Applying Machine Learning to Model Freight Vehicle Type Choice

Usman Ahmed

Matthew Roorda

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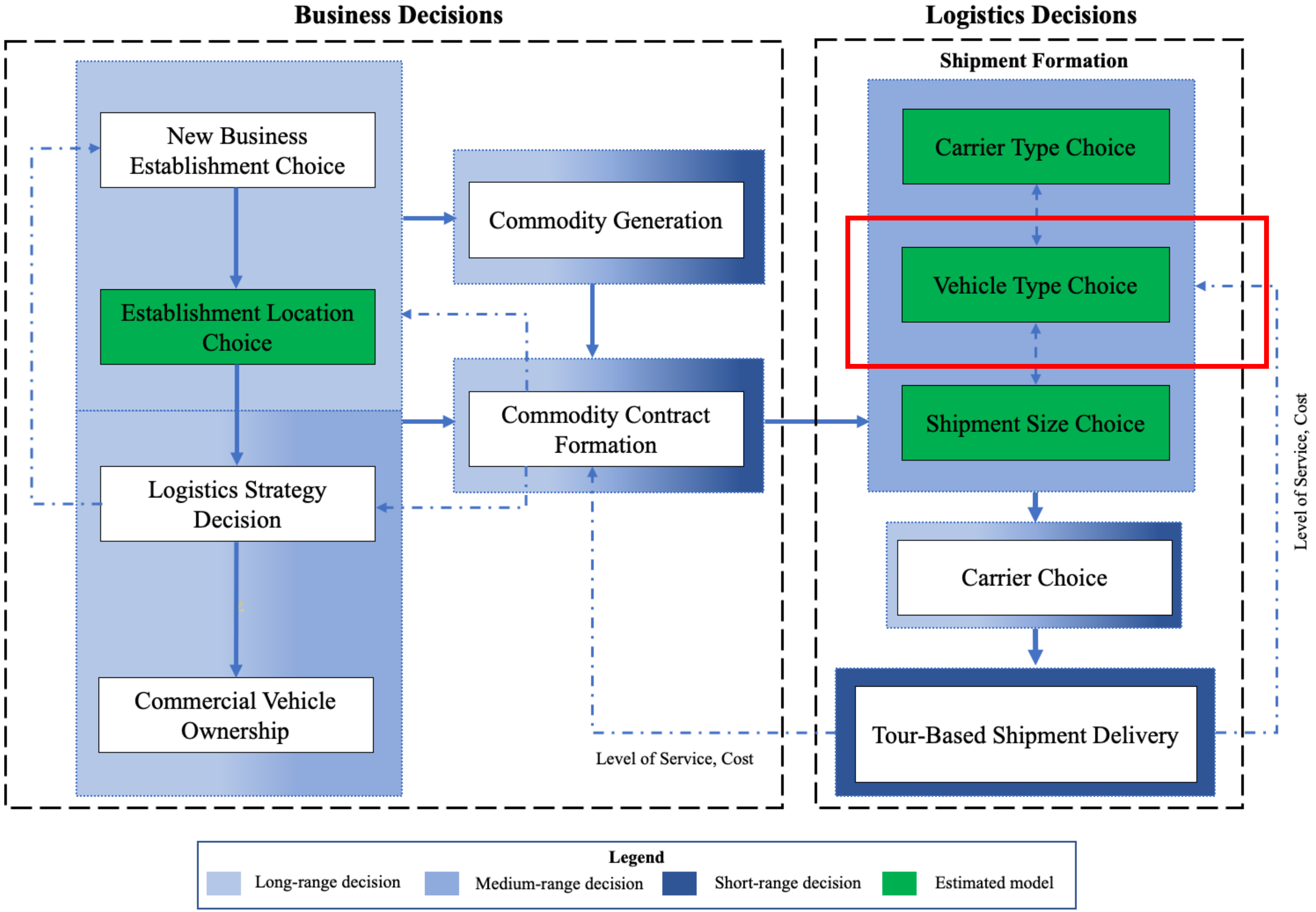
City Logistics for the Urban Economy

