CRISI RESEARCH CONSORTIUM FOR
INDUSTRY 4.0 SYSTEMS ENGINEERING

A PHYSICAL MODEL THAT FITS

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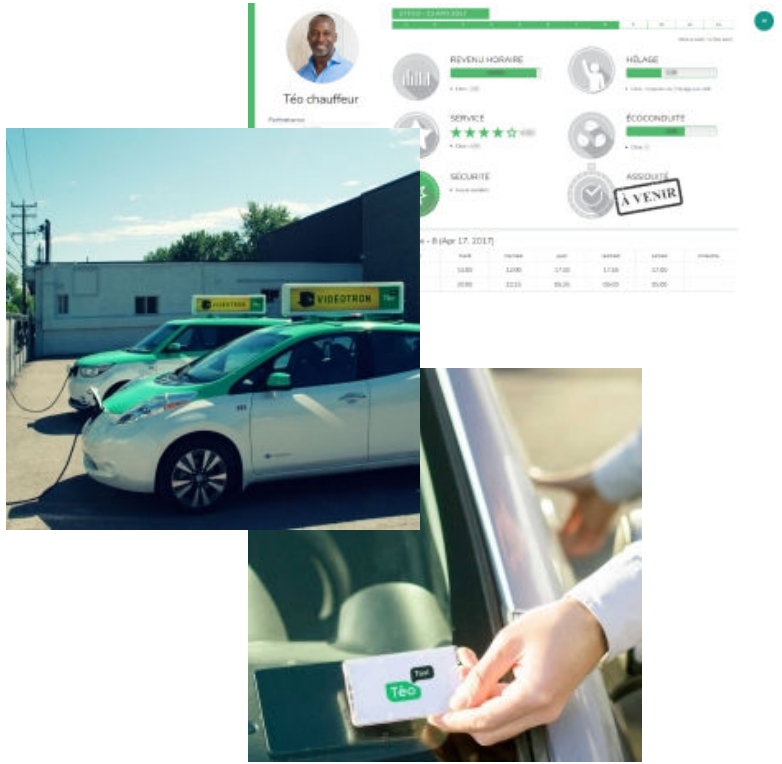
Téo Taxi

200 electric vehicles	Technologies
• No CO2 emission • Nissan LEAF Soul, Tes Tesla X	• Mobile application Consumption ediction orithms

Limited vehicle range

- **Challenges**:
  - Recharge planning
  - Ride allocation
  - Predicting charging time
  - Predicting Energy Consumption



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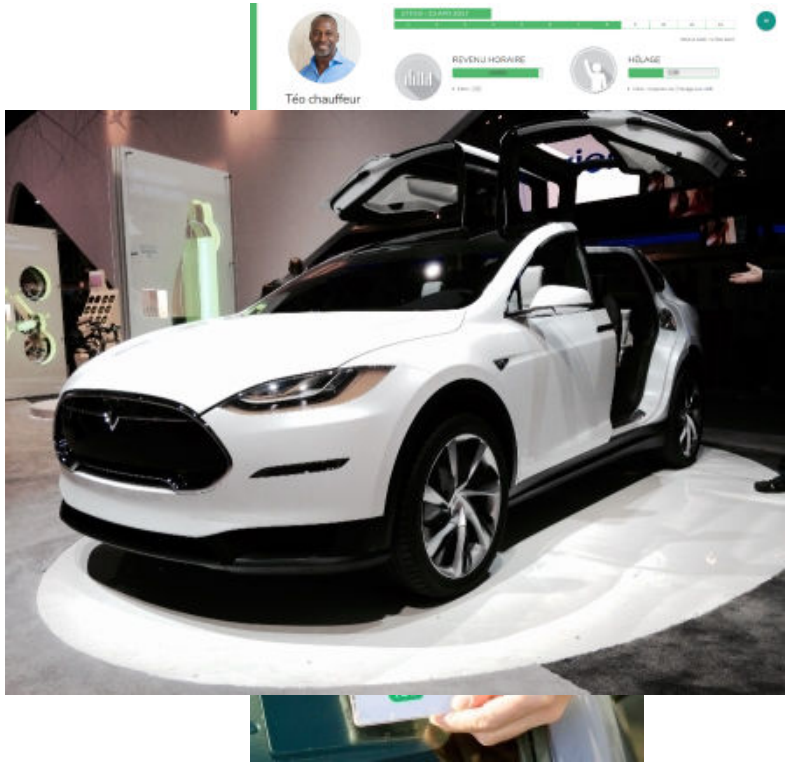
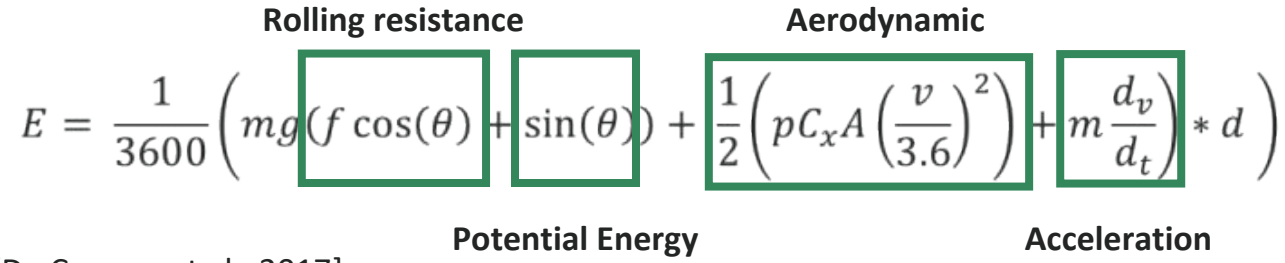


