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Spatio-temporal analysis of charging requirements for Victoria's Electric Bus Fleet

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Research on Transport Electrification

The Conductor Series: The electrification of transport

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24 Nov 2022

09 May 2023

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https://imoveaustralia.com/the-conductor-series-the-electrification-of-transport/

RMIT EV Living Lab


Integration of Electric Buses into the Power Grid

Challenges and Opportunities

KEY MESSAGES

Approximately 1,300 new heavy buses are registered each year in Australia. Electric buses are being trialled in NSW, VIC, WA, ACT, and QLD, with several governments and private sector operators committed to bus electri-

Electrifying the Future of Urban Mobility

Recommendations for Bus Electrification

KEY MESSAGES

- While Australian electricity Distribution Network Service Providers (DNSPs) are conducting the price review for the next five-year regulatory period, the significant shift in the electrification of transportation, specifically bus electric vehicles associated with public transportation, should be considered. In addition to the increase in energy demand, the potential locations of charging stations, along with the opportunity for these “mobile batteries” to support the low voltage network, is important for estimating proposed infrastructure upgrades and the associated costs. A joint committee of electricity and transport sectors is recommended to address the problem.
- Bus operators require a comprehensive business model for charging of Battery Electric Buses (BEBs) that considers depot, terminal, and possibly en-route charging. There are several technologies to reduce both capital

BACKGROUND

While the main debates on the transport electrification are focused on electrifying light vehicles, BEBs have shown the potential and proven technology to contribute to transport decarbonisation [1]. Transport electrification will be one of the main challenges for transport authorities during the next decade as it sits at the intersection of transportation and electricity sectors. Despite shorter range and lower passenger capacity compared to internal combustion engine (ICE)-based buses, BEBs have to deliver a reliable mobility service while their interaction with the electricity network for charging should be managed.

- State-of-the-art facility to research EV-grid integration
- $5.2M investment of the Victorian Government

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Project information

- **Start date**: Jan 2023
- **End date**: Jan 2025

- **Objectives**:
  - To build a spatio-temporal charging map of electric buses for the metropolitan Melbourne public transport network.
  - To investigate optimal daytime charging locations

- **Work Packages**
  - WP1: Spatio-temporal charging maps
  - WP2: Optimal size and location of charging stations

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WP1 - Spatio-temporal charging maps

- GTFS Data – Metropolitan Bus
- Temperature data (from Bureau of Meteorology)
- VolvoConnect data (>1500 records – thanks to Latrobe Valley Bus Lines)

- Driving and idle time
- Total time and distance
- Vehicle Utilization (%).
- Energy consumption of 24V and 600V systems
- Motor energy consumption
- Harsh braking,
- Harsh acceleration amount,
- Harsh curving,
- Total brake use,
- # of Stops,
- # of Stops with door open,
- # of Stops with door closed,
- Avg Driving speed (km/h),
- Vehicle overspeed Speed (km/h),
- Avg speed (km/h).

- Data from depot charger (> 100 records)

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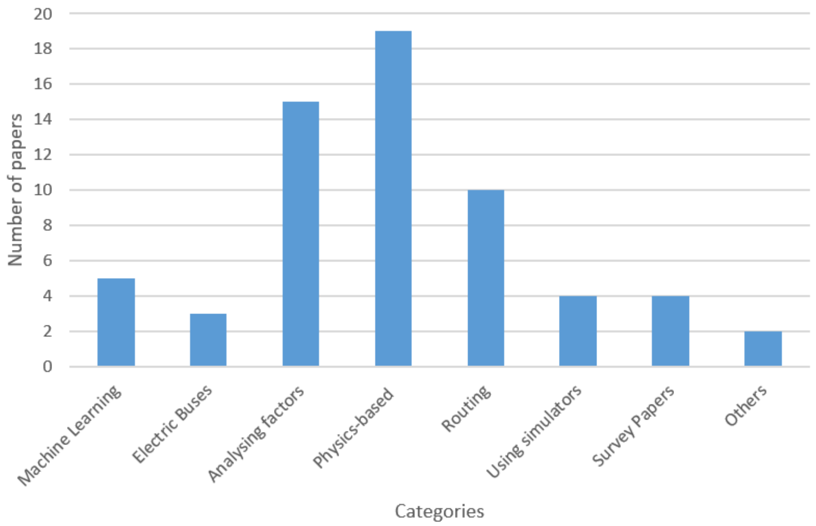
Literature review

- We reviewed about 60 articles from the open literature.
- Most of the articles use a Physics-Based approach to study energy consumption, and few use Data-Driven algorithms.
- Choosing the most important features of energy consumption is the main challenge in the literature.