CLUE

SMART FREIGHT CENTRE

Freight Business and Logistics Decisions Simulation Framework



Freight Mode v/s Vehicle Type

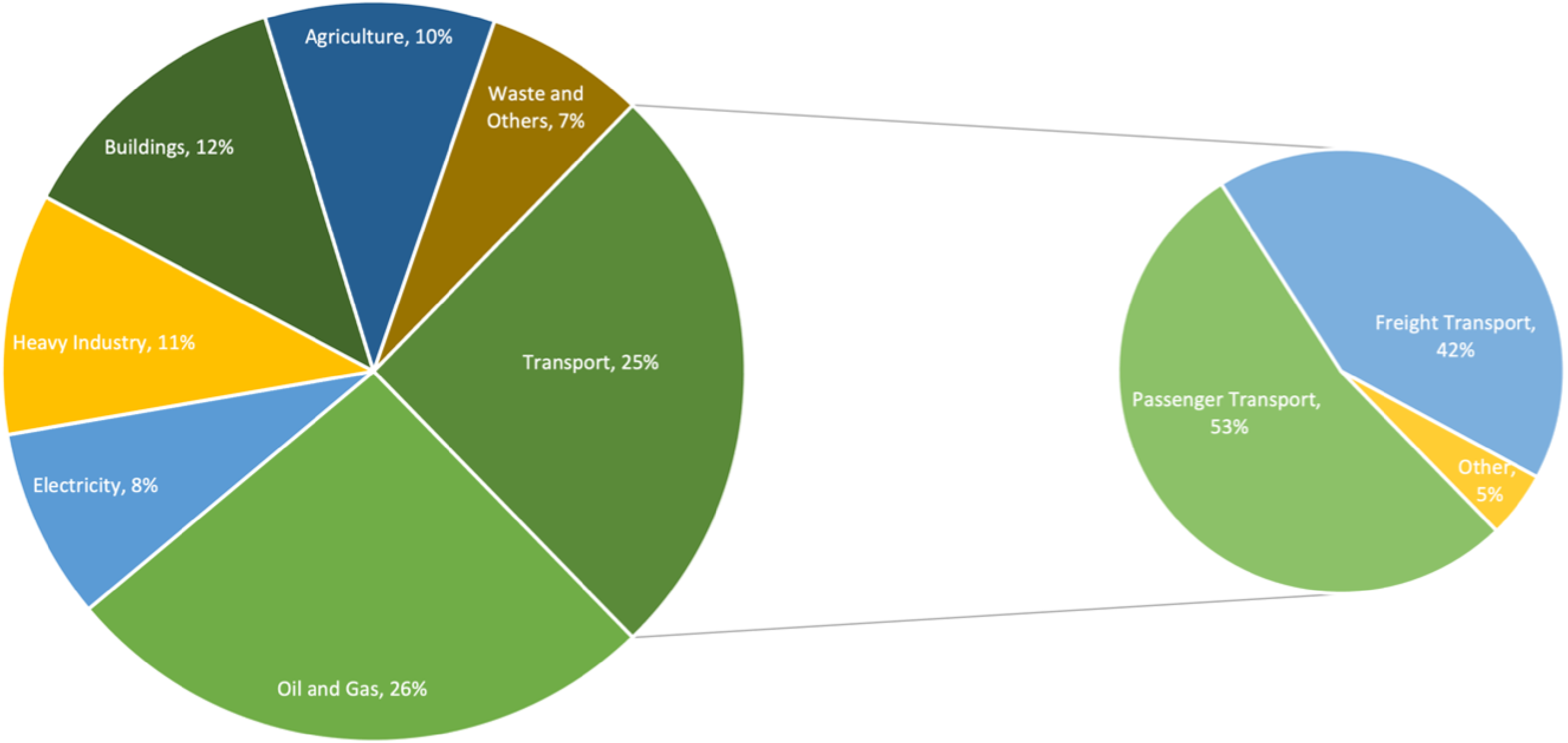
- Mode Choice:
  - Road, rail, air, water
  - Most relevant for inter-city, statewide, and national level studies

- Vehicle Type Choice:
  - Road-based mode: Passenger car, trucks, vans, etc.
  - Most relevant for city or metropolitan area level studies

Background and Motivation

- Freight flows have been increasing in Canada.
  - 16.7% increase in freight shipments from 2011 to 2017 (Statistics Canada 2020)
- Economic development of regions
- Global competitiveness of industries
- Changing trends in supply chain and logistics
- Major contribution to greenhouse gas emissions!

Background and Motivation



Background and Motivation

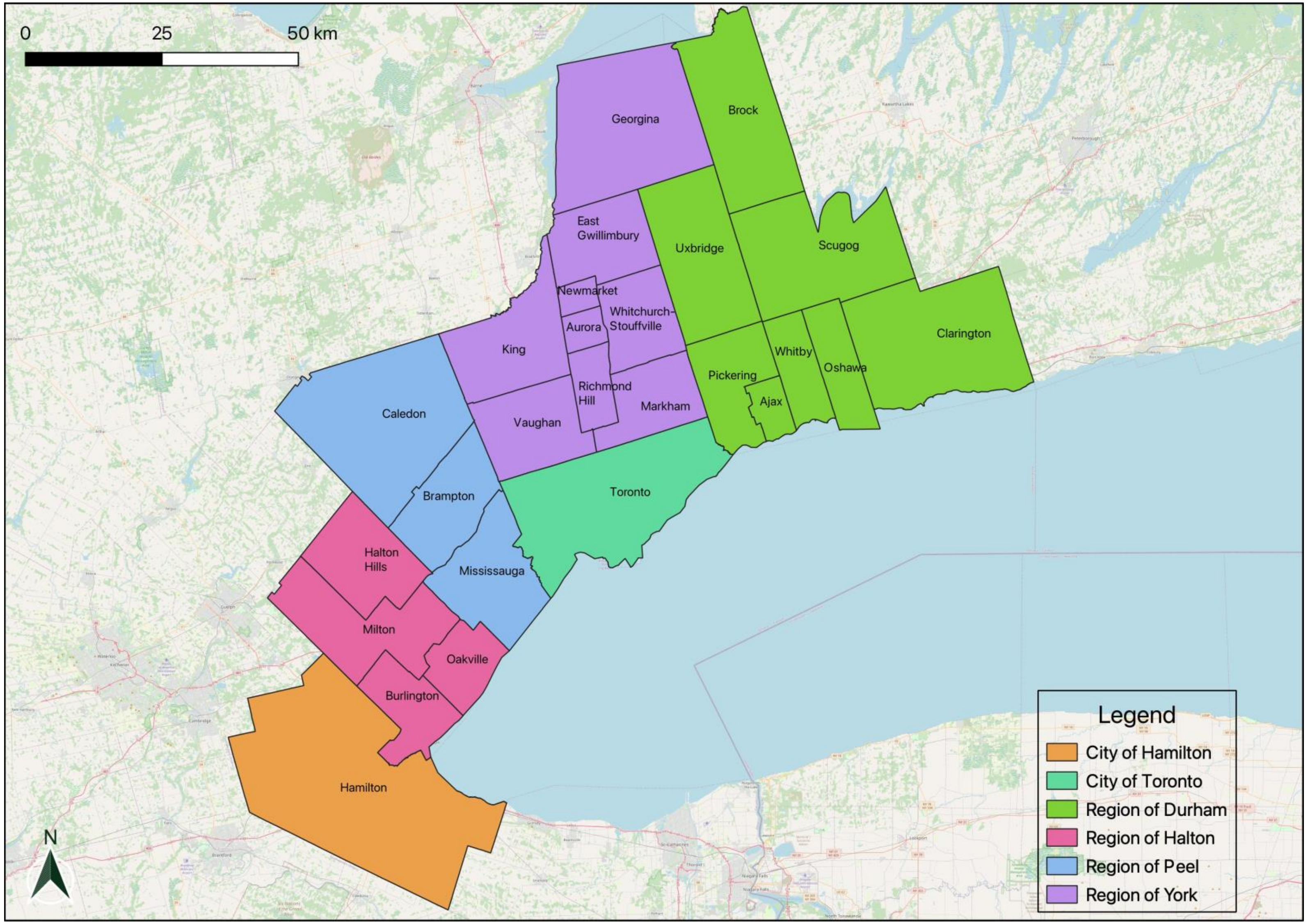
- Implications on quality of life of urban residents
  - Noise pollution
  - Traffic congestion
  - Safety impacts
  - Parking problems
  - Pavement damage

