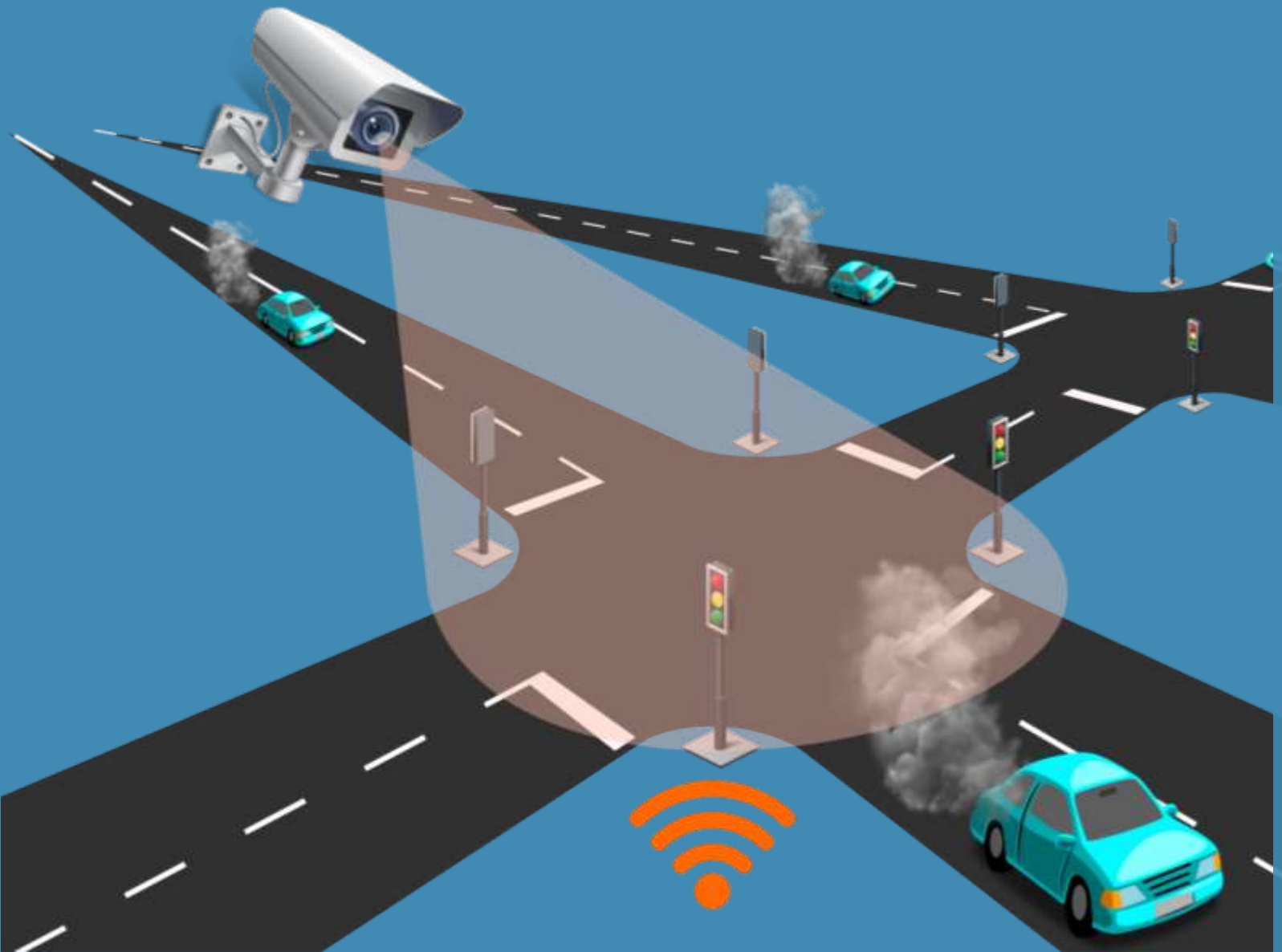

# Using Big Traffic Data to Estimate Vehicle Emissions in Real Time