Objectives

- Use a physical model to predict electric vehicle consumption and enhance its accuracy using historical data from Téo Taxi
- Allow better predictions for a new/unknown vehicle model

Basic Physical Model



[De Cauwer et al., 2017]

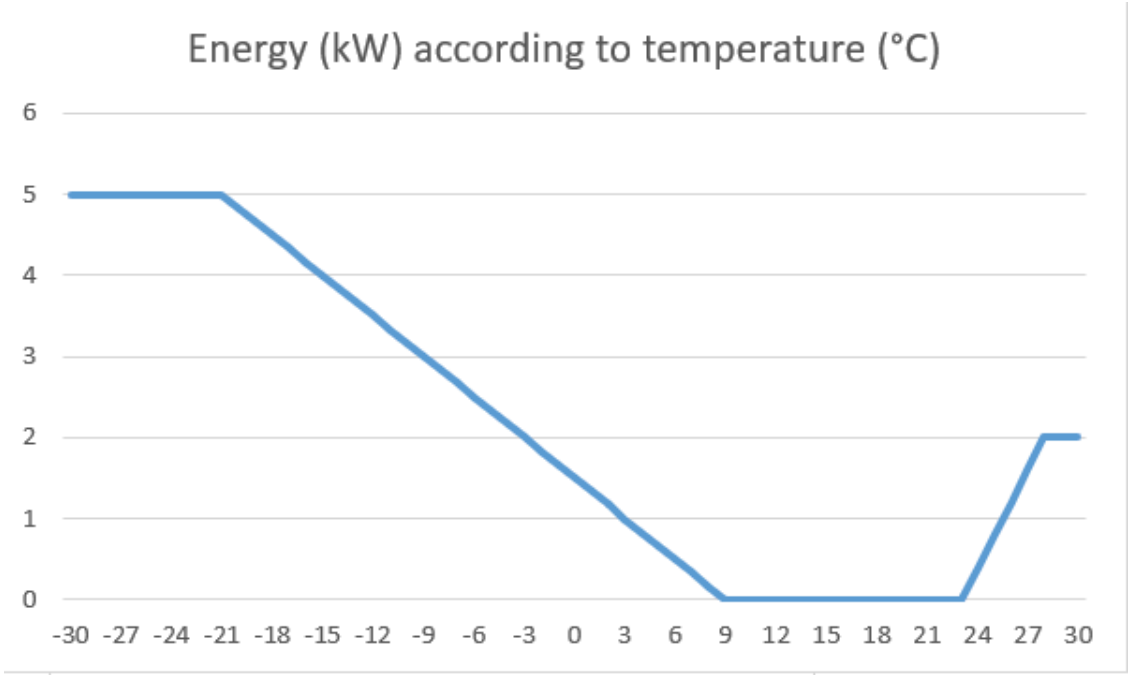
Extended Physical Model

Rolling resistance | Aerodynamic | Climate Control

$$E = \frac{1}{3600}\left(mg(f\cos(\theta) + \sin(\theta)) + \frac{1}{2}\left(pC_x A\left(\frac{v}{3.6}\right)^2 \right) + m\frac{d_v}{d_t} \right) * d \Big) + T + A_c$$

