Freight Energy Efficiency Quantified** | Number of Current Freight Energy Efficiency in Appropriate Units | Complete |
| **Baseline Testing on Commercial Fleet** | Simulation to Determine if Freight Efficiency Improvement is achievable | Complete |
| **Deploy Prototype Intelligent Driver Assistance System (IDAS)** | Data and feedback collection on the IDAS with fleet partner | Complete |
| **Deploy Prototype Fleet Management System (FMS)** | Data and feedback collection on the FMS with fleet partner | Complete |
| **Vehicle Configuration Optimization Workshop** | Workshop with fleet partner on potential vehicle configuration optimizations | Complete |
| **Complete Testing of Prototype Technology** | Complete initial prototype testing with fleet partner | Complete |
| **Assess FMS Impact on Freight Efficiency** | Freight Efficiency Improvement of ≥ 5% | Complete |
| **Assess PRS Impact on Freight Efficiency** | Freight Efficiency Improvement of ≥ 8% | Complete |
| **Assess IDAS Impact on Freight Efficiency** | Freight Efficiency Improvement of ≥ 15% | Complete |
| **Assess the Final Impact of the Co-Optimized System** | Freight Efficiency Improvement of ≥ 25% | Complete |

# Program Approach




**Connectivity Features to Co-Optimize:**

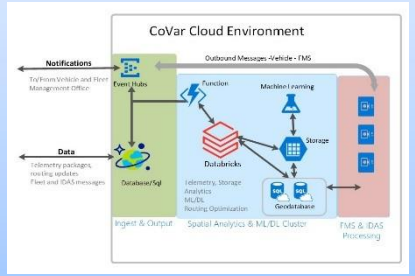
- Powertrain Configuration
- Eco-Routing
- Driver Efficiency
- Fleet Management

# Approach: Eco-Routing

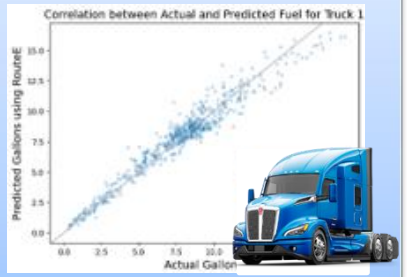
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Cloud Based Data → Vehicle Model Training → Eco-Routing → Turn By Turn Directions

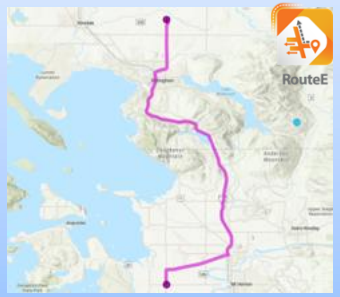
## Advanced Telematics



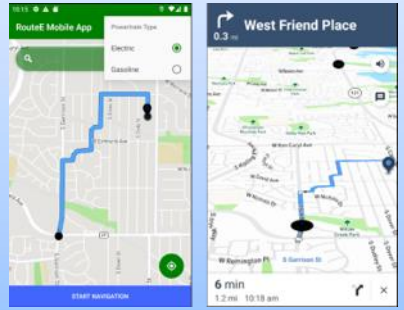

## RouteE Energy Models




## Routing Engine




## In vehicle eco-routing




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# Approach: Telematics Installations

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## Summary:

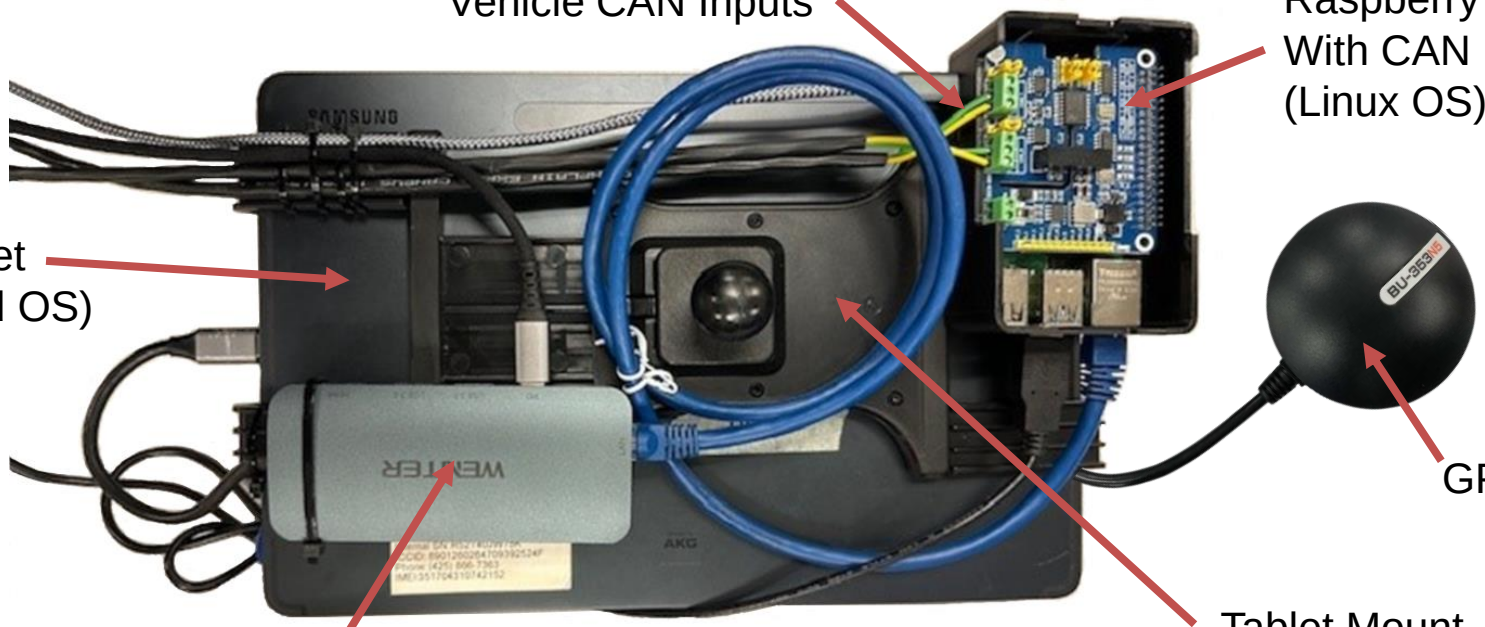
- 2 PacLease customer fleets are participating
  - **Partner 1** is a company that specializes in air freight and LTL delivery
  - **Partner 2** is a company that specializes in used tire pickup and recycling
- Both customer fleets have a mix of heavy duty and medium duty vehicles for different use cases



| Fleet Partner | Truck Class | Quantity |
|---|---|---|
| Partner 1 | Medium Duty | 11 |
| | Heavy Duty | 6 |
| Partner 2 | Medium Duty | 6 |
| | Heavy Duty | 9 |

| Truck Class | Total |
|---|---|
| Medium Duty | 17 |
| Heavy Duty | 15 |
| Combined | 32 |

# Telematics System Hardware Component Overview



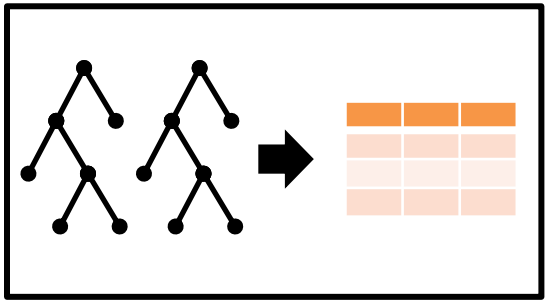
# Technical Accomplishments: RouteE Integration

## RouteE Improvements:

- Original energy models with additional data from project are split into new categories to better estimate consumption and represent use cases:
  - Medium Duty (new)
  - Heavy Duty Bobtail (new)
  - Heavy Duty Laden (existing)

- RouteE-Powertrain models are often random forest regressors which NREL has “flattened” into lookup tables for this project
  - Allows for much faster querying and assignment of estimated energy consumption to links in large road networks by avoiding network latency issues