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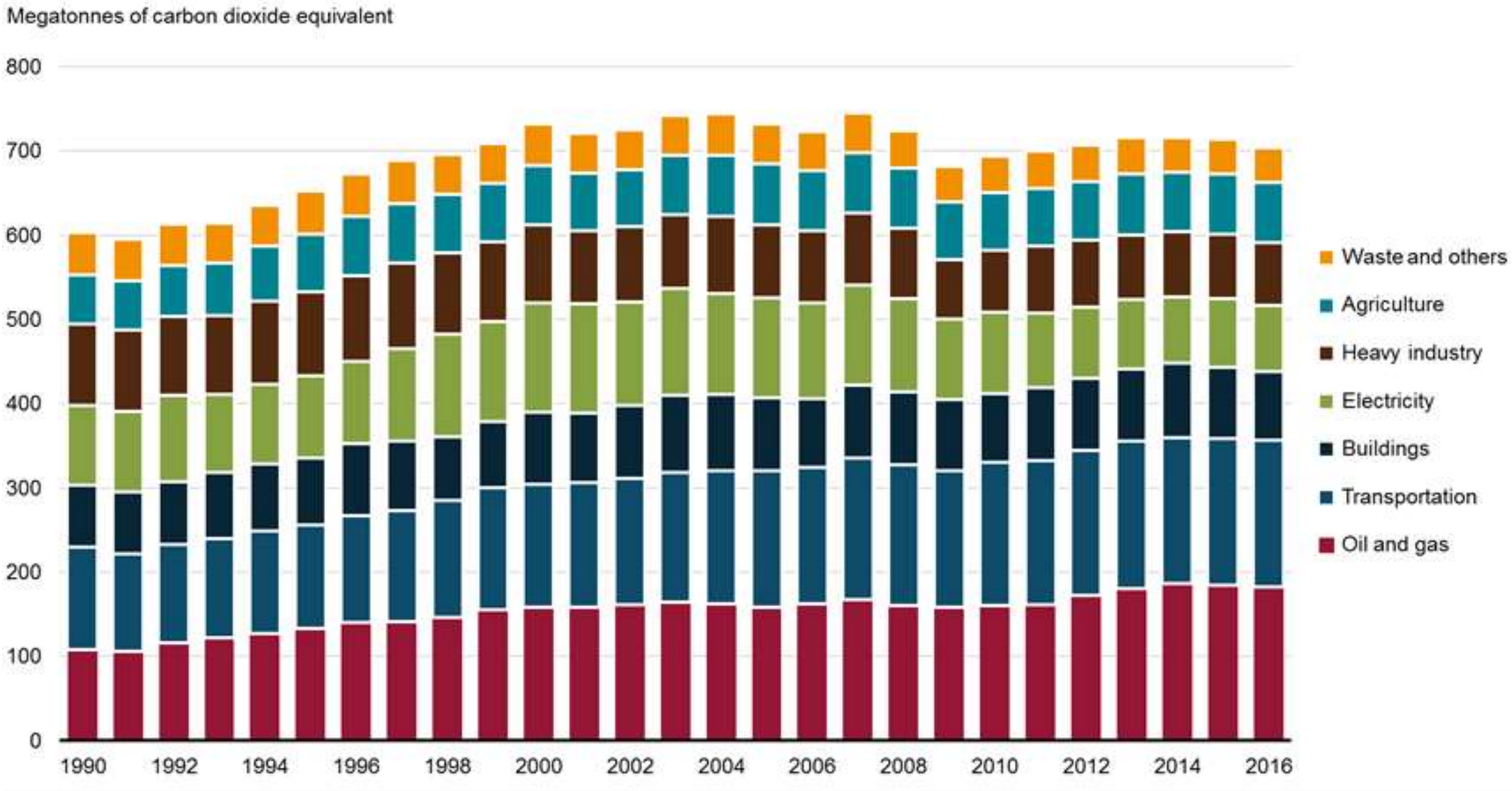
University of Waterloo