Potential Energy | Acceleration | Accessories

Climate Control Term

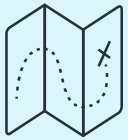


Data

Taxi rides

- Nissan LEAF (26 269)
- Kia Soul EV (131 866)
- Tesla Model S (22 082)
- Tesla Model X (13 130)

Path



- Distance
- Elevation of the road

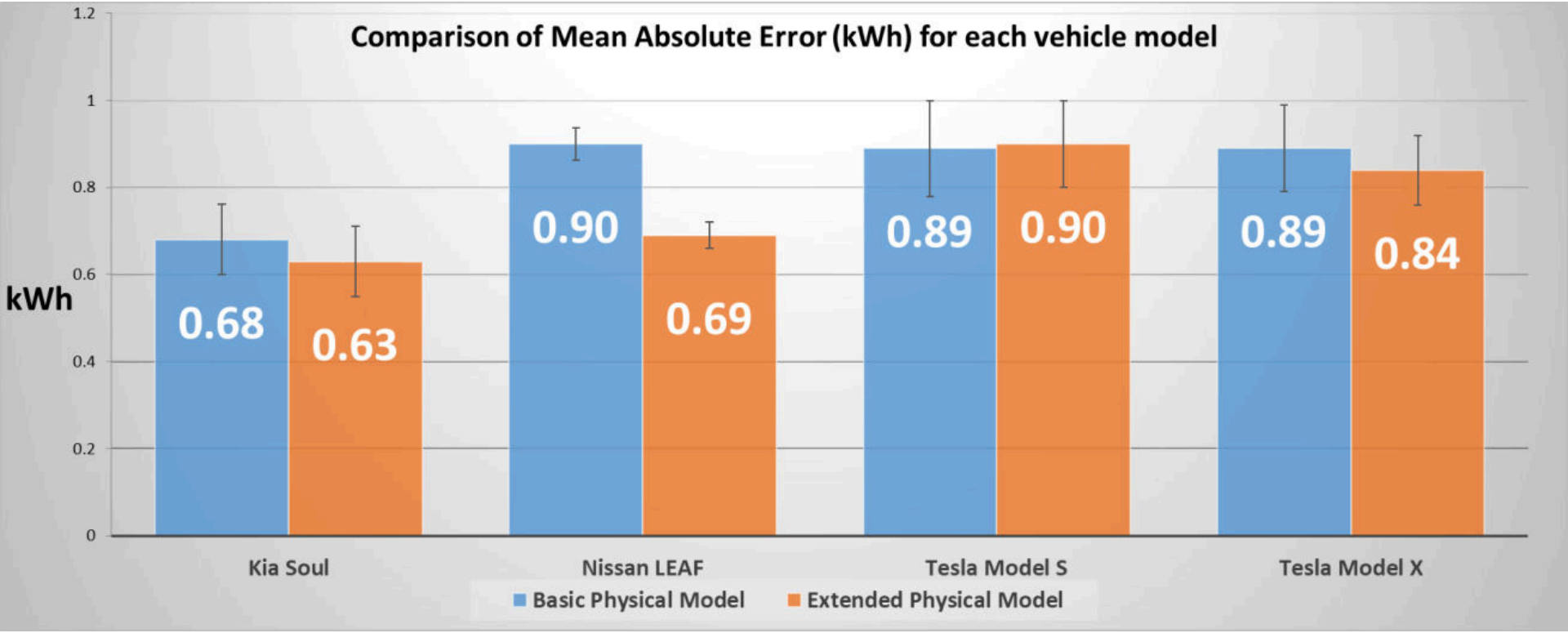
Driving

- Speed
- Duration
- Acceleration

Weather

- Temperature

Comparing both models

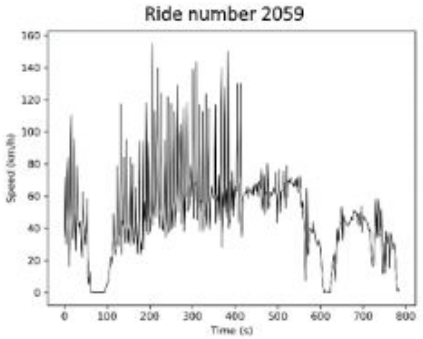


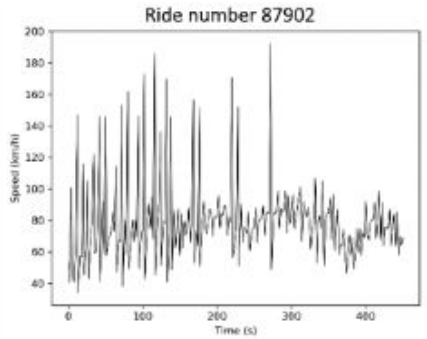
(Training on 80% of data and testing on 20% of data)

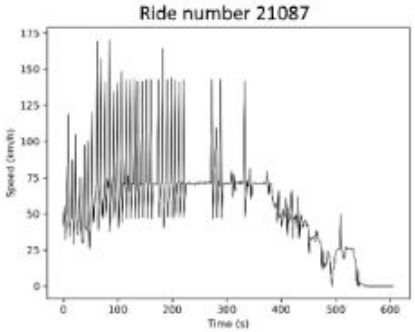
Fitted Extended Physical Model

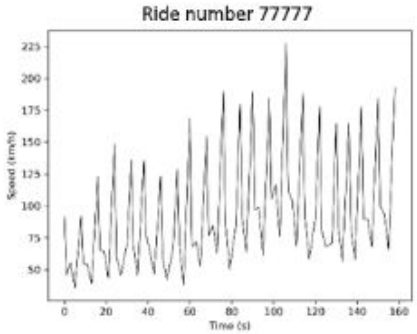
$$E = \alpha_1 mg(f\cos(\theta) + \sin(\theta))d + \alpha_2 pC_x A\left(\frac{v}{3.6}\right)^2 d + \alpha_3 m\frac{d_v}{d_t}d + \alpha_4 T + \alpha_5 A_c$$