Random Forest ML Model to Lookup table



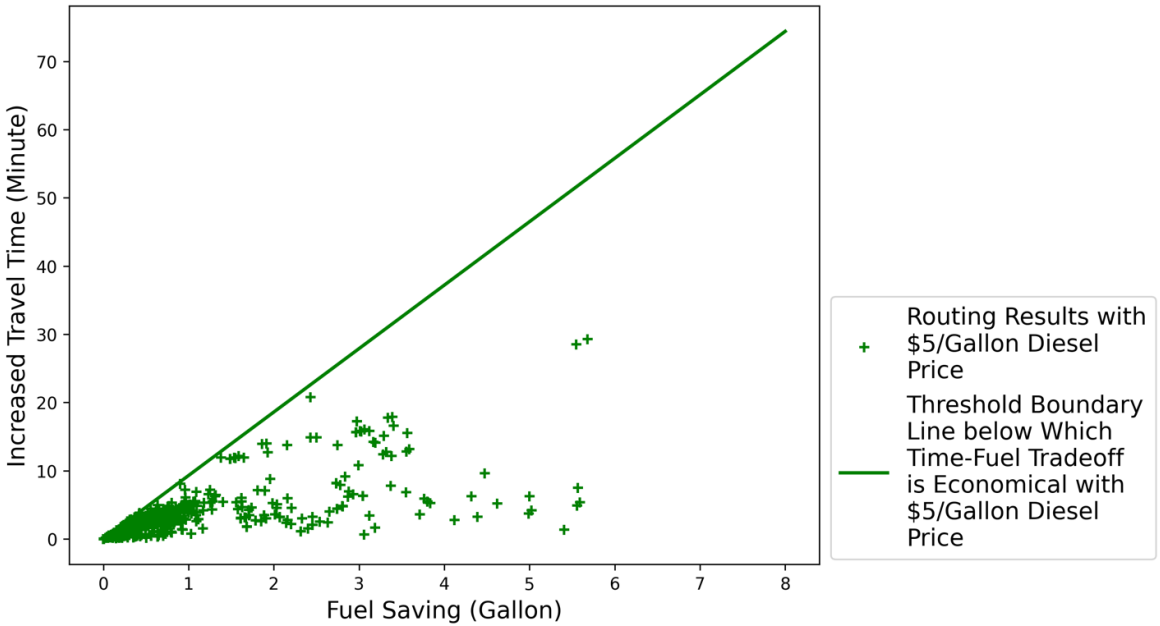
RouteE

# Technical Accomplishments: Baseline Freight Efficiency Investigation

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## Milestones:

- Eco-routing tool tested with 800 O-D pairs to ensure correct functionality
- Analysis uses a composite weight function for energy cost and driver time to determine optimal route
- Results for analysis using optimal routing algorithm show all routes economically feasible at $5/gallon fuel cost