ITS Canada ACGM 2018

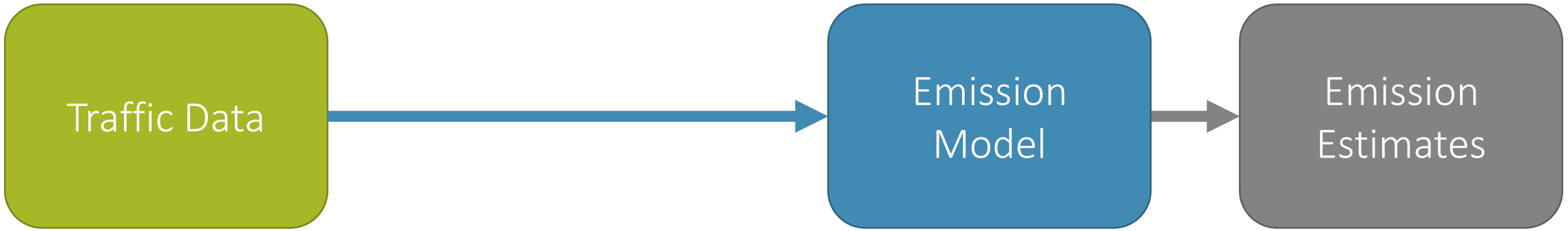



Environment and Climate Change Canada. (2018).