Study Objectives

- Study the factors behind freight vehicle type choice

- Comparison of discrete choice with machine learning methods
  - Discrete choice: Multinomial and mixed logit model
  - Machine learning: Random Forest

Study Area



0
25
50 km
Georgina
Brock
East Gwillimbury
Uxbridge
Scugog
Newmarket
Whitchurch-Stouffville
Aurora
King
Clarington
Whitby
Oshawa
Pickering
Richmond Hill
Ajax
Markham
Caledon
Vaughan
Brampton
Toronto
Halton Hills
Mississauga
Milton
Oakville
Burlington
Hamilton
N
Legend
City of Hamilton
City of Toronto
Region of Durham
Region of Halton
Region of Peel
Region of York

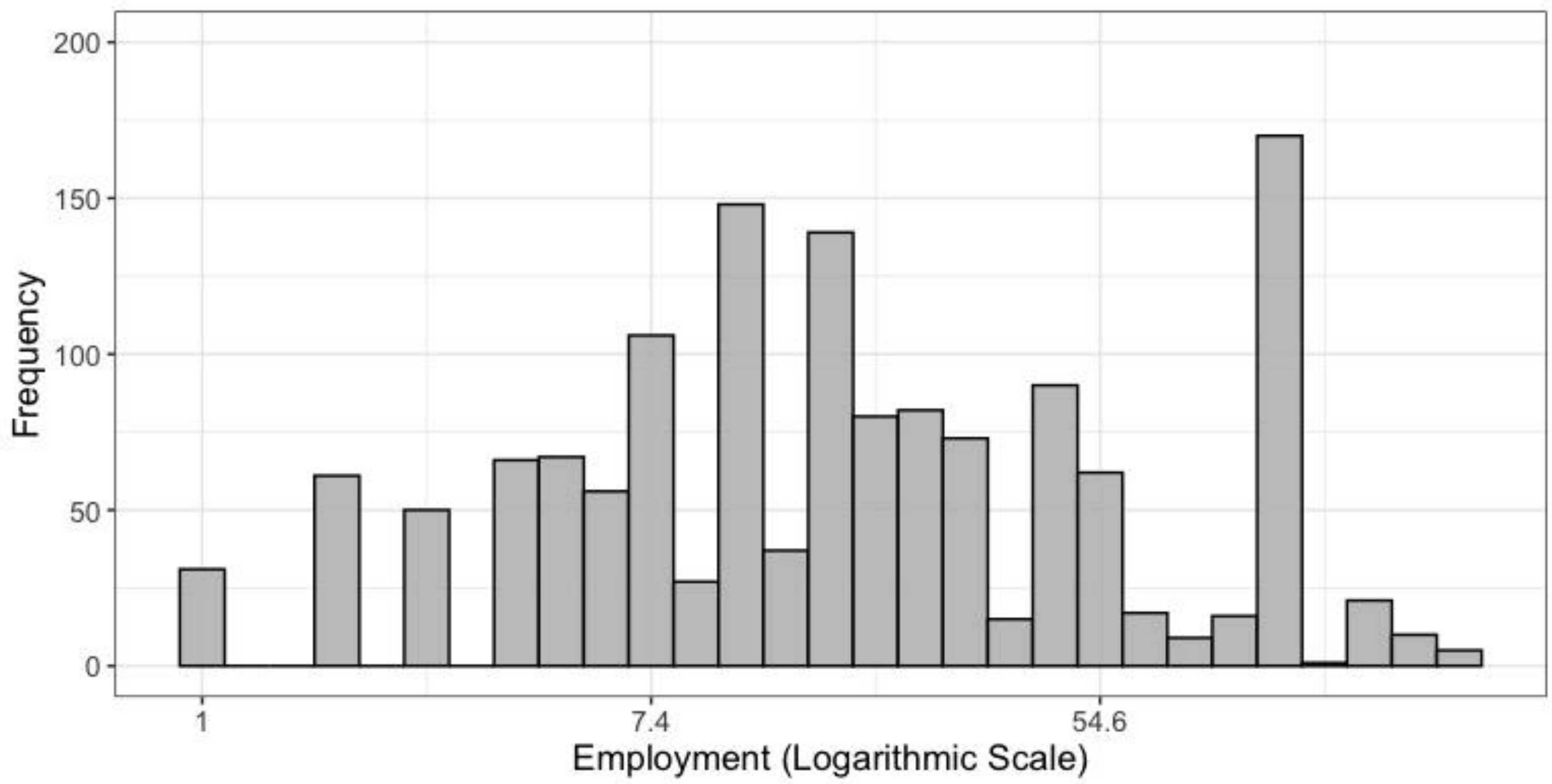
Data Source

- Commercial Travel Survey
  - Region of Peel (2006/07), Region of Durham (2010), Toronto Area (2012)