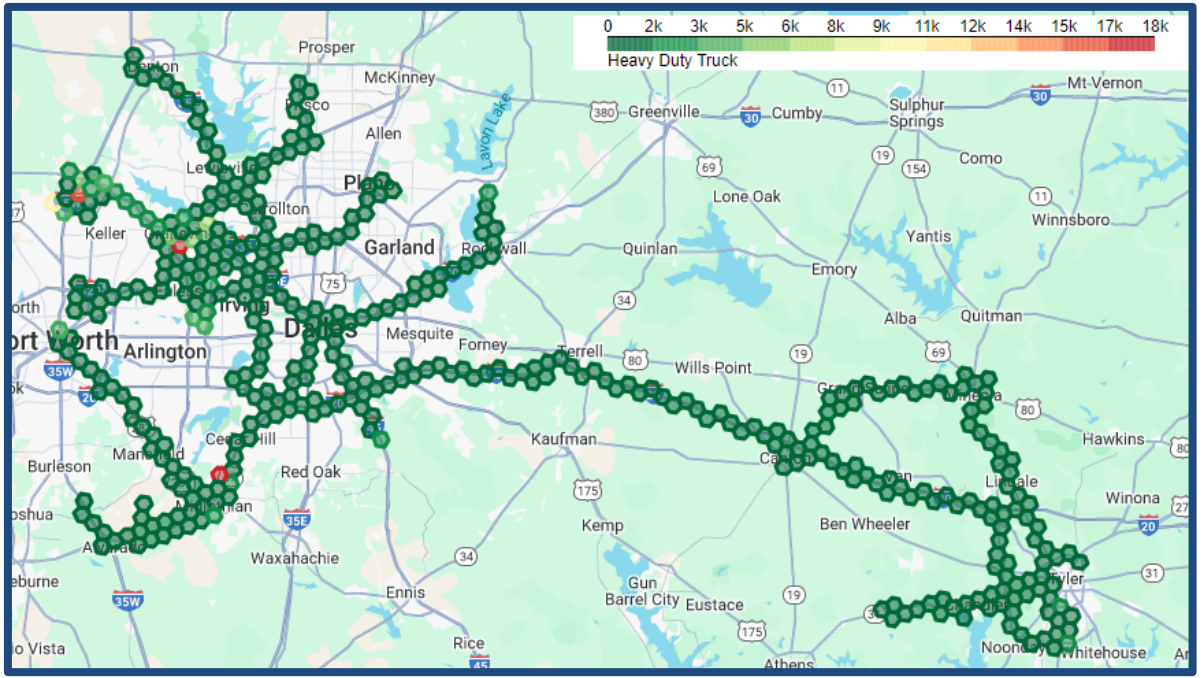

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# Technical Accomplishments: Baseline Freight Efficiency Investigation

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## Milestones:

- H3 Uber Package used to visualize the density of GPS data across the geographic area based on customer heavy duty truck GPS data
- Catalog fleet partner O-D pairs for baseline route analysis and improvement calculations
  - Energy Consumption
  - NOx Emissions




Sample plot of GPS data using H3 Uber Package

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# Technical Accomplishments: Cloud Infrastructure

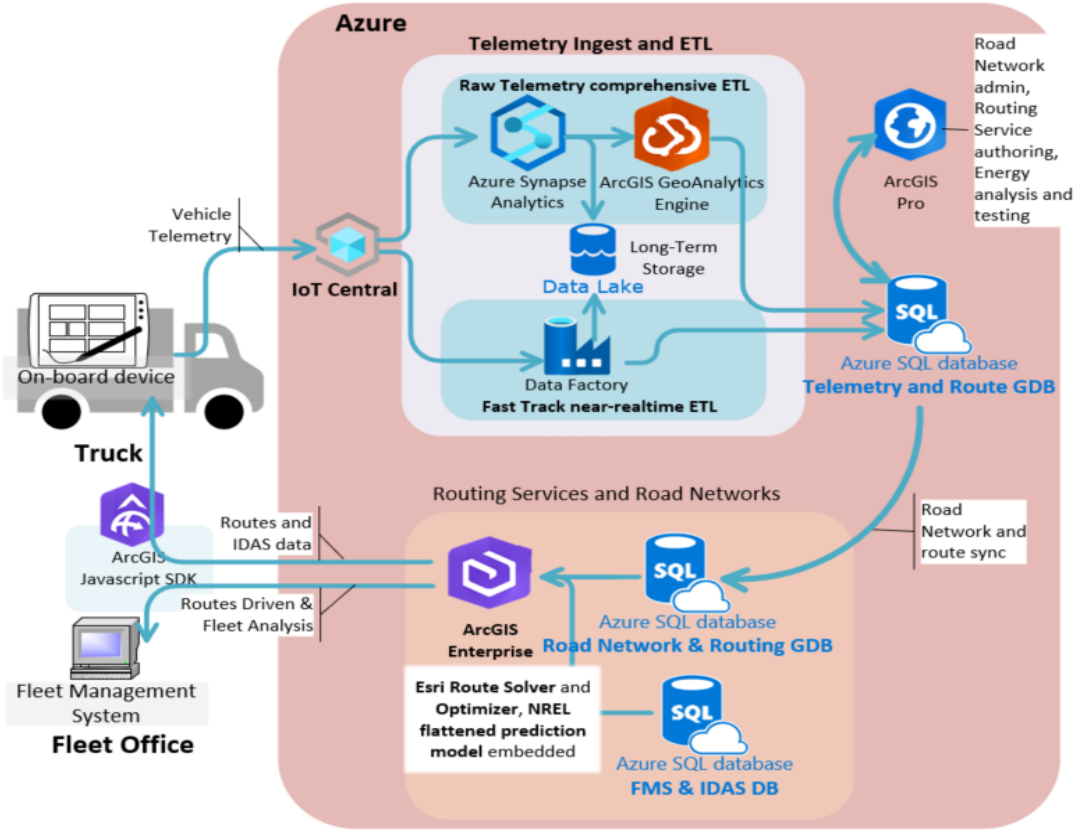
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## Milestones:

- TomTom road segment gradient data added to Continental US
- SVMS (Single Vehicle Multi-Stop) functionality added to routing service
- Additional route metrics added to SQL server instance to allow efficiency improvement calculations

## Summary:

- Routing deployed for Continental US with tracking for route driven compared to optimal route provided.




Cloud Architecture Diagram for CoVaR

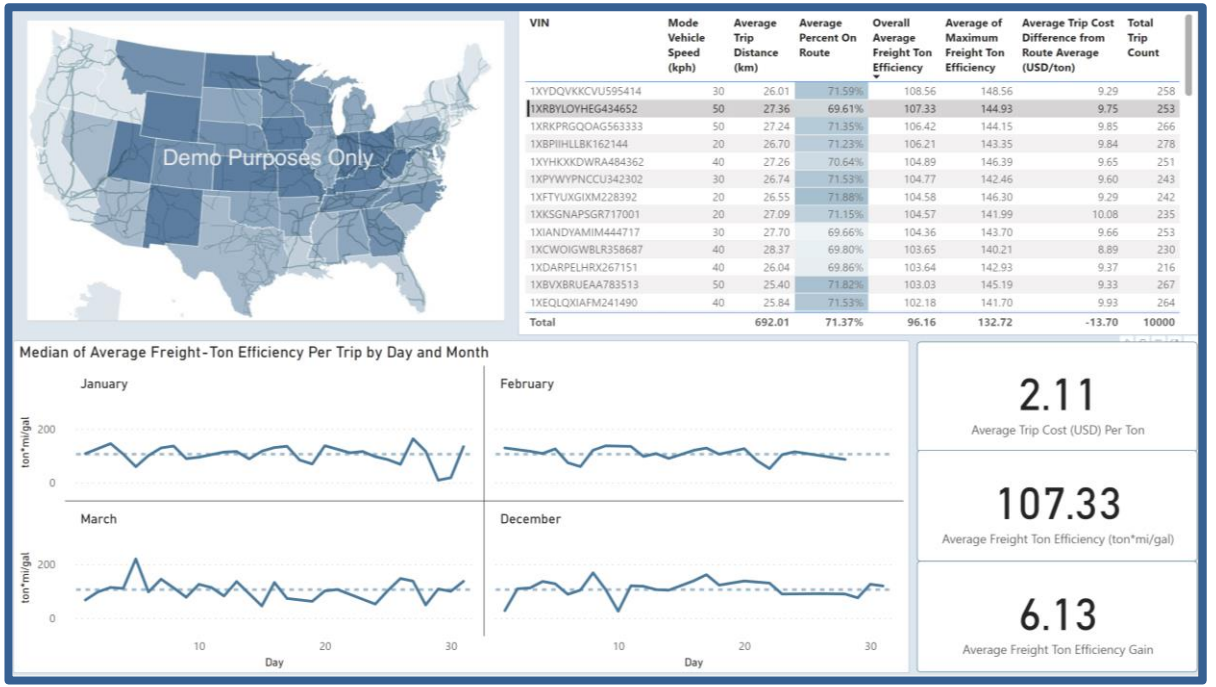
# Technical Accomplishments
# Fleet Management System

## Milestones:

- Add Fleet ID and Trip ID to telemetry data stream
- Completed ETL mechanism to map single ingest table into multi-dimensional data structure used in the fleet dashboard
- Add mass as an input to the routing function

