VoICE-MR: Vocation Integrated Cost Estimation for Maintenance and Repair of Alternative Fuel Vehicles (AFV)

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Organization: West Virginia University
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ACKNOWLEDGMENTS

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Funding Partners

- South Coast Air Quality Management District: Sam Cao
- Southern California Gas Company: Michael Lee

Project Partners

- Wale and Associates Corp.: Adewale Oshinuga
- WCROG: Meifung Wu, Taylor York, Tyler Masters
- CFO: Tim Cho, Megan stein, Andrew Conley
- PRCC: Richard Price
- WV Clean Cities: Kelley Bragg
- PERC: Joe Calhoun, Gokul Vishwanath, Stephen Whaley

The project team would like to extend our appreciation to all the participating fleets, for their enthusiasm and commitment to sharing data.

OVERVIEW

Timeline

Project Start: November 2020
Project End: December 2023
Budget Period 1: Nov 2020-Dec 2021
Budget Period 2: Jan 2022-Dec 2022
Budget Period 3: Jan 2023- Dec 2023
Percent Complete: ~70%

Barriers

1. Lack of detailed maintenance cost (MC) comparison between heavy-duty diesel and alternative fuel vehicles (AFV) across different vocation and geographical regions
2. Gap in knowledge related to the influence of duty-cycle on MC estimates of AFV
3. Gap in knowledge related to MC of AFVs in regions with high seasonal temperature changes

Budget

Budget Period 1: Federal: $445,947; Cost Share: $445,867
Budget Period 2: **Federal: $335,045; Cost Share: $336,076**
Budget Period 3: **Federal: $304,690; Cost Share: $304,609**
Total: Federal: $1,085,682; Cost Share: $1,090,552

Coalition Partners

WRCOG Western Riverside Council of Governments
PITTSBURGH REGION CLEAN CITIES
WEST VIRGINIA OFFICE OF ENERGY
CLEAN FUELS OHIO — OHIO'S CLEAN TRANSPORTATION ADVOCATE
Wale & Associates Corp.

Funding Partners

South Coast AQMD
SoCalGas A Sempra Energy utility
PROPANE education & research COUNCIL

PROJECT OBJECTIVES

Objectives

Budget Period 1

- Conduct an in-depth survey of heavy-duty (HD) fleets operating in various vocations to collect maintenance records for diesel and AFV vehicles
- Analyze vehicle telemetry data to discern the effects of duty on MC of AFVs in different vehicle vocations
- Understand the impact of extreme seasonal temperature changes on the MC of AFV
- Develop the VoICE-MR estimation model to deliver comparative MC estimates between Diesel and AFV as a function of vehicle duty cycle.

VTO TI Goals

- Improving Fuel Diversity
  Provide an accurate estimate of MC for AFV in different vocation, that will help offset existing diesel vehicles with domestically sourced alternative fuel options

Impact

- Empower fleets with accurate data to transition from diesel fuel to domestic alternative fuel powertrain technology
- Improve fleet decision making related to selection of appropriate AFV technology for a certain vocation/duty-cycle
- Illustrate maintenance practices and climate effects that can adversely affect MC of AFV powertrain

PROJECT APPROACH

Budget Period 1

- Task 1.1- Project Initiation, Fleet Identification and Working Agreements
  - Forming steering committee
  - Identify target fleets for data collection
  - Develop data sharing agreements
- Task 1.2- Fleet Maintenance Cost Data Collection
  - Develop a web interface for data gathering
  - Engage coalition partners and subcontractors for data collection activity

Budget Period 2

- Task 2.1- Data Classification and Analysis
  - Analyze telemetry data from archive data and from BP-1 data collection
  - Classify MC data as a function of vehicle vocation
  - Analyze the MC data to study the changes in MC with seasonal temperature changes
  - Assess changes in MC with vehicle aging

Budget Period 3

- Task 3.1- VoICE-MR Model Development and Cost Reduction Strategies
  - Develop a machine learning model to estimate MC of AFV as a function of vehicle duty-cycle
  - Provide comparative cost estimates for maintenance between diesel and AFV for different vocations