- Outbound Shipments
  - 1,439 shipments
  - 385 firms

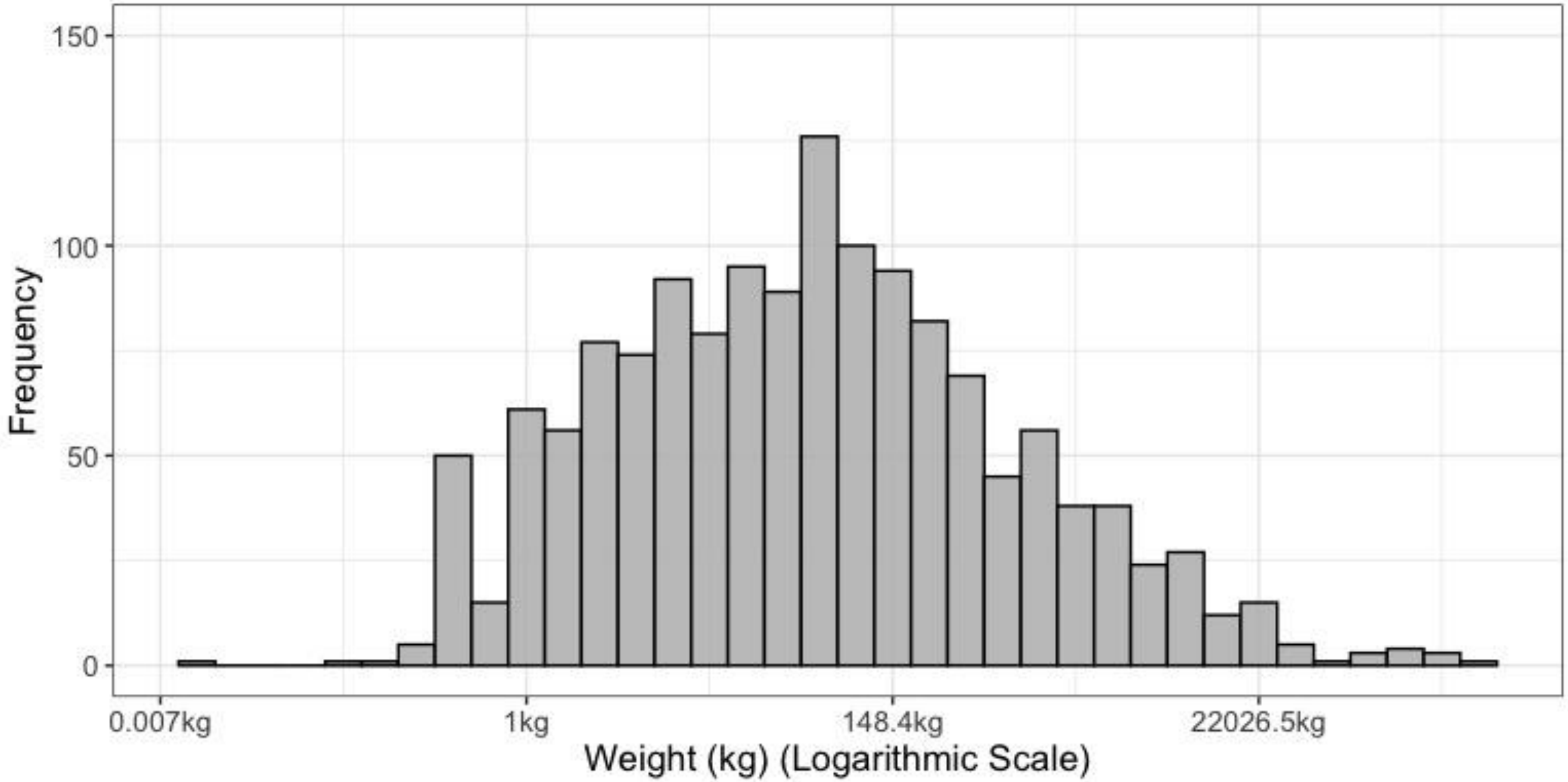
- Explanatory Variables
  - Industry type, commodity type
  - Shipment origin and destination (cities)
  - Employment and shipment weight

Data Source



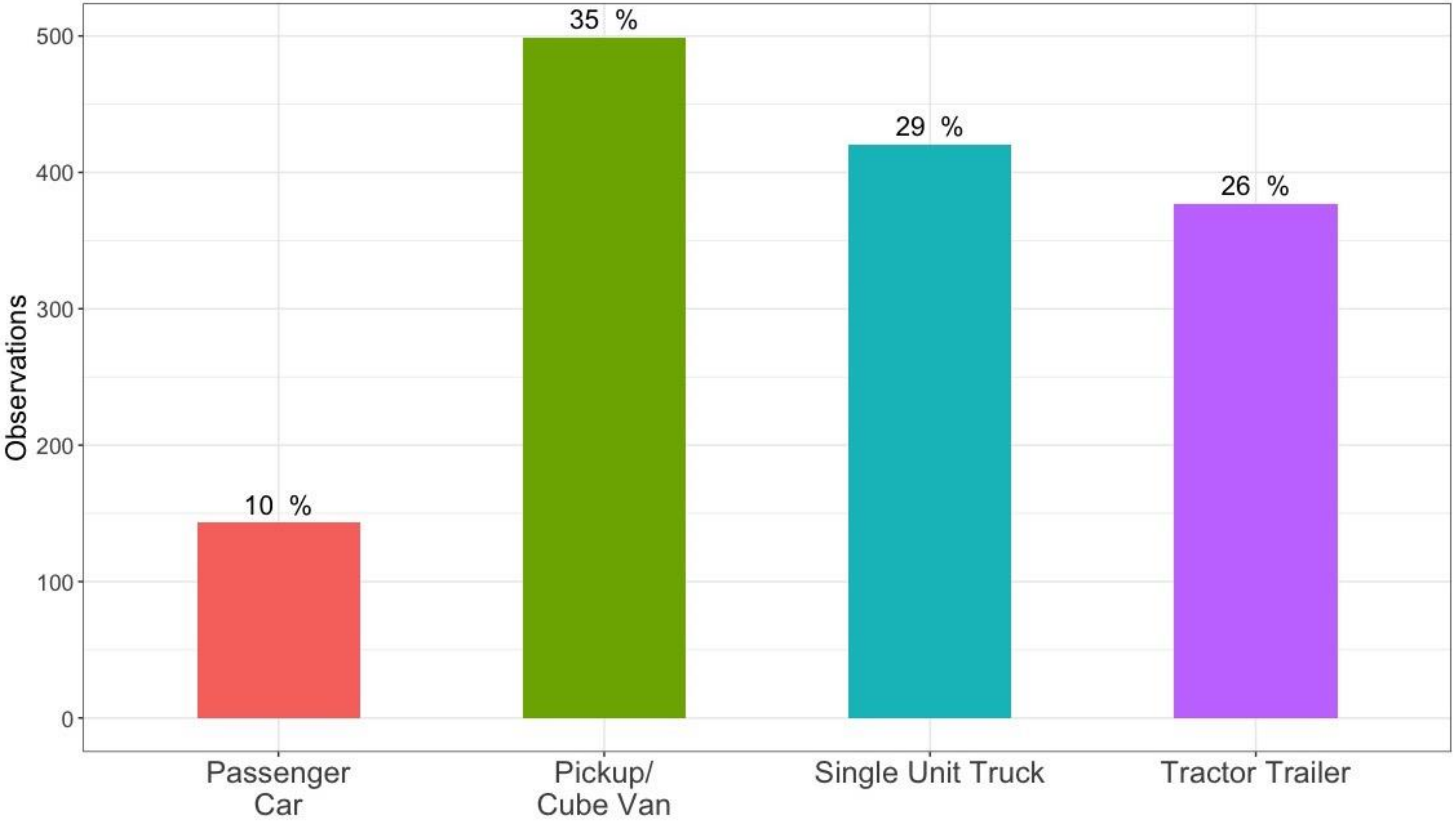
200
150
100
50
0
Frequency
1
7.4
54.6
Employment (Logarithmic Scale)

