Carnival Cruise Line - Engine Optimization

PURDUE UNIVERSITY | The Data Mine

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Carnival

1. INTRO: PROJECT GOALS

- To monitor diesel engine performance for 3 ships over a 3-year time period.
- To identify anomalies and outliers in engine component behavior.
- To improve engine reliability and operational efficiency through data-driven insights.

2. RESEARCH METHODOLOGY

• Cleaned datasets to represent values when the engine was actively running by filtering on specific engine parameters such as load, running hours, and turbocharger speed.
• Integrated baseline regression lines based on engine performance post overhauls, to compare current performance against baseline performance.
• Incorporated Time, Diesel Generator, and Ship slicers to detect and filter remaining outliers from the dataset.
• Constructed 1-hour moving averages for individual engine parameter to reduce noise, reveal clear performance trends, and assess the reliability of individual engine components.
• Developed a Power BI dashboard displaying correlations between engine parameters via scatter plots and time history trends to assess and visualize engine trends across all 3 ships.

Cleaned Data
↓
Added Regression Lines
↓
Filtered Outliers
↓
Created Moving Averages
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Completed Power BI Graphs

3. KEY FINDINGS

• The turbocharger speed increases quadratically as engine load increases, indicating a strong positive polynomial correlation between engine load and TC speed. (Fig. 1)
• The minimal deviation from expected turbocharger speed indicates that current engine performance closely aligns with baseline conditions. (Fig. 2)
• Identified variability in turbocharger differential temperature with frequent deviations in both positive and negative directions indicates further research to fully understand the reason behind this trend. (Fig. 3)
• The moving average of exhaust gas temperature deviations reveals performance of different cylinders and their combustion characteristics, which helps us to identify a failing fuel injector/pumps or issues with cylinder inlet/exhaust valves for each cylinder. (Fig. 4)