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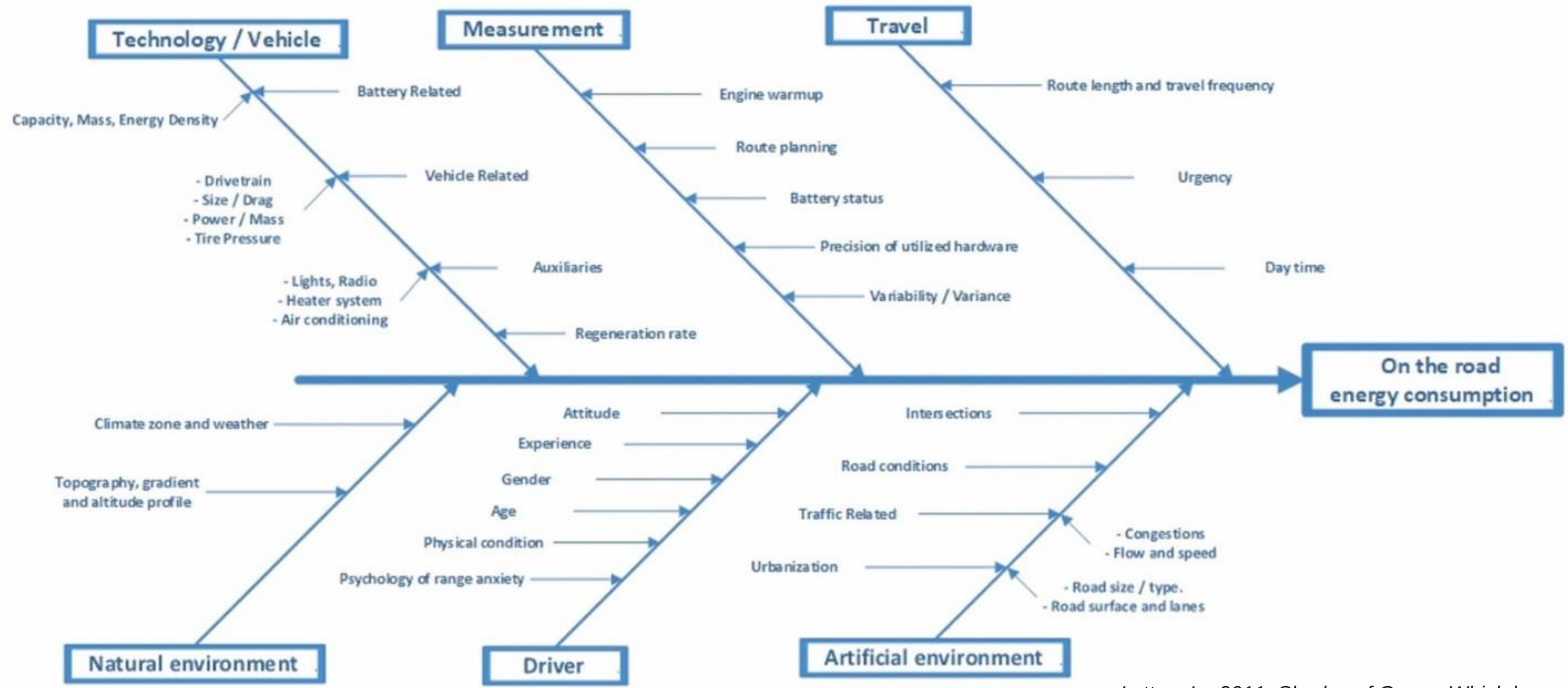
Important features



Lytton, L., 2011. Shades of Green: Which low-carbon cars are the most eco-friendly.