Data Source

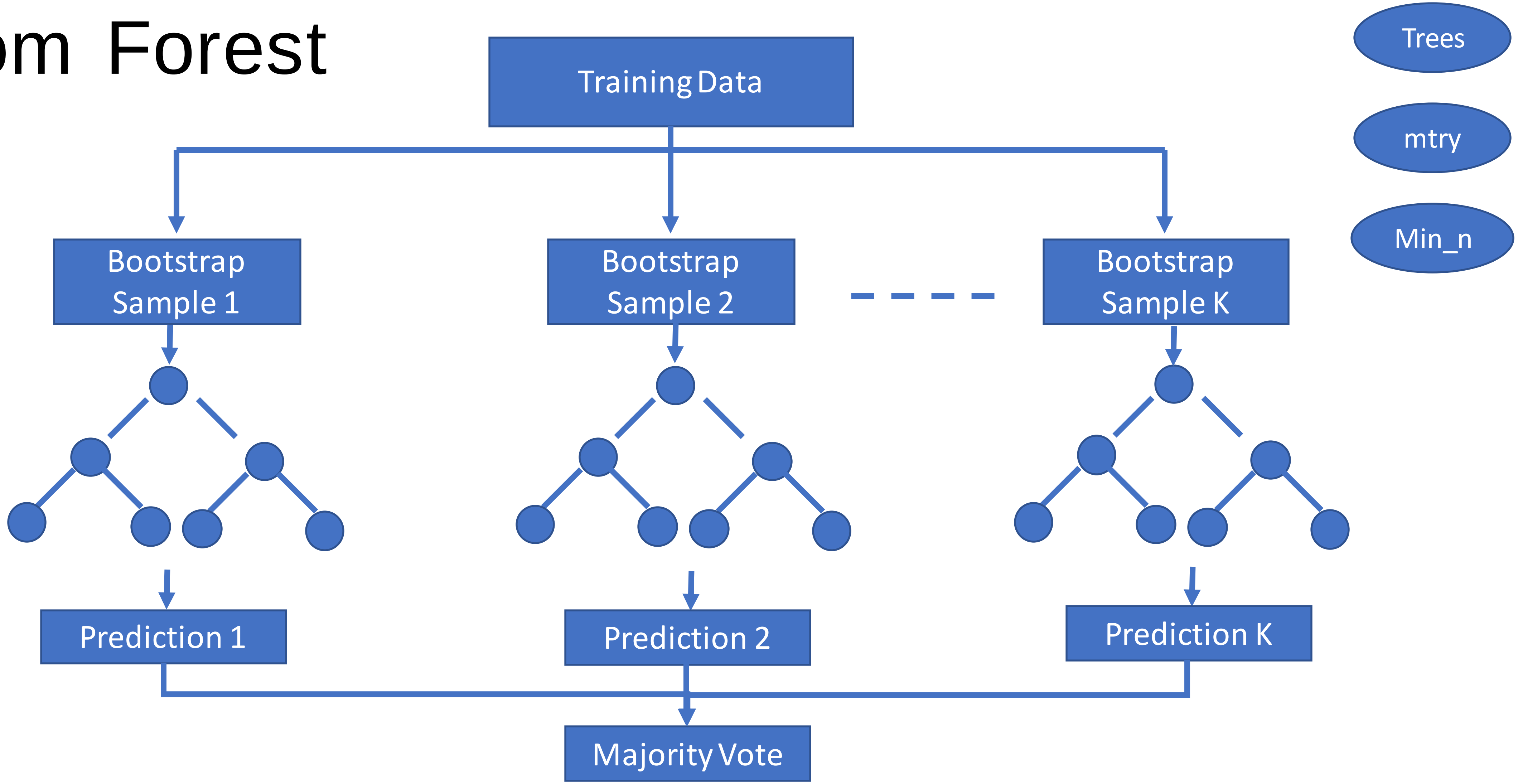


150
100
50
0
Frequency
0.007kg
1kg
148.4kg
22026.5kg
Weight (kg) (Logarithmic Scale)

Data Source – Vehicle Types



Random Forest



Random Forest – Variable Importance

- Shapley Additive Explanation (SHAP)
  - To assess the impact of explanatory variables on the model output
  - Comparison of model prediction with and without the variable
  - SHAP value is calculated for every observation
  - Variables are sorted based on the impact
  - Color of the point shows its value
    - Red: high value
    - Blue: low value

