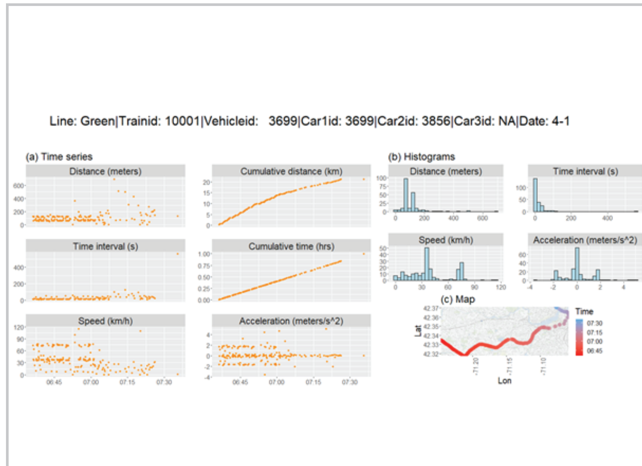
Research Summary

Tracking the Energy and Emissions of MBTA Rapid Transit Vehicles (TREEM)

Research Need

The Massachusetts Bay Transportation Authority (MBTA) spends $38 million on electricity for traction power annually. Sustainable strategies are required to reduce energy consumption, costs and environmental impacts. Furthermore, decision support tools would enable the MBTA to plan for sustainability, as well as respond effectively and equitably to disruptive events.



Goals/Objectives

1) Analyze real-time train position and electricity consumption data to quantify the energy use, costs, and subsequent emissions of the rapid transit vehicle system of the MBTA

2) Expand current knowledge on how the speed and acceleration of the trains relates to the demand draw of the traction power network.

3) Develop planning metrics for energy use per vehicle-mile and per vehicle-hour to assist with planning for future energy demand and Operations & Maintenance (O&M) budgets.

4) Demonstrate the potential of a system-wide model to explain and predict energy use, even under disruptive events.

Methodology

1) Trajectory computation for all trains using real-time train location data from MBTA Research Database.

2) Pipeline to process trajectories (and related movement variables), ridership, energy, weather and other operations variables for eventual modeling.

3) Estimation of statistical model to explain and predict energy consumption in relation to train movement and other factors.

4) Demonstration of model potential for planning and decision-making by using it to analyze impacts of COVID-19 on the system.

Key Findings

Via our research framework, we obtained:
1) Detailed train trajectories computed from the MBTA's train location data
2) A high performance energy consumption model robust to large disruptions, such as the COVID-19 pandemic

Through this project, we computed baseline planning metrics for the MBTA based on 2019 data:

- Energy: 2.12 MWh/veh-mi; 0.92 MWh/veh-hr

- Cost: $1.49/veh-mi; $10.7/veh-h

- Emissions: 1002 tCO2e/veh-mi; 437 tCO2e/veh-hr

The metrics indicate that distance is a higher-impact dimension with regard to energy usage. For costs, however, operating time is of much greater significance. In terms of emissions, twice as much GHG is emitted for each mile traveled than for each hour.

From the estimated statistical model (R^2 = 0.93), we identified the following key drivers of energy usage in the system:
1) Temperature (and related interactions)
2) Train operations (number of vehicles)
3) Train movement (speed-acceleration)

We observed that ridership impacts are relatively minimal. Critically, we also found that the intercept of the model is 59 MWh, much of which can be attributed to operating energy overnight when trains are not running. This points to opportunities for energy savings from better facility management.

In this project, we also analyzed the impacts of COVID-19 in order learn lessons for the future. Our model predicted 2020 energy usage to a high degree of accuracy (4% error), despite the significant service disruptions and demand reductions experienced in that year.

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Project Information

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Key Words:
rapid transit vehicles; systems analysis; modeling; sustainability; electric train energy; COVID-19

Use of Findings

We expect our findings (particularly the planning metrics) to be of immediate use to the MBTA in future planning cycles. We also developed a prototype visualization that could eventually be further extended to a real-time dashboard monitoring tool for identifying train speed/acceleration and corresponding energy demand at a high spatio-temporal resolution.

We are further simplifying (upscaling) the estimated model in order to transform it into a decision-support tool that the MBTA can use to provide energy demand estimates, using parameters such as vehicle-miles or hours of operation.

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