PROJECT APPROACH

Budget Period 2

- Task 2.1- Data Classification and Analysis
  - Analyze telemetry data from archive data and from BP-1 data collection
  - Classify MC data as a function of vehicle vocation
  - Analyze the MC data to study the changes in MC with seasonal temperature changes
  - Assess changes in MC with vehicle aging

1. Data Sanitization
2. Convert paper records to electronic format
3. Convert fleet maintenance record to categories defined by project scope
4. Upend data to a database

1. Data Classification accomplished through Microsoft PowerBi
2. Final data cleanup also performed through PowerBi reports
3. Seasonal temperature changes and duty cycle added as relational database to PowerBi

PROJECT APPROACH

Budget Period 2

Milestone	Type	Description	Progress
Estimation of overall maintenance cost of AFVs and diesel vehicles complete	Technical	Established the categorization of the MC data from the database for different AFVs. Present statistics of the MC data collected from different fleets for different vehicle components and maintenance categories	Completed
Duty-cycle telemetry data combined with MC data	Technical	Present to steering committee the correlation of vehicle duty cycle to MC data. Trends linking vehicle operation to MC will be assessed from a technical standpoint.	In Progress
Correlation Analysis	Go/No-Go	Correlation analysis demonstrated between maintenance and seasons demonstrates reliable predictability	In-Progress
Categorization of seasonal changes in temperature and vehicle age complete	Technical	Provide statistics of MC classified according to the different seasons in a year and correlated to average ambient temperatures during that period	Completed

PROJECT ACCOMPLISHMENT AND PROGRESS

Task 2.1- Data Classification and Analysis

Task 2.1.1- Data stored in the data base will be categorized according to vocation, types of maintenance, model year of vehicles, sub-systems of the vehicles

- Data extracted from the database for different fuels were processed using PowerBi
- PowerBi is a powerful tool that simplifies the data categorization process through relational database
- PowerBi provides flexibility in categorizing the data with multiple filters based on unique identifiers such as vocation, truck sub-system, types of maintenance etc.

Task 2.1.2- Analyze both the telemetry data for the different vocations and the maintenance cost information for AFVs and diesel

- Duty cycle metrics for different vocations have been incorporated into PowerBi
- Work is in progress to develop an analysis linking MC data to duty-cycle based on relational database

Task 2.1.3- Recipient will analyze the data collected from the fleets for changes in maintenance cost as a function of seasonal temperature

- Powerbi classification based on quarterly periods in a year has been performed
- Preliminary approach to link average quarterly temperatures with MC has been performed
- Preliminary results do not indicate any patterns to the MC observed during the different quarters

Task 2.1.4- analyze histrocal records from fleets to study the impact of vehicle aging.

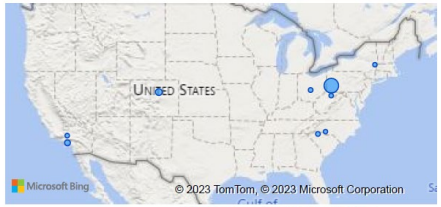
- For most fleets we were able to retrieve data for close to 4-5 years of vehicle history
- For a given vocation the study was able to develop MC trends for years ranging between 2010 - 2022

PROJECT ACCOMPLISHMENT AND PROGRESS

Task 2.1- Data Classification and Analysis

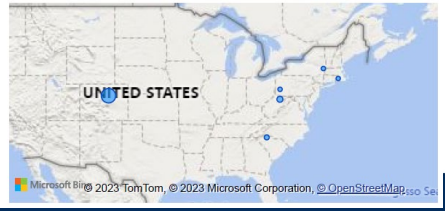
- The project has collected data from a total of 72 diesel, 86 propane, 102 natural gas and 25 Electric heavy-duty vehicles.
- Depending on vocation some applications show more data records than others
- Project has collected a total of 7000 MC records for diesel, 13000 MC records for NGV and 1800 MC records for propane.
- Data is being processed for EV vehicles from a large transit fleet.
- Geographical regions covered include, mid-Atlantic, Midwest, east coast, southwest and central regions of the country.