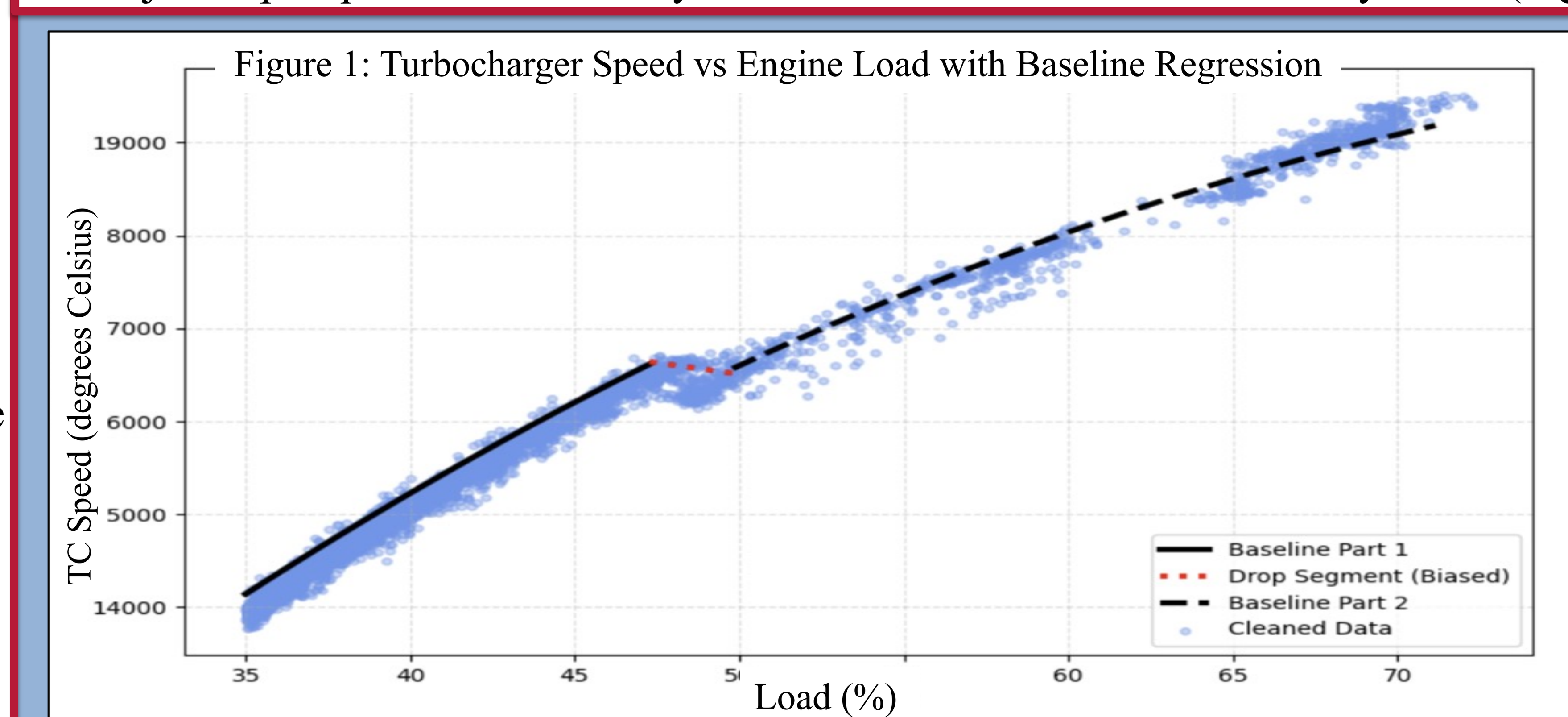

Figure 1: Turbocharger Speed vs Engine Load with Baseline Regression

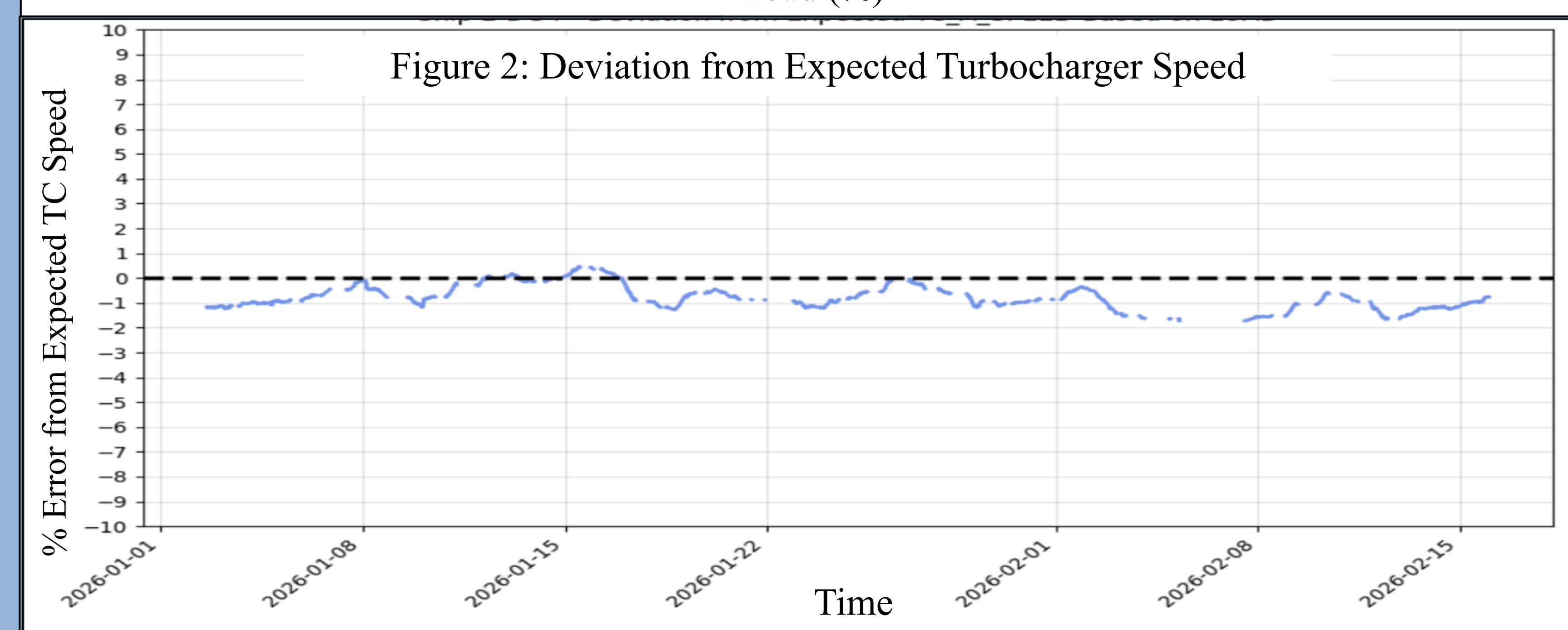

Figure 2: Deviation from Expected Turbocharger Speed

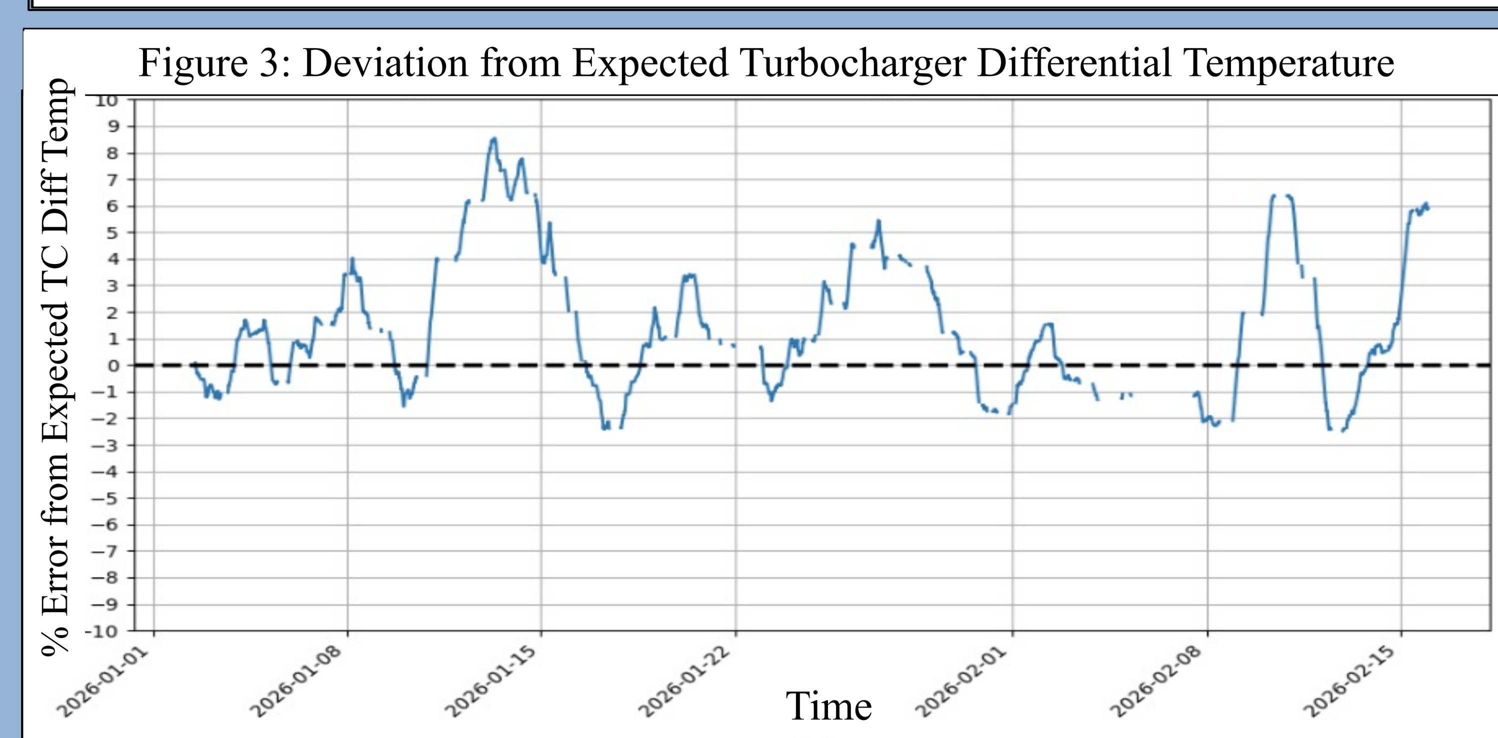

Figure 3: Deviation from Expected Turbocharger Differential Temperature

4. CONCLUSION

The strong correlation between engine load and TC speed empowers the vessel owner to proactively identify potential issues in turbocharger at an earlier stage with continuous monitoring of live data. The minimal deviation from expected baseline performance for turbocharger speed confirms the engine is operating within design parameters, without requiring corrective maintenance, ensuring stable and efficient operations. Identified variability in turbocharger differential temperature with deviations in both positive and negative directions indicates further research to fully understand the reason behind this trend. One reason could be thermal instability, suggesting the turbochargers are operating inconsistently and creating thermal stress on the engine components. This signals a high probability of developing mechanical inefficiencies leading to increased fuel consumption, higher maintenance costs, and reduced component lifespan. Finally, the unexpected positive and negative exhaust gas temperature deviations across specific cylinders helps us to identify a failing fuel injector/pumps or issues with cylinder inlet/exhaust valves for each cylinder. This allows the CCL team to proactively plan engine maintenance schedules, and offline maintenance windows, without disrupting guest itineraries.

