Longitudinal Analysis of Trends in Greenhouse Gas Emissions and Fleet Renewal for Transportation Network Companies in Toronto, Canada

João Pedro Bazzo Vieira, Marc Saleh, Marianne Hatzopoulou

*Department of Civil & Mineral Engineering, University of Toronto, Canada, Email: joao.bazzo@mail.utoronto.ca, Site: joaobazzo.netlify.app

Introduction

Background

- Ride-hailing (RH) has surged globally, with Uber alone completing 9.4B trips in 2023, contributing significantly to urban mobility and emissions
- In Toronto, daily RH trips tripled from 2016 to 2019, raising concerns over deadheading, emissions, and electrification challenges

Motivation

- Electrification offers substantial greenhouse gas (GHG) reductions but is hindered by diverse driver profiles and operational volatility
- Existing studies overlook long-term RH system transitions and evolving impacts on emissions and driver behaviors

Data and Methods

Data

Analysis uses trip records, cruising data, and motor vehicle characteristics from the City of Toronto, supplemented with EPA fuel efficiency data and Ontario's passenger car fuel type distribution.

- **Trip Dataset**: Covers 179.47M trips from 2020–2023 with details on trip ID, driver ID, locations, travel metrics (distance, speed, time), fare, service type, timestamps, and cancellation reasons.
- **Cruising Dataset**: Includes 157.1M from 2020–2023, detailing periods when drivers are available but without passengers, with coordinates, traveled distance, and timestamps.
- **Fleet Dataset**: Contains anonymized driver IDs, vehicle makes, models, and model years for fleet characterization.

Method

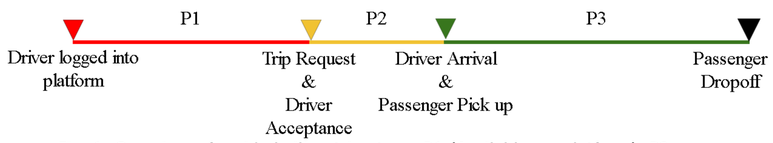

Fig. 1: Overview of a ride-hailing trip stage: P1 (Available on platform), P2 (Dispatch), P3 (Passenger Pick up)

GHG Estimation: Emissions are calculated using trip distance, mean speed, and emission factors (g/km) from the MOVES model, accounting for Toronto urban conditions and Ontario's passenger car age distribution

Driver Activity Analysis:

- Investigated weekly driver counts, mileage, and days needed to complete mileage.
- Analyzed active days, mileage in P1-P3 stages, and trip cancellation rates.
- Classified 55K active drivers (Dec 2023) using a 3-month trip record threshold.
- Used k-means clustering on six operational metrics to profile drivers and estimate Total Cost of Ownership (TCO) considering three fuel types:
  - Electric: Tesla Model Y (2023)
  - Hybrid: Toyota Prius-Prime (2020)
  - Gasoline: Honda Civic (2019)

Total cost of ownership

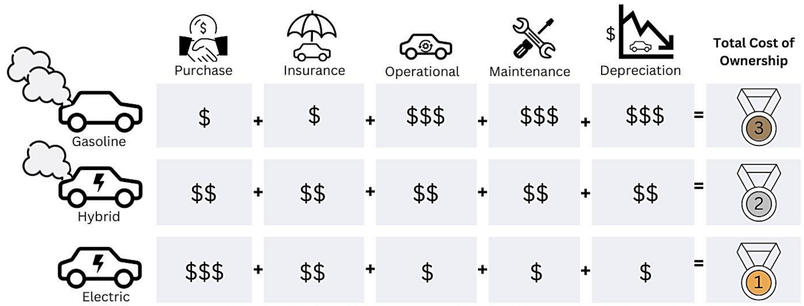

Fig. 2: Total Cost of Ownership between Gasoline, Hybrid and Electric

Results and Discussion

- RH in Toronto has seen increased trips, distances, and GHG emissions, with deadheading rates remaining steady at 33–37% from 2022 to 2023, showing no reduction

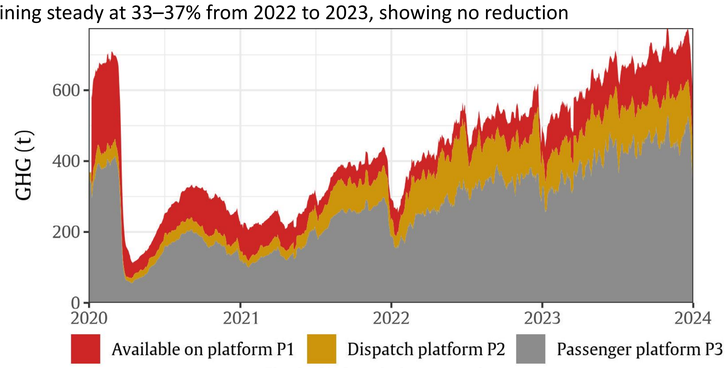

Fig. 3: GHG emissions overtime.