## Summary:

- Real-Time fleet performance monitoring and fleet energy optimized routing can be conducted with the FMS tool




Fleet Dashboard Example

# Technical Accomplishments: Intelligent Driver Assistance System

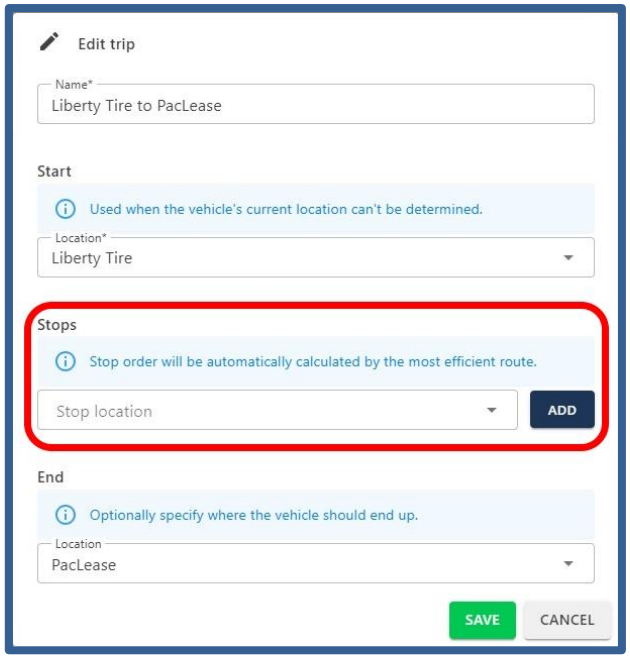
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## Milestones:

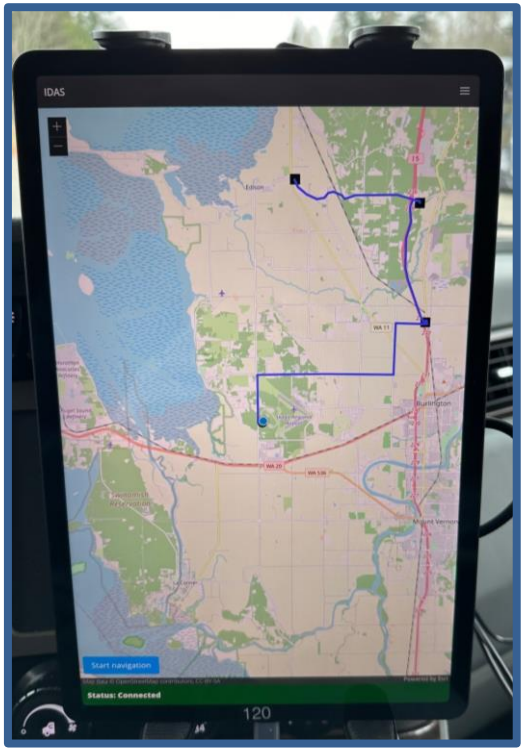
- Stops have been added between the Start and End points in the FMS to allow the use of the SVMS functionality to optimize the display order of stops along a route in the IDAS

## Summary:

- SMVS functionality integrated into FMS and IDAS to guide user to stops in the most efficient order




FMS Trip Definition Dialog Box




Test Example of SVMS Routing

# Partnerships and Collaborations

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- Kenworth: Vehicle Deployment, Fleet Partnership
- NREL: Fleet Data Analysis, Eco-Routing, Route Optimization,
- OSU: Powertrain Configuration Optimization
- Kopius: Fleet Management System and IDAS
- Esri: Cloud Infrastructure and Routing

# Challenges and Barriers

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**Main Barriers:**

- No barriers remain, end of project.

**Technical Challenges:**

- Resolving the need to have low cost, accurate, robust, and secure telematics units to collect customer data.

# Proposed Future Research

## FY24: Project Completion

- No additional proposed research related to the project

Any Proposed Future Work is Subject to Change Based on Funding Levels.