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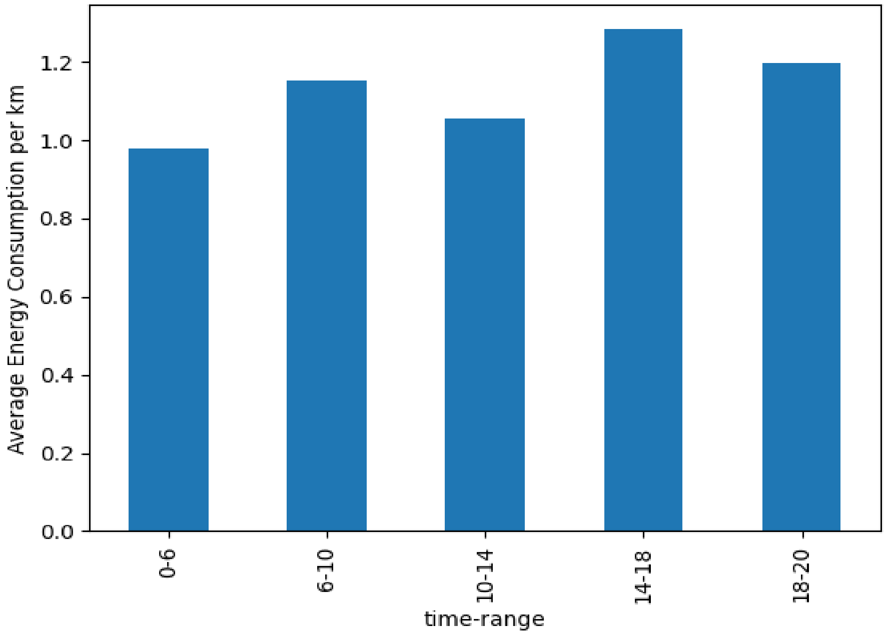
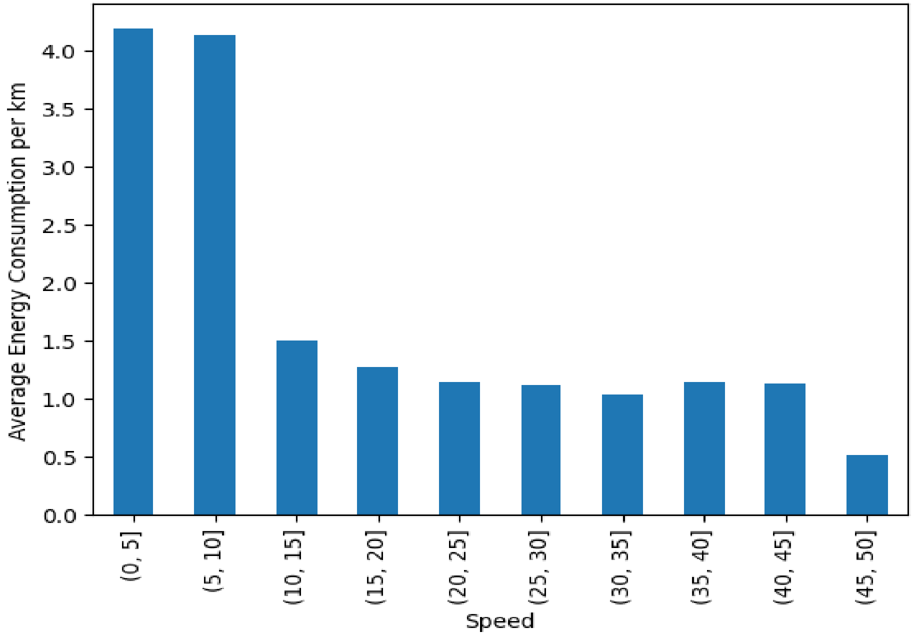
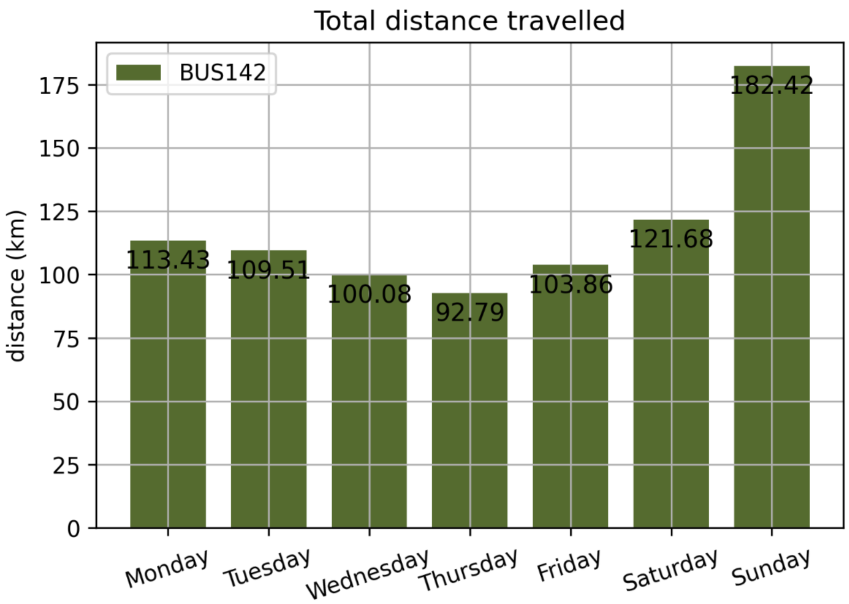
Analysis of the data