Driver Insights:

- 42.9% operate part-time (<200 km/week), with high turnover and inefficiency (43.9% deadheading)
- 40.2% drive >400 km/week, stay longer, and are more likely to cancel trips and work for multiple Private Transportation Companies

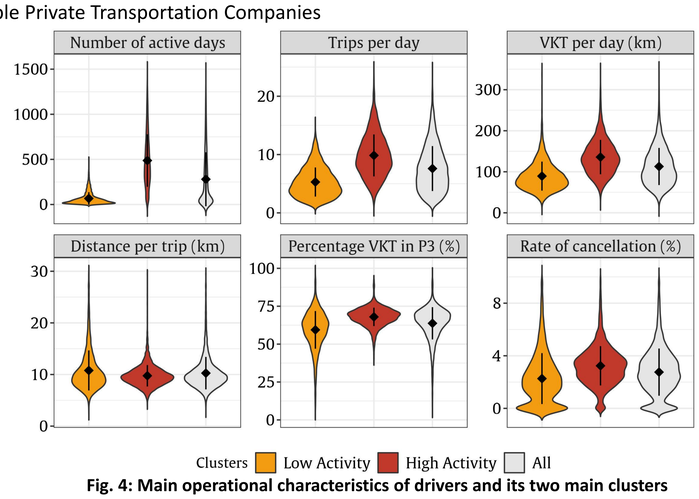

Fig. 4: Main operational characteristics of drivers and its two main clusters

TCO Insights:

- Electric vehicles (EV) demonstrated better cost competitiveness compared to hybrid and gasoline vehicles, with a 7–46% lower TCO for new vehicles across fuel types

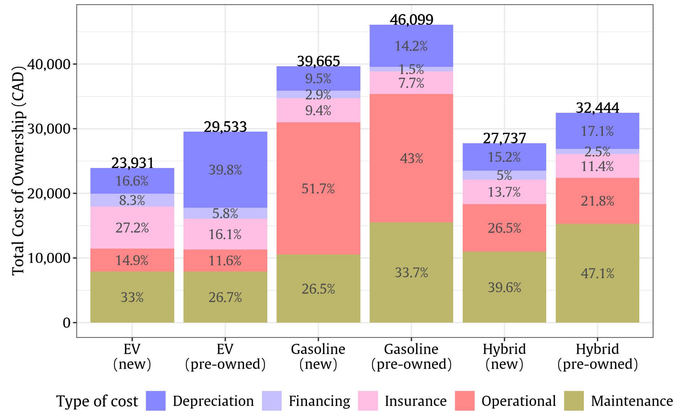

Fig. 5. Mean TCO break-down costs after 24 months of commitment for high activity drivers.

The cost per mile (Levelized Cost of Ownership - LCO) decreases for drivers with higher mileage and longer operational periods, benefiting those committed to a longer RH career.

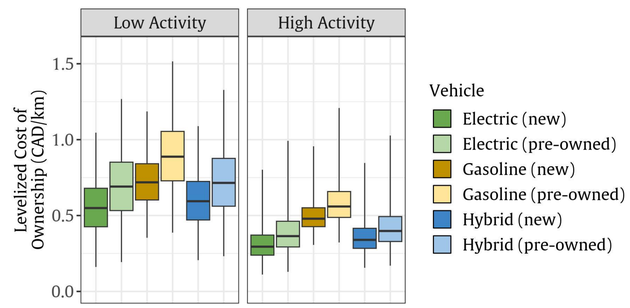

Fig. 6. LCO for high-activity drivers after 24 months of commitment.

Key Takeaways

Policy Recommendations

- Focusing on the 20% of drivers with the highest mileage tends to save 43.1% of total emissions
- Reduce deadheading by targeting part-time drivers with informational tools
- Promote EV adoption with long-term incentives, rental programs, and fair wage policies

Limitations: Excluded life-cycle emissions, driver vehicle transition data, and variability in maintenance and recharging costs