# Summary

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## Accomplishments:

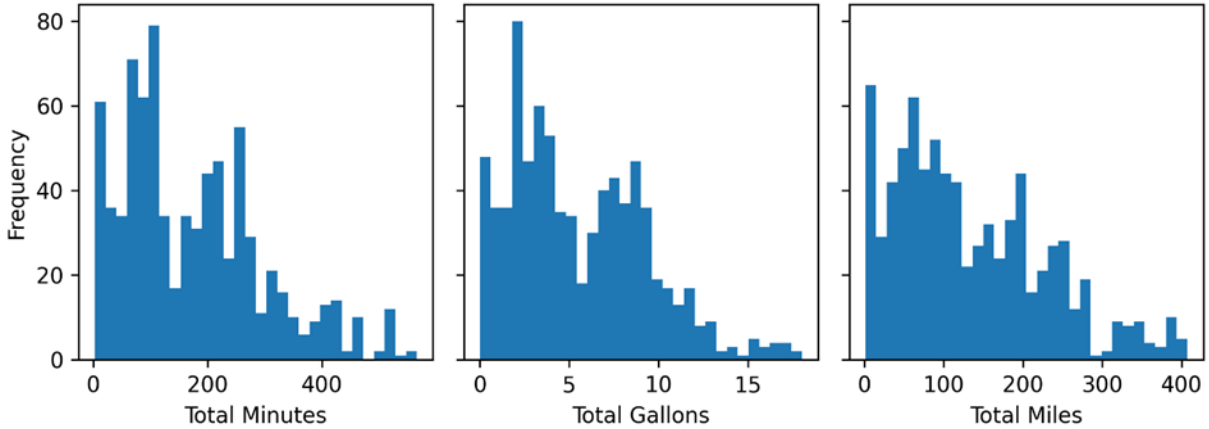
- Baseline data analysis on O-D pairs to understand customer fleet energy consumption
- Collected grade data from MD truck and bobtail HD trucks to create RouteE energy consumption estimation for those scenarios
- Completed training session on FMS/IDAS use with fleet partners

## Impact:

- Potential for 25% Freight Efficiency Improvement
- Integrates Several Connectivity Technologies Which Builds Potential for Future Projects
- Powertrain Agnostic Which Makes This Technology Applicable for More Vehicles

# TECHNICAL BACKUP

# Backup



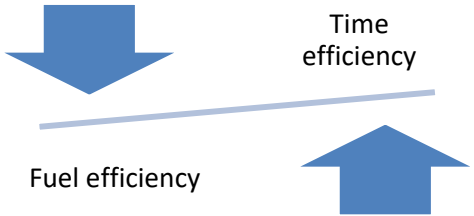

## NREL O-D pair testing:

- Shows distribution of the 800 O-D pair scenarios tested.

# Economics Based Routing

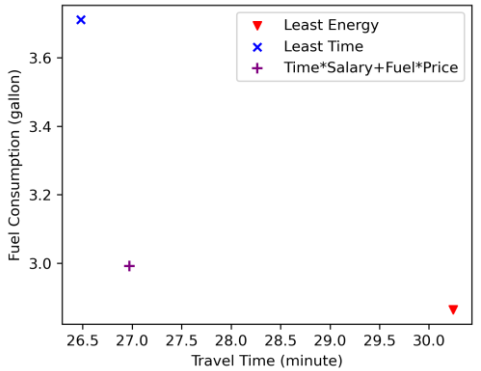
Optimal route includes value of travel time, fuel cost, and distance cost.

- Weight for travel time: Labor cost, $ 0.54/minute ($32.368/hour), U.S. DOT 2016 value inflation adjusted to 2022
- Weight for energy consumption: fuel price (diesel) = $4-6/gallon
- Weight for Distance: currently zero but $/mile costs can be considered based on fleet preference










| Route | Time (minutes) | Energy (gallons) | Distance (miles) | Monetary cost ($) |
|---|---|---|---|---|
| Least energy | 30.2 | 2.8 | 15.8 | 27.8 |
| Least time | 26.4 | 3.7 | 14.6 | 29.1 |
| Time*Salary+Fuel*Price | 26.9 | 2.9 | 14.8 | 26.5 |