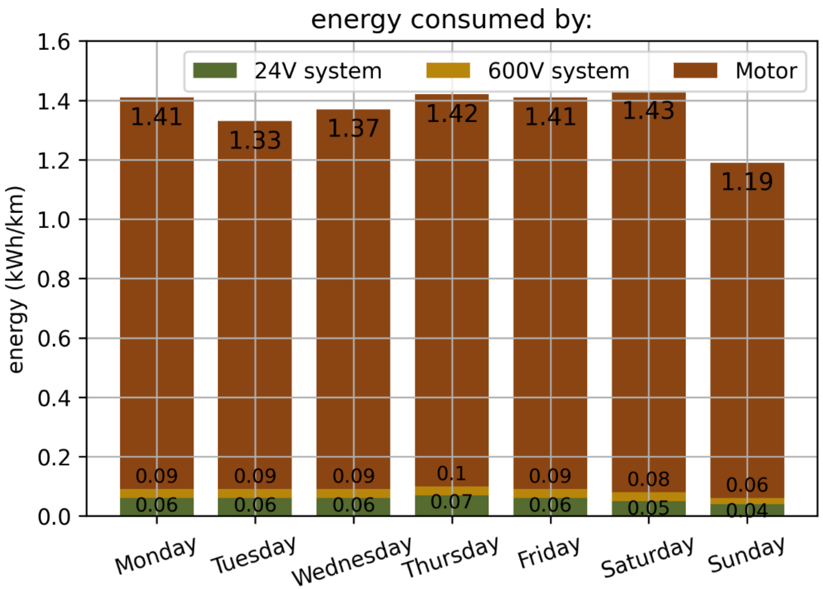




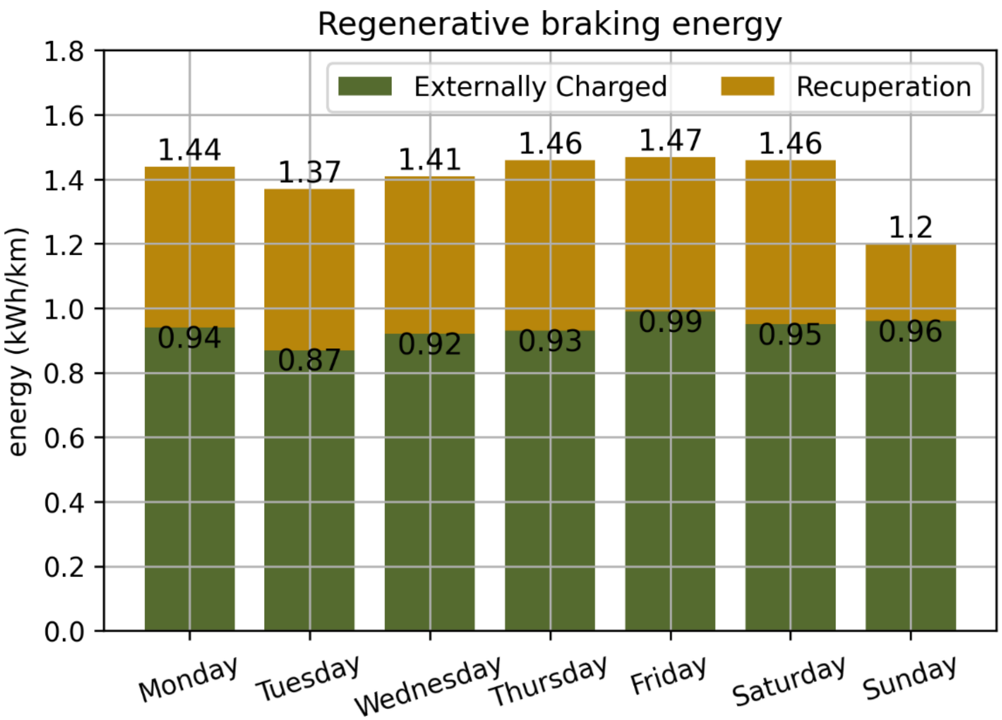
- Average energy consumption is between 1 and 1.5 kWh/km .
- Maximum energy consumption happens in frequent stop-run sequences.
- Further studies are required on richer datasets.