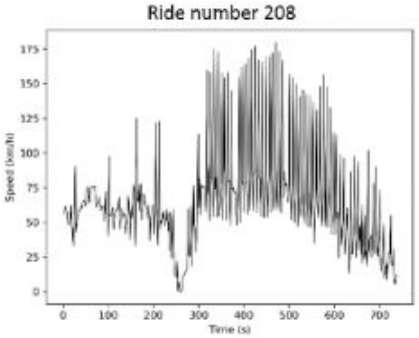
Speed issues

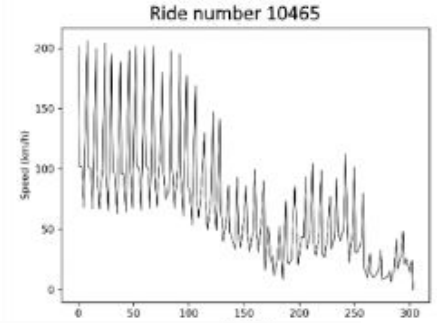


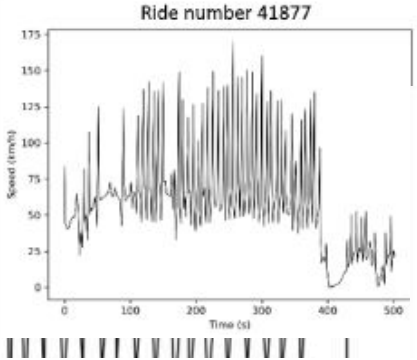