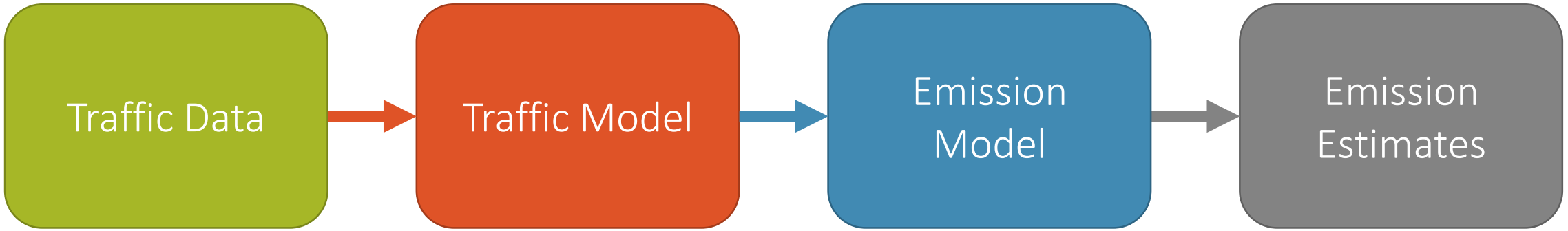
# Methodology

# Objective

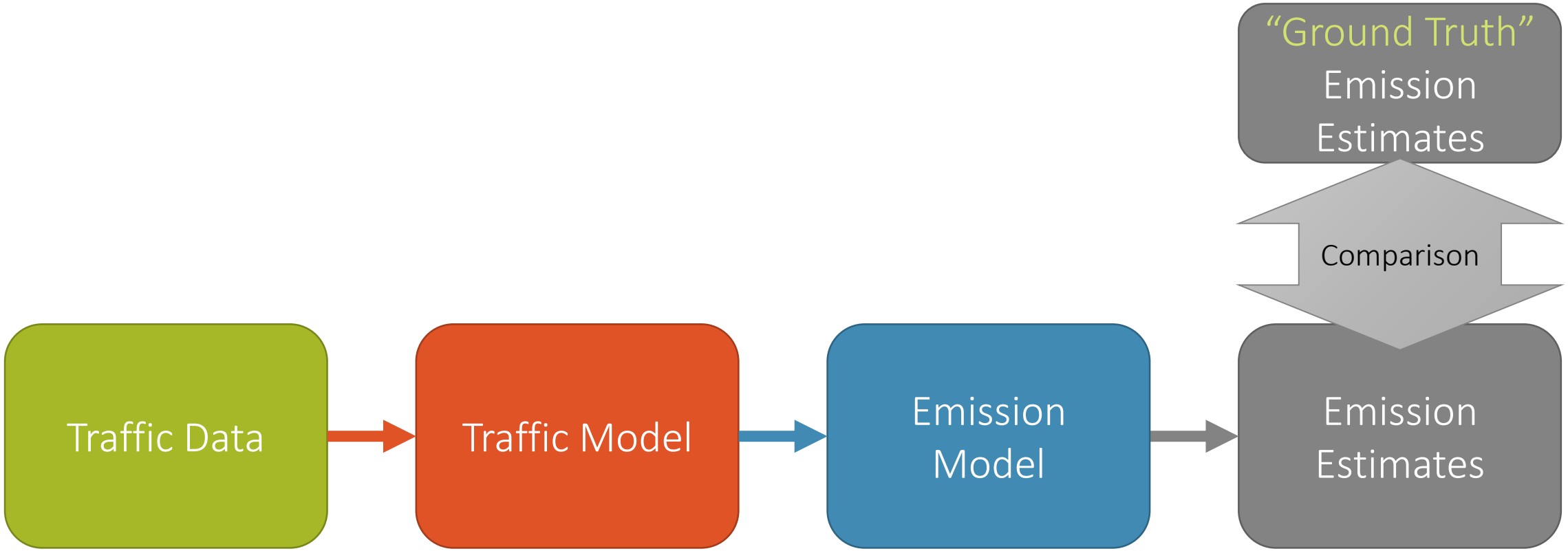
# Framework



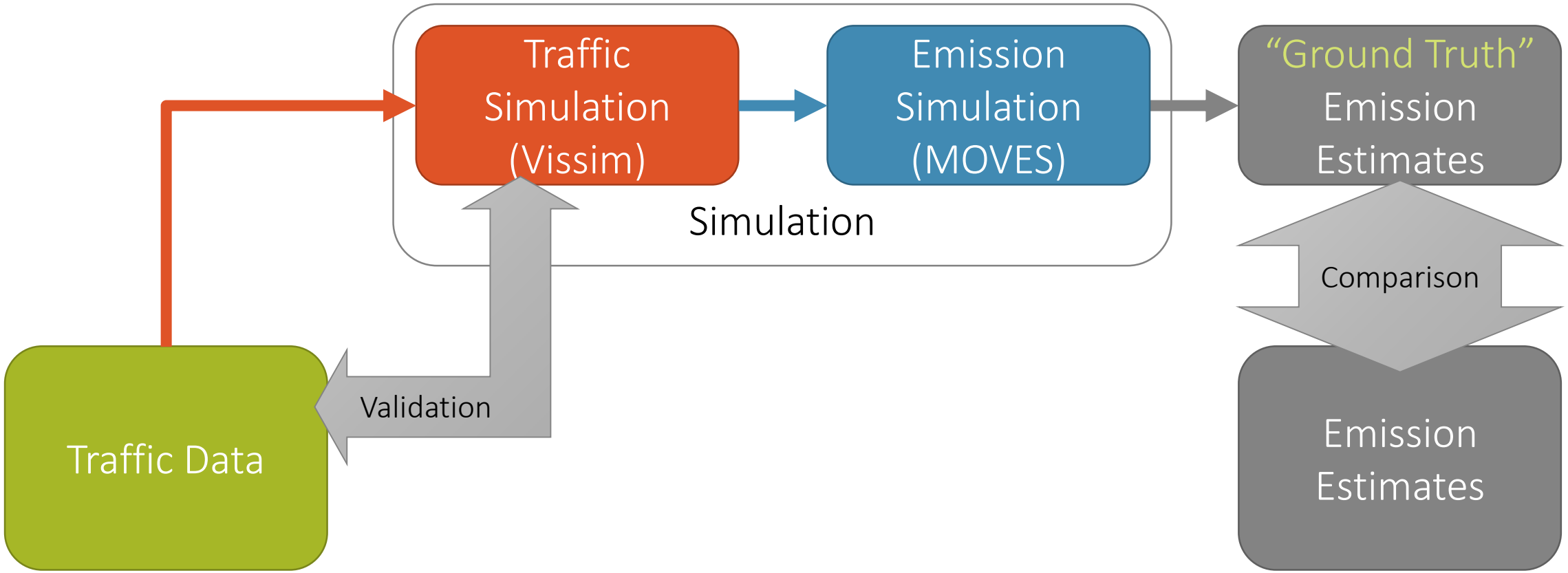
# Framework


Traffic Data
Traffic Model
Emission Model
Emission Estimates

# Framework


"Ground Truth" Emission Estimates
Comparison
Traffic Data
Traffic Model
Emission Model
Emission Estimates