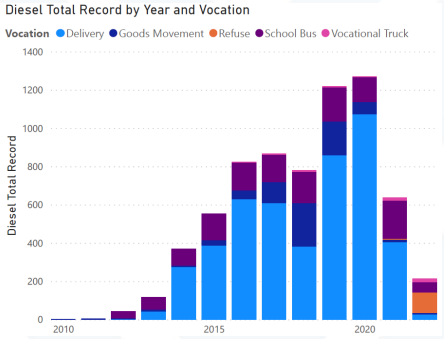
Diesel Vehicle Data

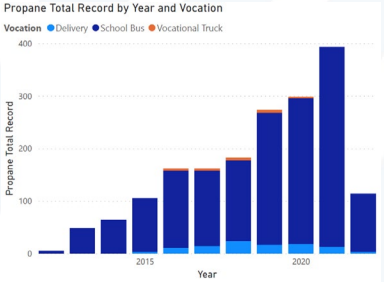


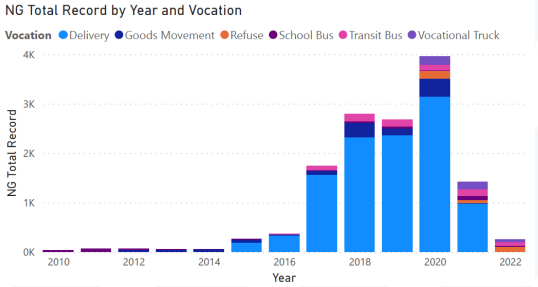
NG Vehicle Data

Propane Vehicle Data

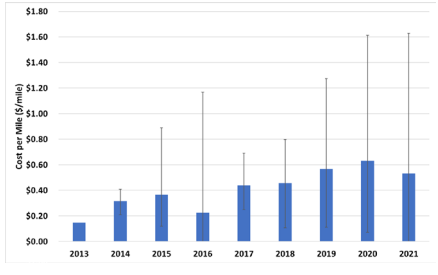


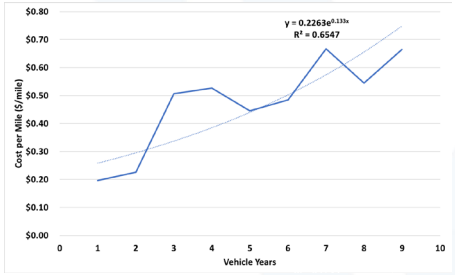


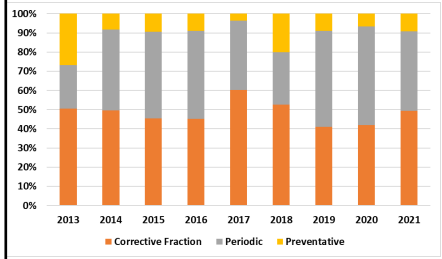




PROJECT ACCOMPLISHMENT AND PROGRESS



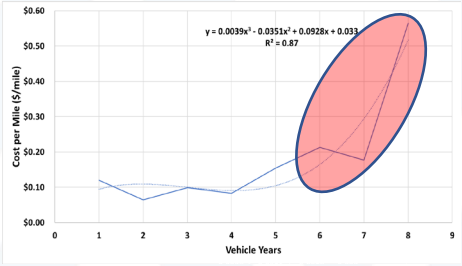


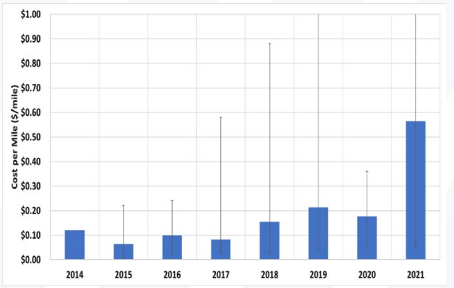


Many vehicles did not report periodic oil changes and aftertreatment maintenance at OEM recommended intervals