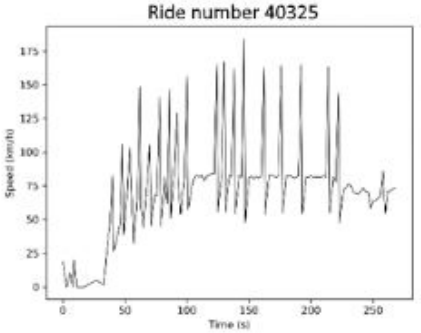


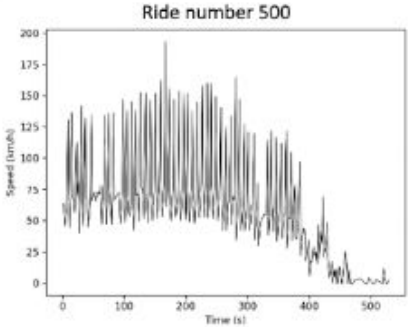


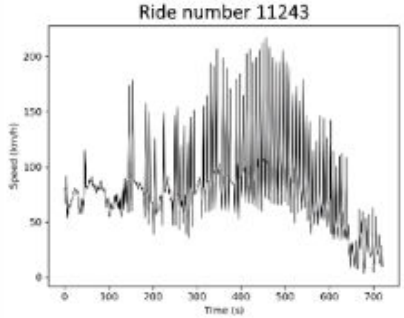




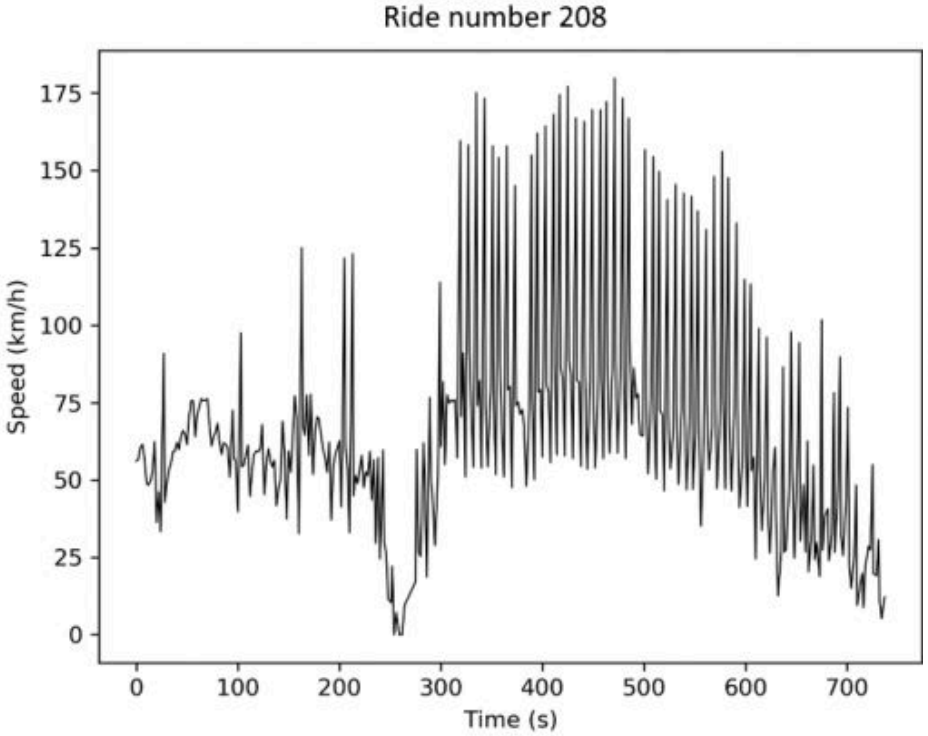