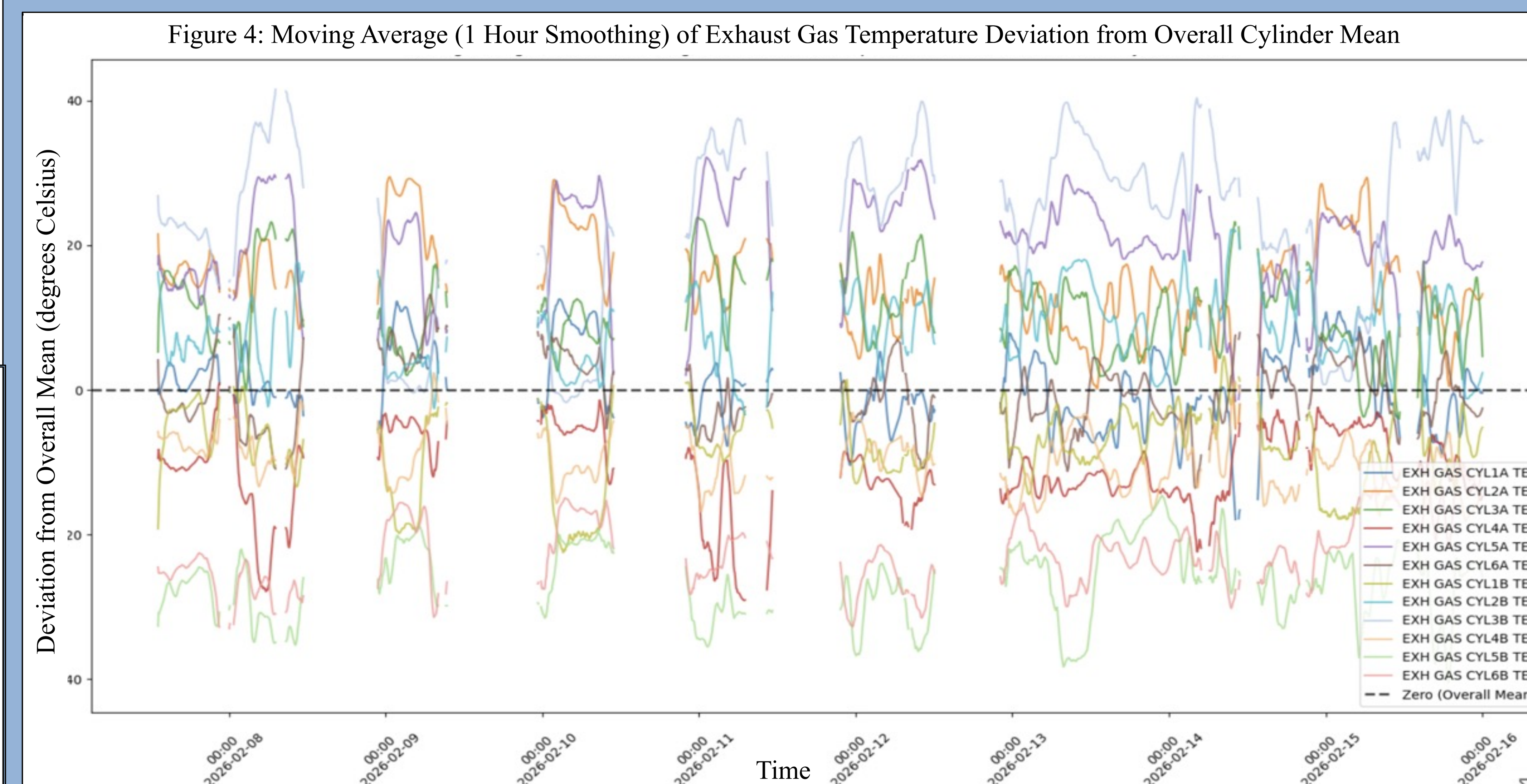

Figure 4: Moving Average (1 Hour Smoothing) of Exhaust Gas Temperature Deviation from Overall Cylinder Mean

5. FUTURE GOALS

• Apply machine learning algorithms such as decision trees, random forests, and neural networks to predict future engine performance and detect anomalies earlier.
• Expand visualizations and analysis to additional ships using more interactive tools to identify unique cross-fleet engine trends.
• Assess engine reliability using additional engine parameters and components beyond turbocharger and exhaust gas temperature.
• Support Carnival's sustainability goals by leveraging engine optimization insights to reduce fuel consumption and carbon emissions in alignment with international maritime environmental standards.

6. ACKNOWLEDGEMENTS

Special Thanks To:

- Corporate Partner Mentor: Biswajoy Roy for clarifying our questions and giving us feedback on our weekly deliverables.
- Andrew Harrison, Mathew Thomas, and Edmund Roper for uploading the company datasets and taking notes during the meetings.
- The Data Mine Staff, especially Ashley Arroyo on helping with the regression lines.