Diesel Delivery

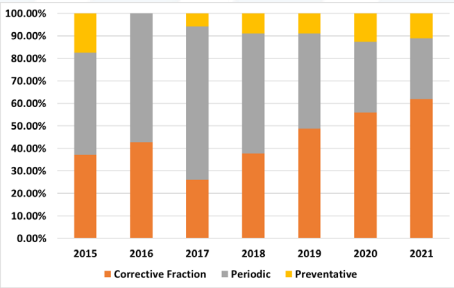
- Corrective actions dominate the MC costs of diesels
- MC steadily increases with age of vehicle
- Some vehicles exhibited high dollar amount failures such as turbochargers and engine head replacement
- Lower periodic maintenance can be indicative of the historical practice/opinion associated with the durability of diesel engines



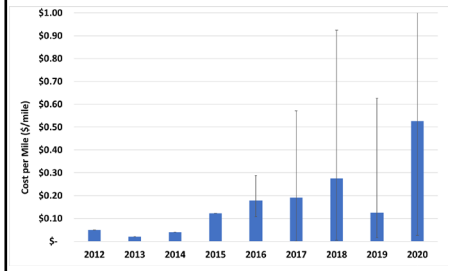


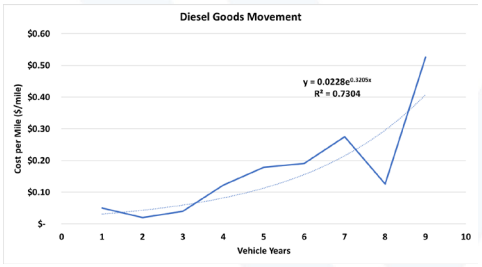
NGV Delivery

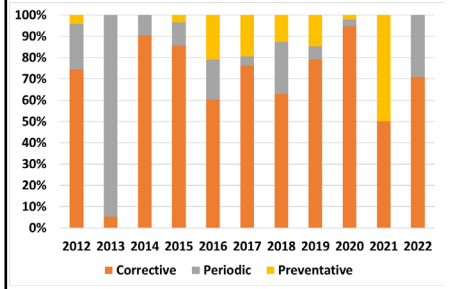
- Periodic maintenance dominates MC of NGV
- Could be attributed to the maintenance requirements of a spark ignited engine
- Some vehicles exhibited high dollar amount failures such as turbochargers and engine head replacement
- MC with age is flat for newer vehicles and increases exponential beyond age 5 years



PROJECT ACCOMPLISHMENT AND PROGRESS

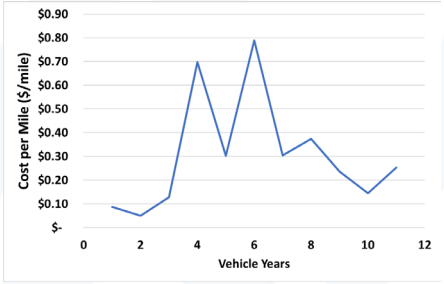


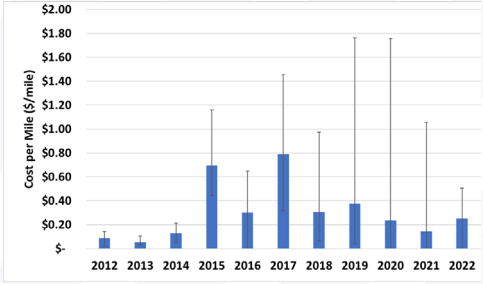




Diesel Goods Movement

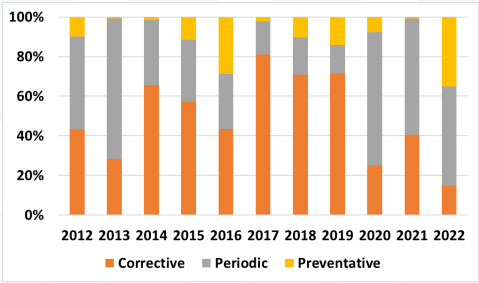
- Diesel goods movement data were mostly collected from port drayage trucks
- Many fleets did not have a proper periodic maintenance process
- Higher failure rates could be attributed to lesser periodic maintenance
- Turbochargers, EGR related components and sensors were observed to be the highest failure rates