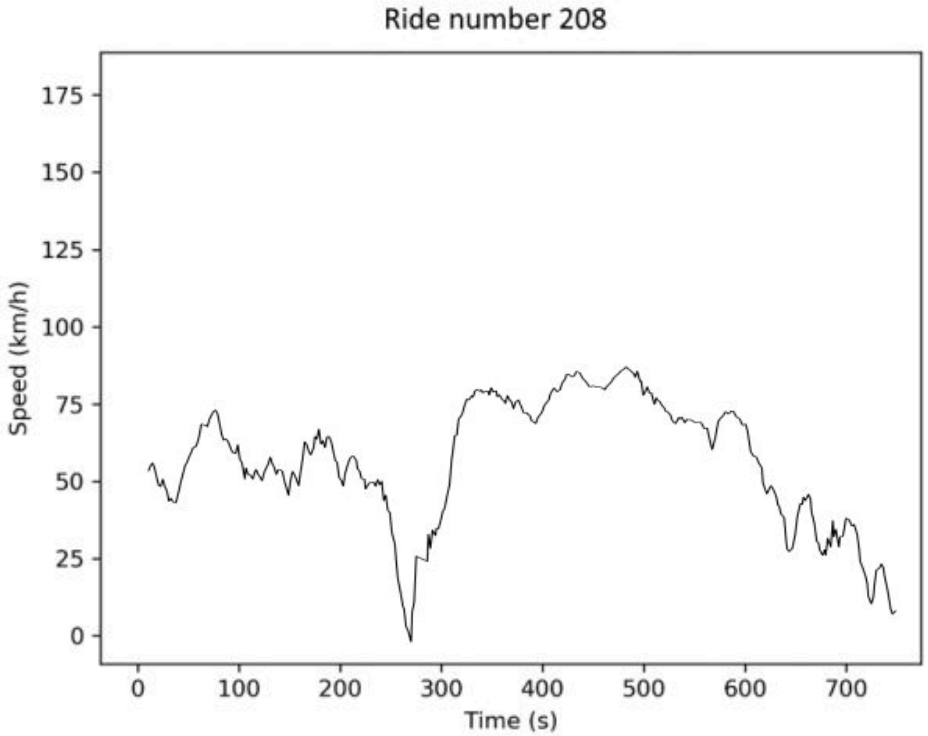




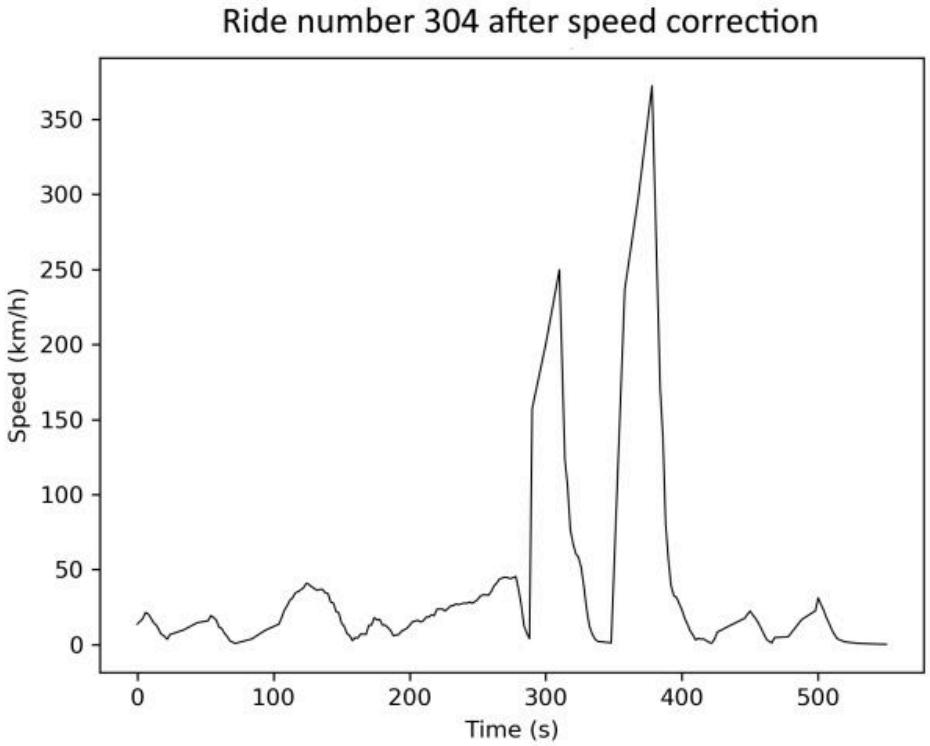


Correcting speed issues

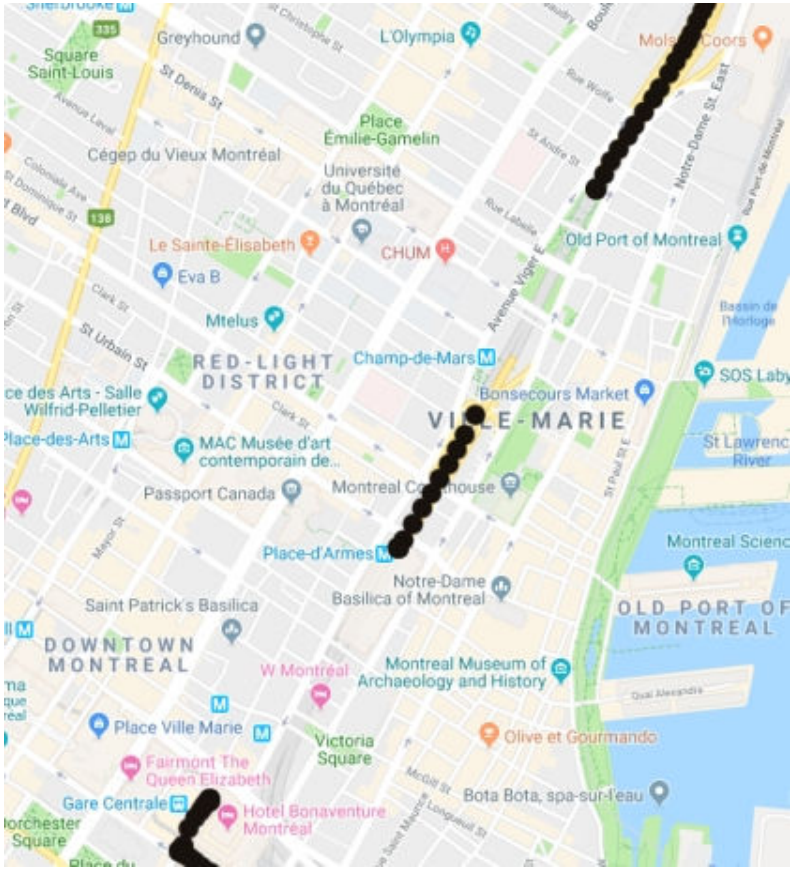