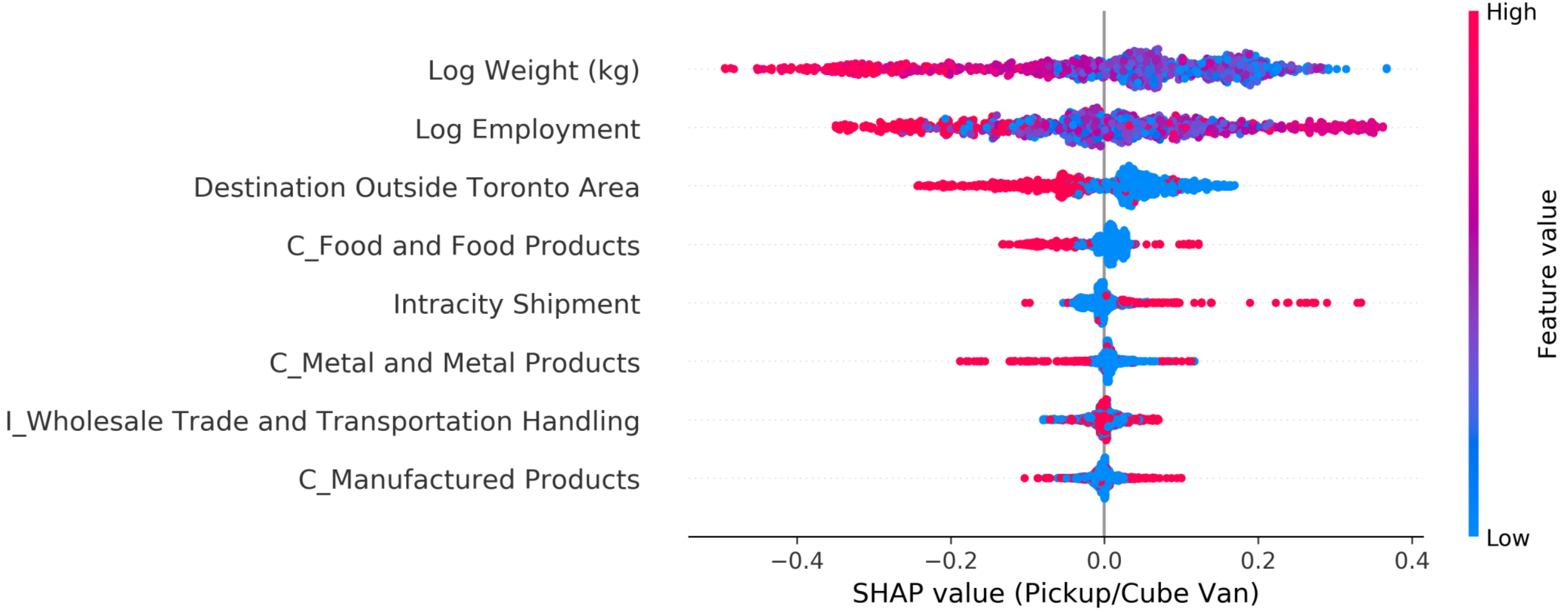
Training v/s Testing Data

- Models are developed on training data
  - RF: 10-fold cross validation
- Model prediction accuracy is calculated on testing data

- Training and testing data are divided based on firms
  - Training data: 269 firms with 1114 shipments (70%)
  - Testing data: 116 firms with 325 shipments (30%)