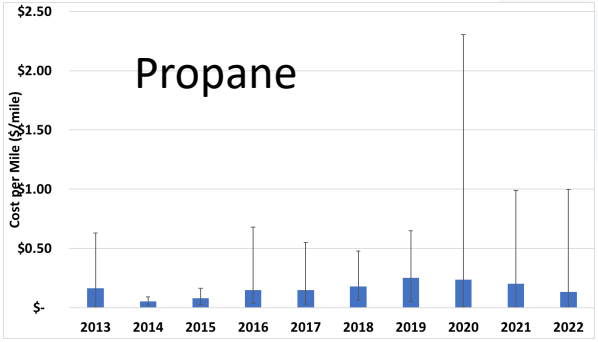


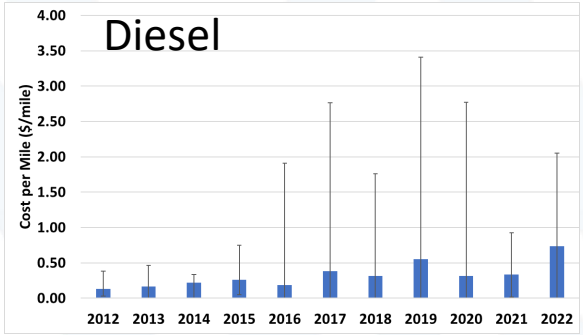
NGV Goods Movement

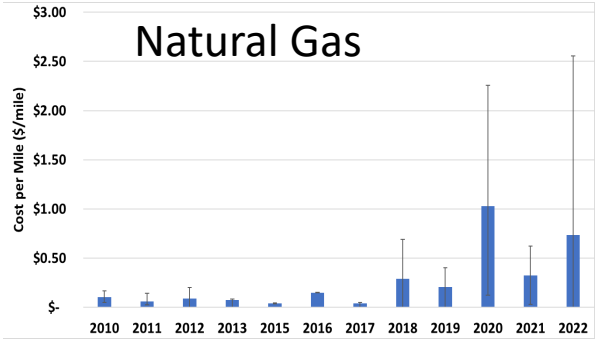
- Higher failure rates were observed for NGV goods movement primarily operating as port drayage trucks
- Port drayage duty cycle and load capacity is significantly higher than delivery application and could be linked with higher failure
- Inconsistencies in periodic maintenance could also be a contributing factor



PROJECT ACCOMPLISHMENT AND PROGRESS







- Propane school bus show significant lower MC compared to diesel and natural gas
- The data does not indicate any significant increase in MC with age
- This could be attributed to the vocational characteristics and better maintenance practice

COLLABORATION AND COORDINATION AMONG PROJECT TEAM

- Monthly meetings with coalition partners
- Quarterly reports

CONTRIBUTION TO ENERGY EQUITY AND ENVIRONMENTAL JUSTICE

Impact

- The project will address the gaps in knowledge related to wide-scale adoption of AFVs in rural regions of the country
- Increase the use of domestic and cleaner fuels in heavy-duty vocations not restricted to urban locations

Current and Future Project Goals

- The project team plans to increase the data available for EV platform
- The project team is working to develop machine learning based models to integrate vocation characteristics, seasonal temperature and vehicle age.

Challenges

- Collecting maintenance information from production HD EV has been challenging.
- Most historical data available is for demonstration vehicles which may not be representative of production vehicles

SUMMARY

GOALS

- Address the knowledge gap related to the impact of duty-cycle on MC of AFV
- Develop the VoICE-MR cost estimation model to empower fleets with a tool to help in adoption of AFVs

APPROACH

- In-depth MC data collection from fleets across the country, covering various vocations
- Collect new and use historical telemetry data to link vehicle activity to collected MC data
- Use the relationships to build a machine learning based model to estimate MC as a function of vehicle duty cycle

PARTNERS

- Four Clean Cities Coalitions
- South Coast Air Quality Management District
- Alternative Fuels Stake holders
- Steering committee comprised of public and private sector members

Achievements

- Vehicle model years range from 2008-2018
- Historical maintenance records span from 2015-2021.
- New telemetry data from vehicle operation in the east coast of US collected
- Model development for predicting MC based on vocation characteristics

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