Analysis of the data (energy consumption)





Analysis of the data (Regenerative braking)



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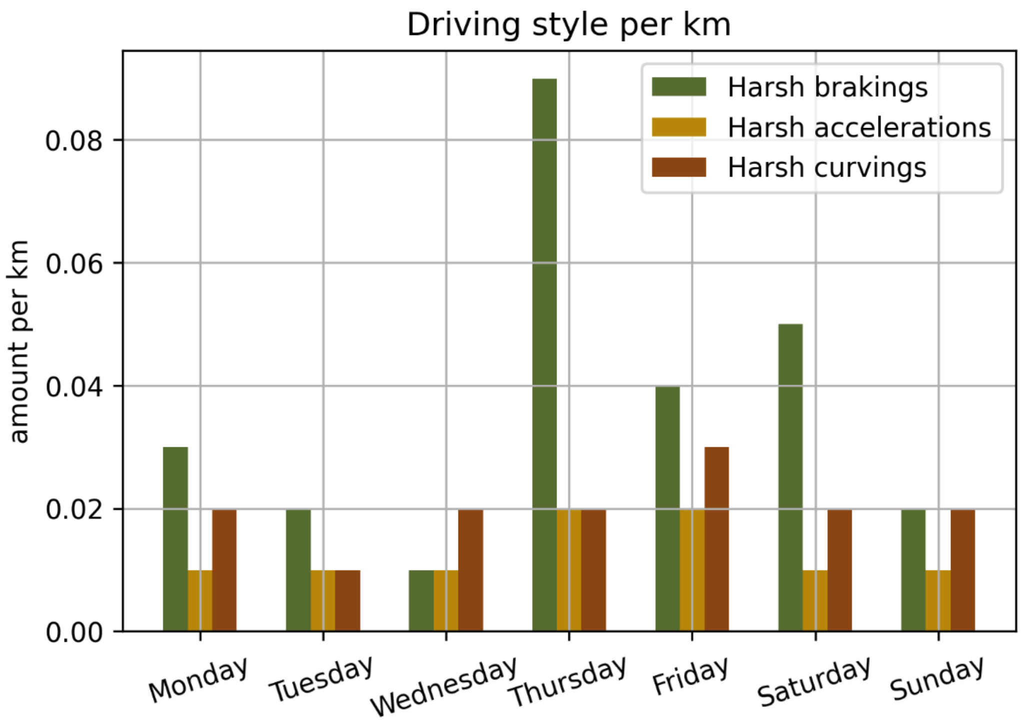
- Regenerative braking compensates about 30% of the consumed energy (supporting the literature).

Analysis of the data (Driving style)



- Harsh driving on Thursdays (?!)

RouteZero tool

Project Overview

Duration: November 2021 – April 2024

Budget: $36 million

Contact: Dr Björn Sturmberg, Research Lead, Battery Storage and Grid Integration Program, ANU. Email: bjorn.sturmberg@anu.edu.au

Partners: **ARENA**, **Clean Energy Finance Corporation**, **Transgrid**, **Transit Systems**, **Transport for NSW** **and** **Zenobe**

https://routezero.cecs.anu.edu.au/

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Machine Learning model

Features

- Distance
- Speed
- Time
- Air conditioning
- Route gradient
- Number of passengers
- Temperature

Methods

- Neural Networks
- Support Vector Machines
- Linear Regression
- Random Forest Regression
- Decisions Tree
- K-Nearest Neighbours
- Ensemble