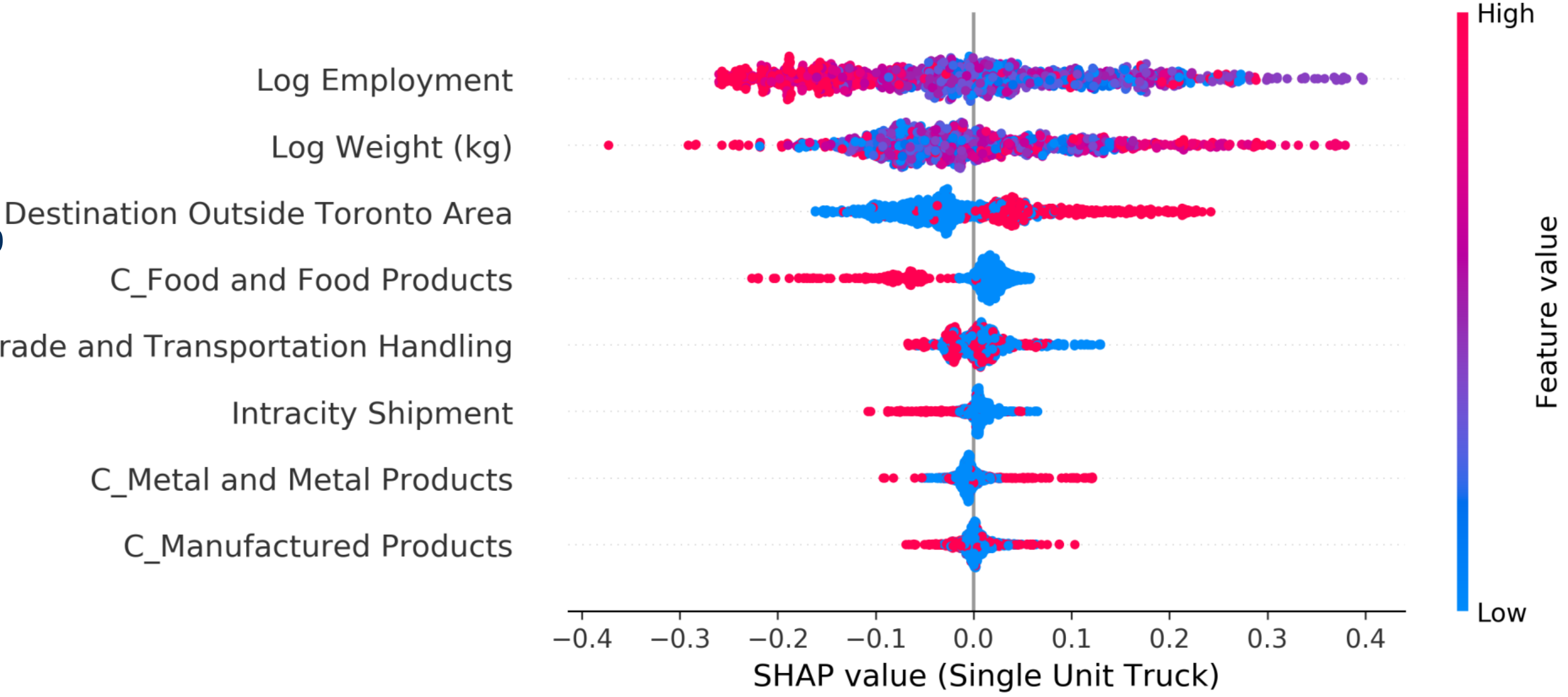
Results

Variable Importance



Variable Importance

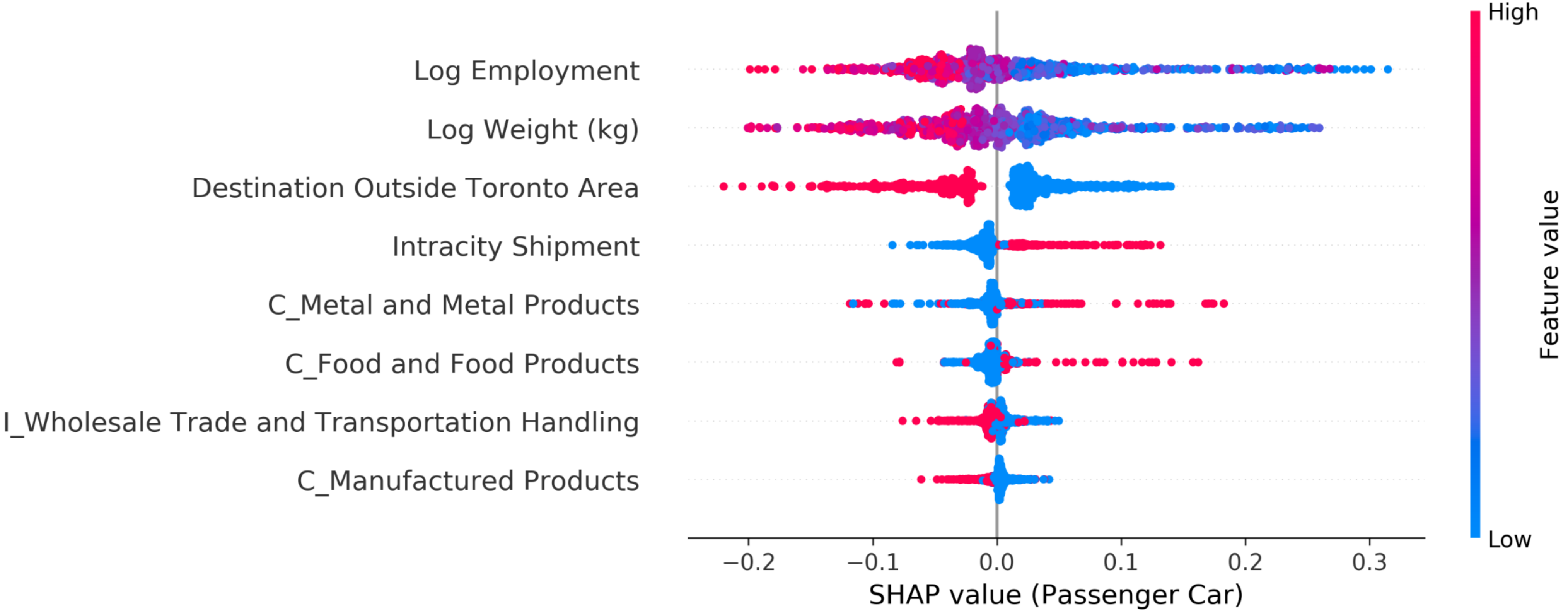
MNL: 1.64
Mix-MNL: 1.79



Variable Importance

MNL: 0.88

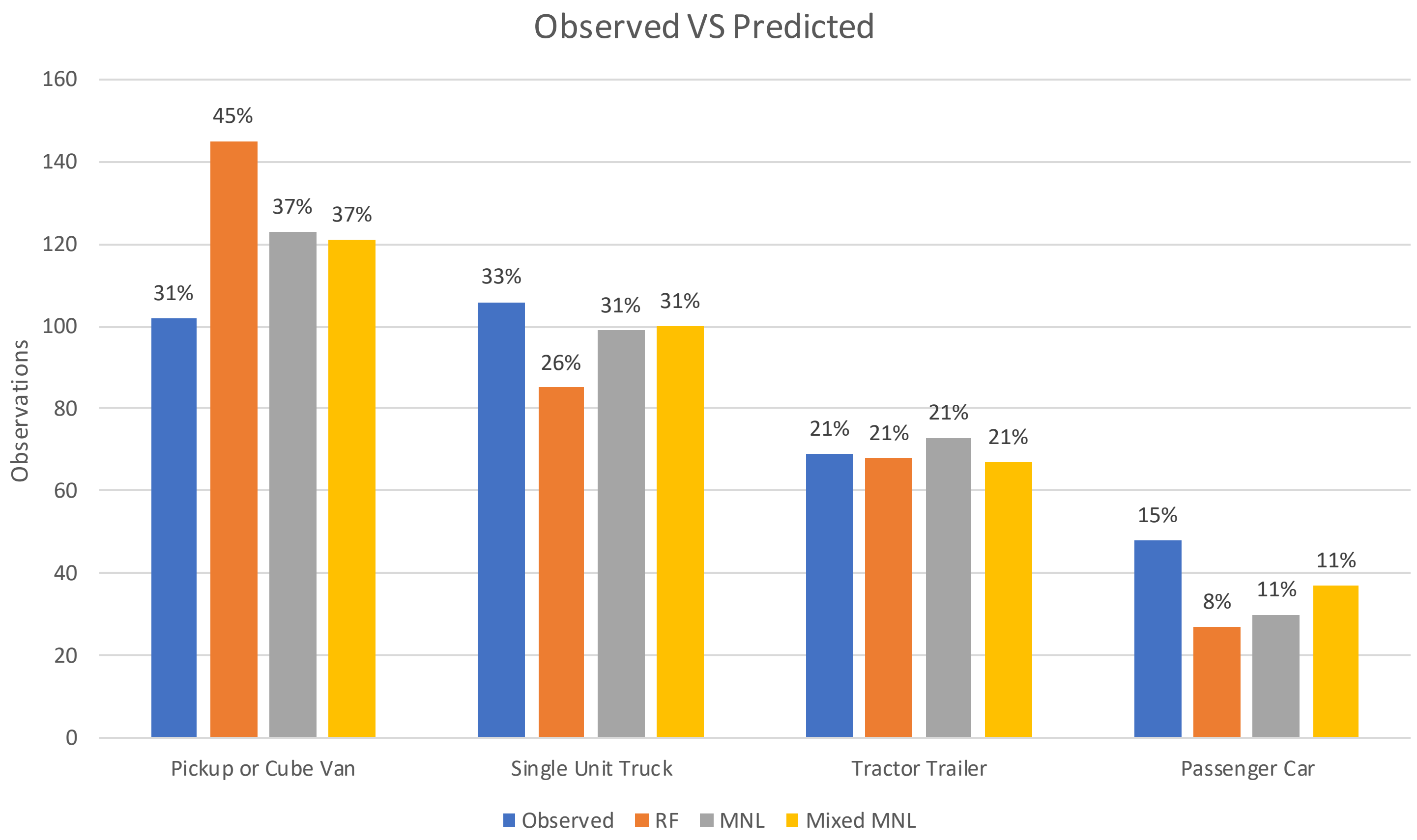
Variable Importance



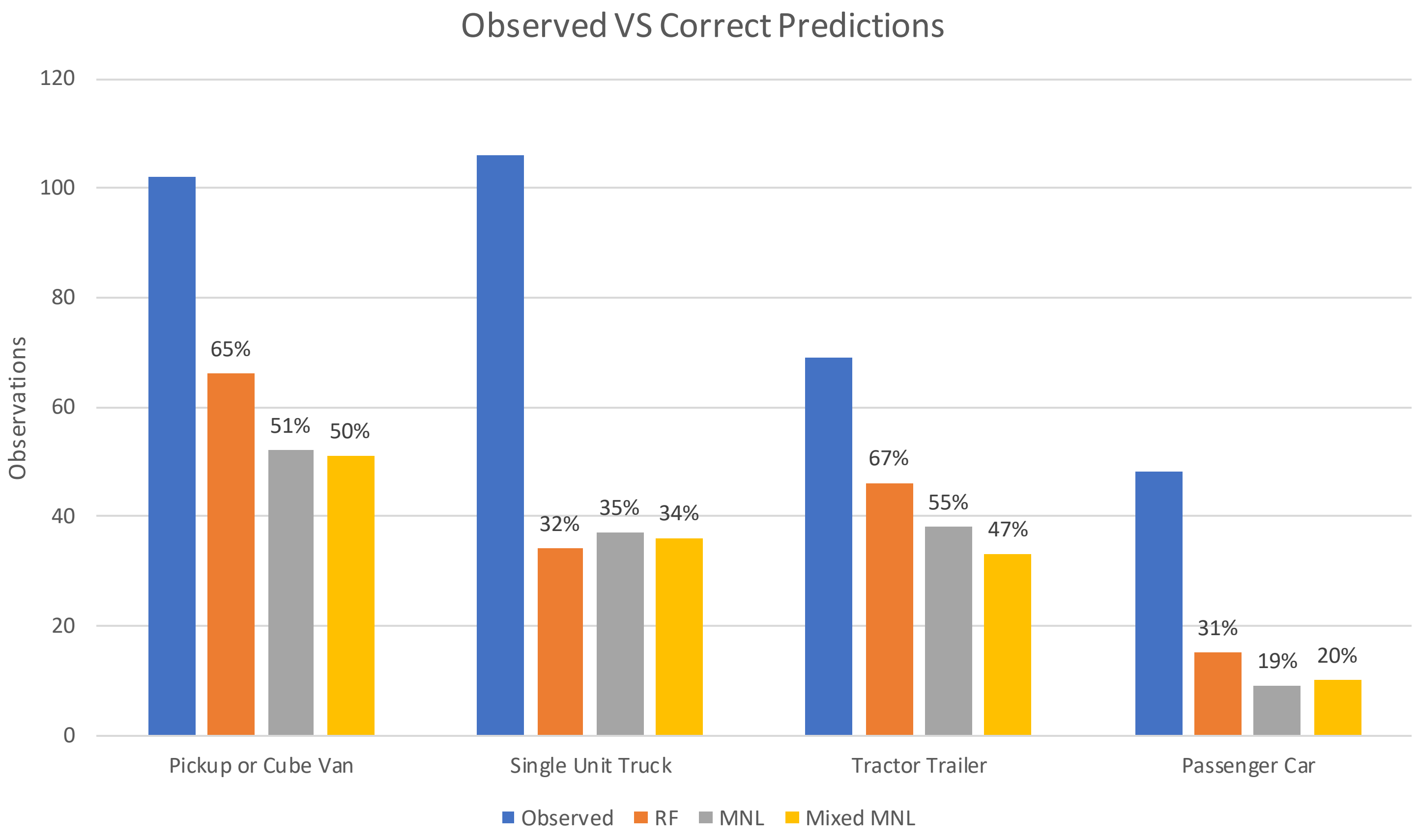
Discrete Choice Methods

- Larger firms are more likely to use larger vehicles
- Larger vehicles are more likely to be used for heavier shipments
- Intracity shipments are more likely to be transported using smaller vehicles
- Larger vehicles are more likely to be used for shipments destined outside of Toronto Area

Model Predictions



Prediction Accuracy



Results Summary

- Overall prediction accuracy
  - Random Forest: 50%
  - MNL: 42%
  - Mix-MNL: 40%

Conclusion

- Applications in policy analysis
  - Demand for parking facilities
  - Greenhouse gas emissions
  - E-commerce, same-day deliveries

Conclusion

- Freight vehicle type choice is studied using discrete choice and RF methods
- Commercial travel survey data are used to develop models for the Toronto Area
- RF results are interpreted using SHAP based variable importance
- RF model has higher prediction accuracy than DCM

More about this work!

- More details about models and results can be found in:

Ahmed, U., & Roorda, M. J. (2022). Modeling freight vehicle type choice using machine learning and discrete choice methods. Transportation Research Record, 2676(2), 541-552.