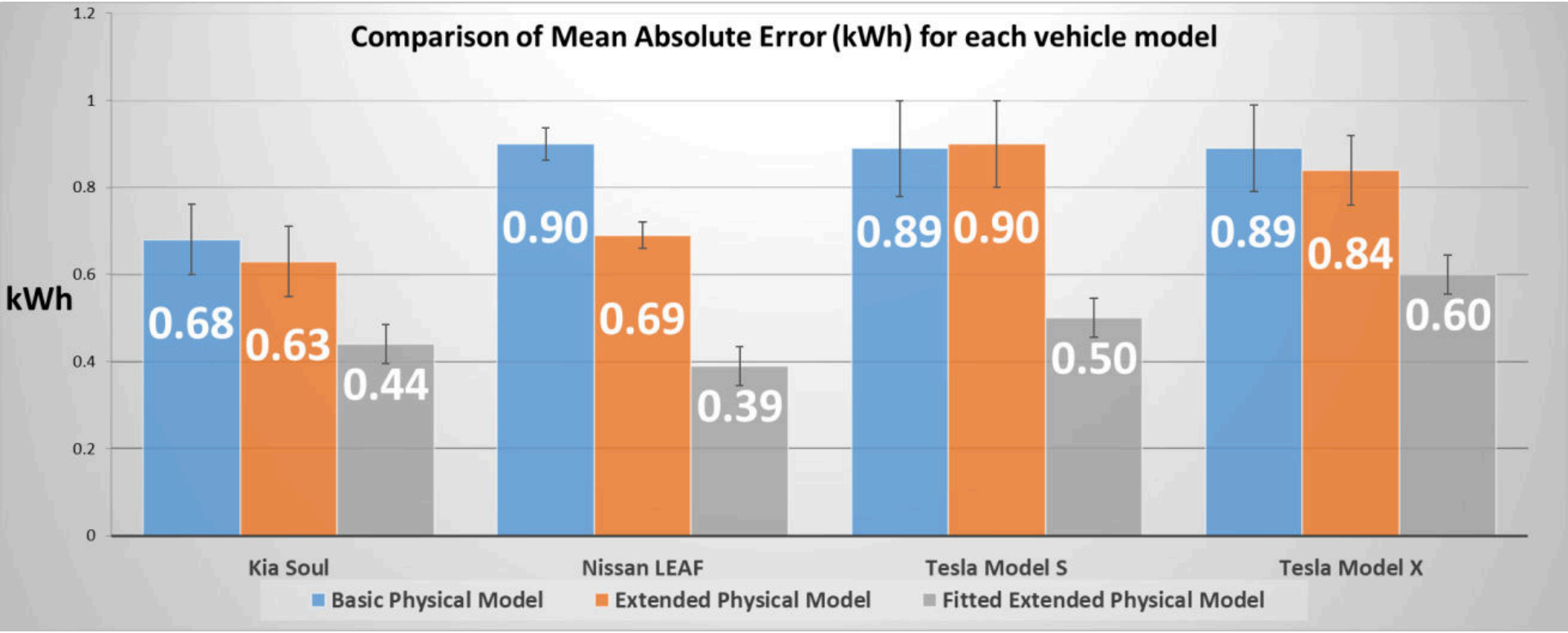
Still some issues…



Teleportation



Results



(Training on 80% of data and testing on 20% of data)