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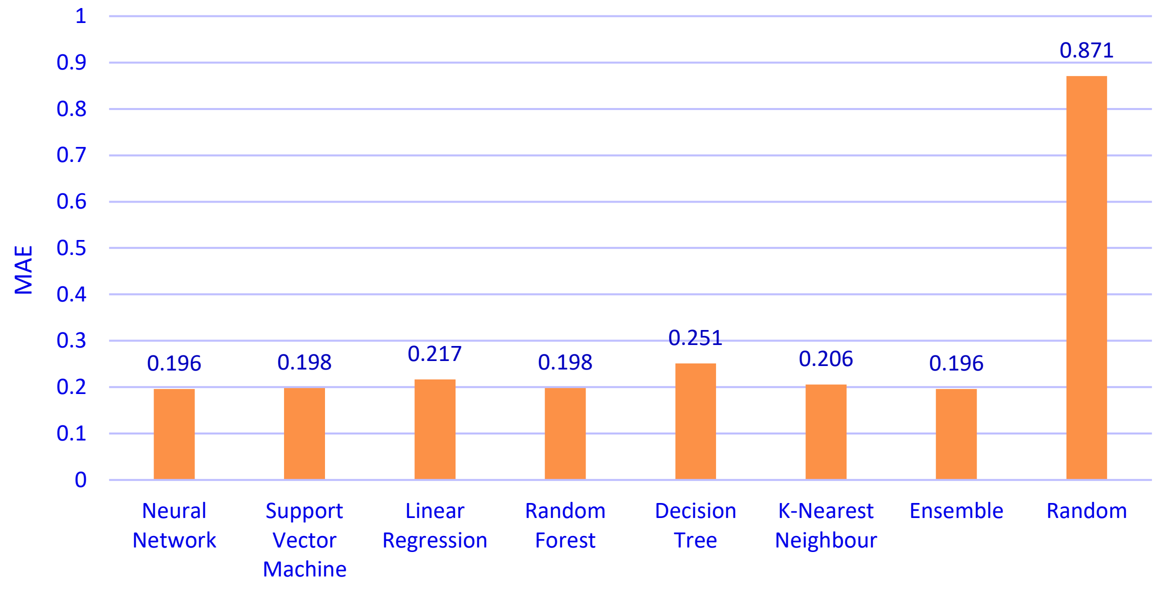
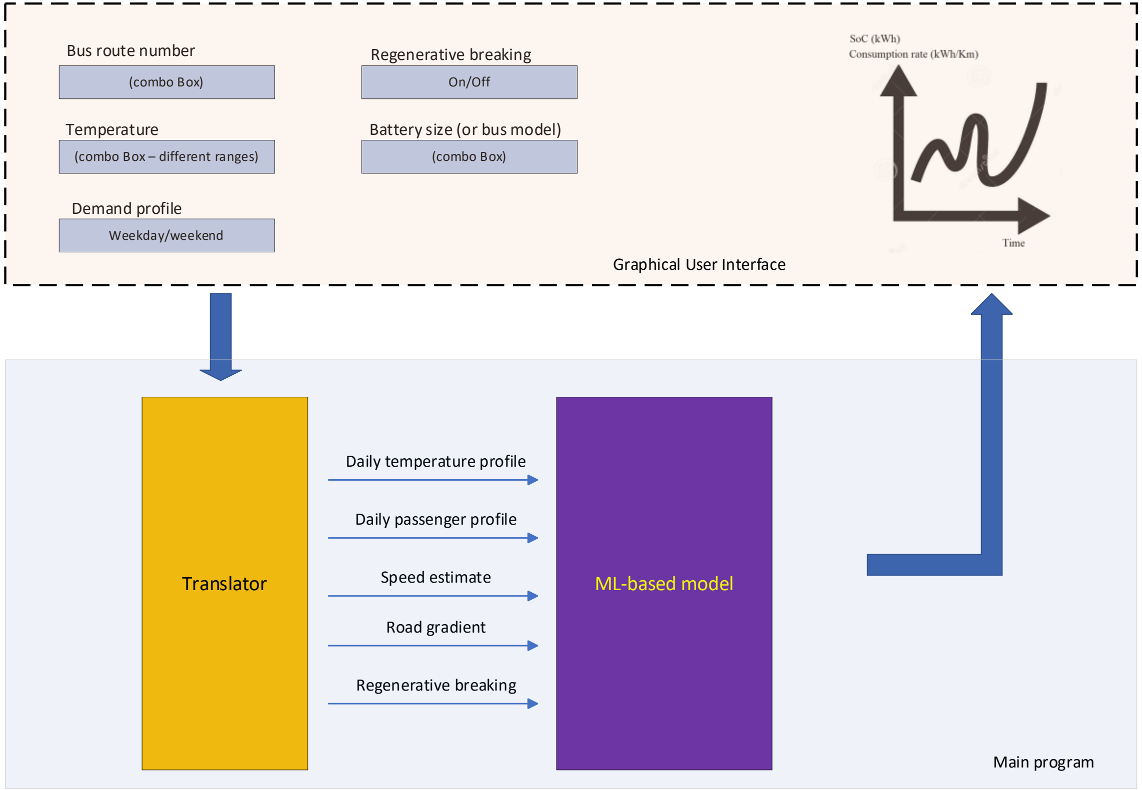
Modeling BEB Energy Consumption



Training (70%)
Testing (30%)

Software package



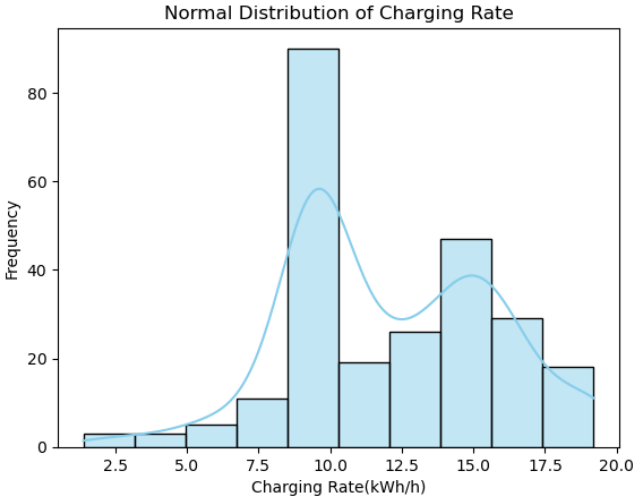
https://master.de2wsxpwhszg3.amplifyapp.com/

Charging data

Number of records: 251

Start date: 09-02-2023 **End date: 20-09-2023**

	Charge Duration (hour)	Initial SoC (%)	End SoC (%)	Charging Rate (kW)	Delivered energy (kWh)
Min	0	0	23	1.38	0.01
Max	18.3	100	100	19.2	262
Mean	5.93	54.79	81.45	12.09	82.15
25%	1.31	40	61	9.46	12
50%	4.99	56	99	11.43	68
75%	10.04	70	100	14.86	139
Total	1488				20620



WP2: Optimal size and location of charging stations

Assumptions:

1- We assume that electric buses have to exactly follow the same daily schedules as ICE-based ones.

2- We limited charging to interchanges and terminals.

Objective: Minimum number of charging locations

Methodology: Optimisation - Mixed integer programming

Challenge: The size of the Metropolitan bus network is large. So, a computationally efficient method is required.

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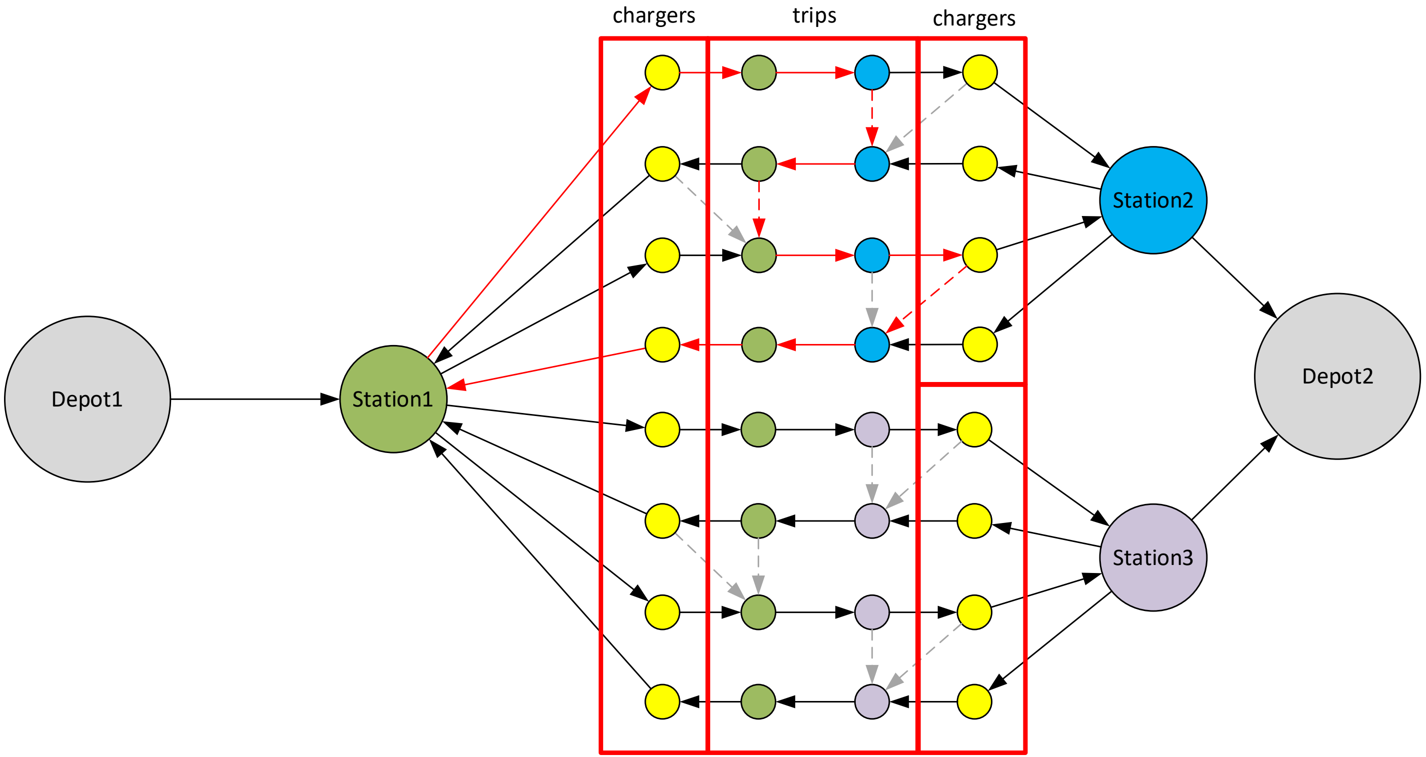
WP2: Optimal size and location of charging stations