Approach for new vehicle

Training

Kia Soul EV

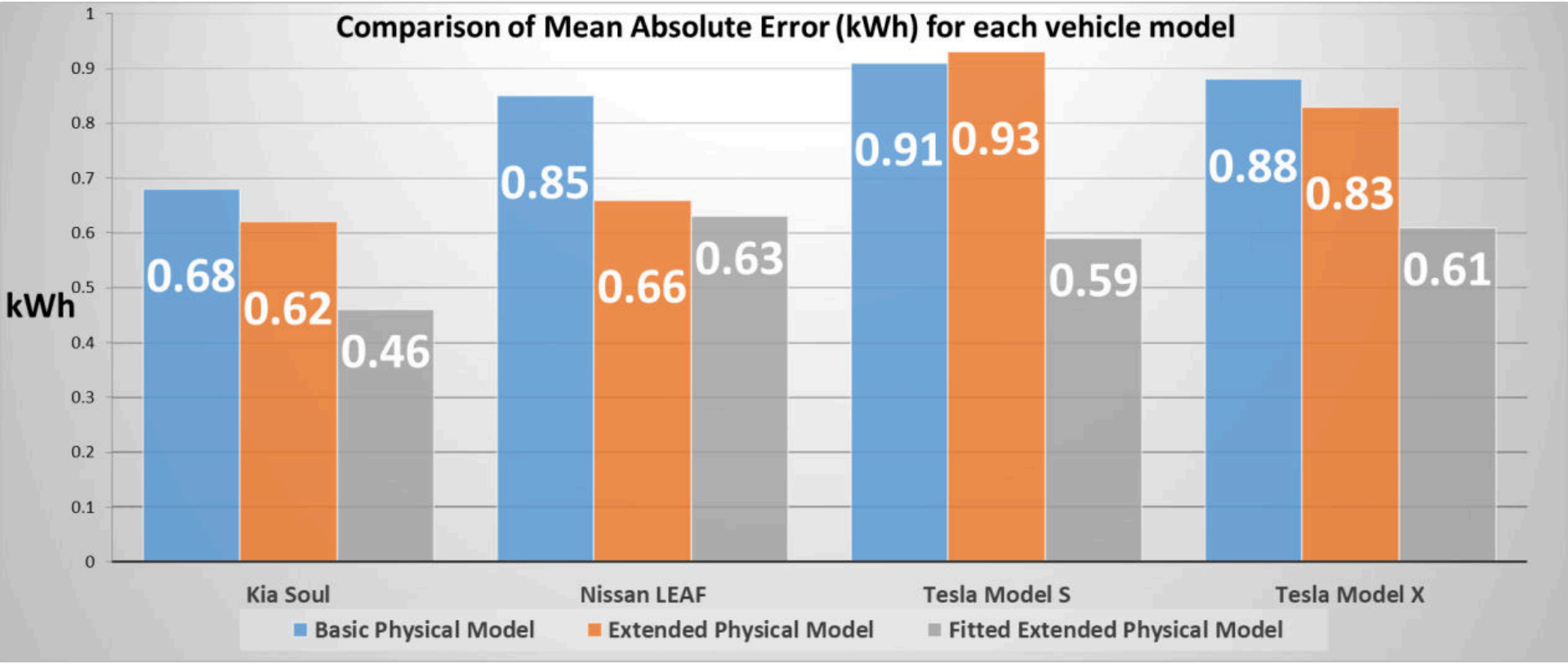
Nissan LEAF

Tesla Model S

Tesla Model X

Testing

Results


Comparison of Mean Absolute Error (kWh) for each vehicle model
kWh
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.68
0.62
0.46
0.85
0.66
0.63
0.91
0.93
0.59
0.88
0.83
0.61
Kia Soul
Nissan LEAF
Tesla Model S
Tesla Model X
Basic Physical Model
Extended Physical Model
Fitted Extended Physical Model

Conclusion

- Improvement of as much as 44% (Tesla Model S)
- Data quality challenge
- Now exploring non-linear models (such as Neural Networks)