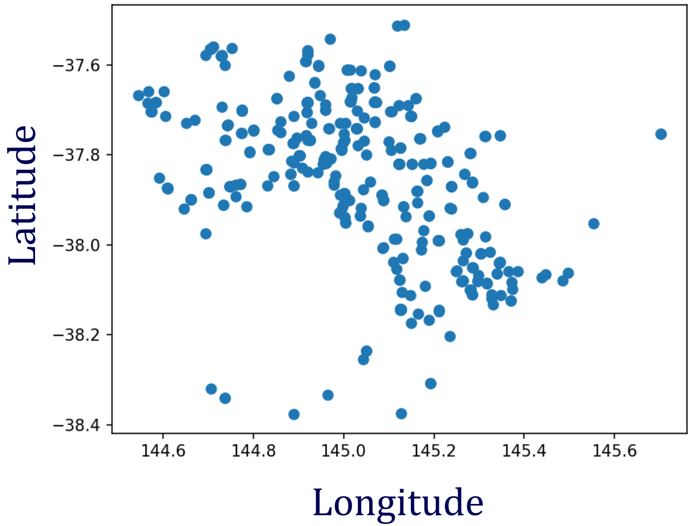
Modeling the problem as a “graph” context

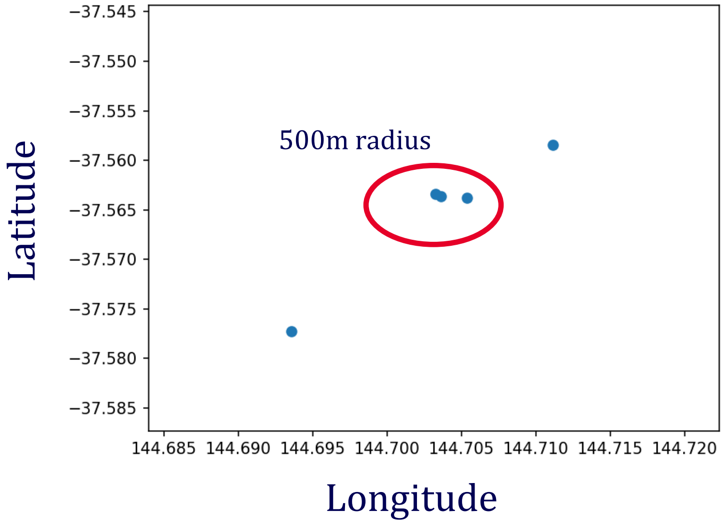


WP2: Optimal size and location of charging stations

Introducing Virtual Terminal by augmenting all terminals in the radius of 500m as one point.
It reduces complexity of the problem.

Distribution of Terminals in Melbourne





Results will be presented in the next events ....

Further research

- Business model for depot charging facilities, including
  - Number and size of chargers
  - Charging plan for mass E-bus uptake
  - Bus Depot and V2G

First Bus is trialling the use of its charging infrastructure to third-party businesses during the day when its buses are out on service.

https://www.busnews.com.au/

- Charging planning for buses
- Dynamic bus allocation for e-buses

Caledonia depot, Glasgow, UK - The depot will allow over 150 buses to be charged at one time

Thank you.

Q&A

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