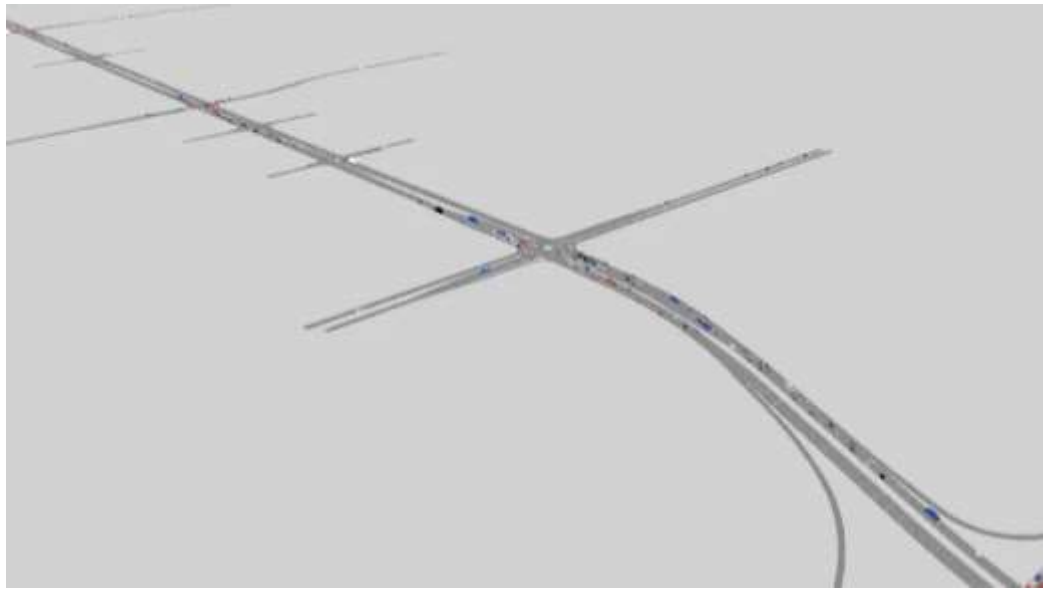
# Framework


Traffic Simulation (Vissim)
Emission Simulation (MOVES)
Simulation
"Ground Truth" Emission Estimates
Comparison
Emission Estimates
Validation
Traffic Data

# Vissim and MOVES

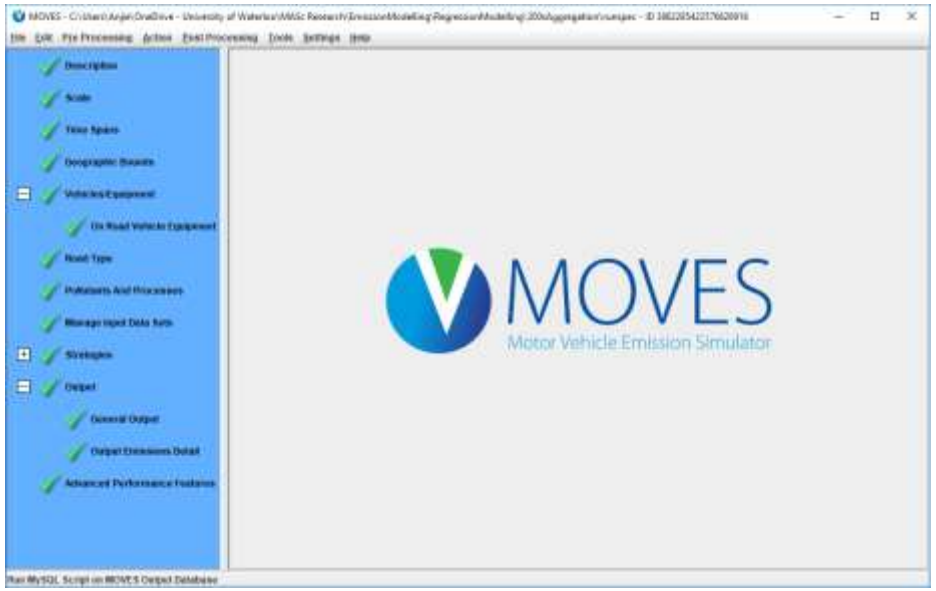
PTV Group

Traffic Simulation (Vissim)

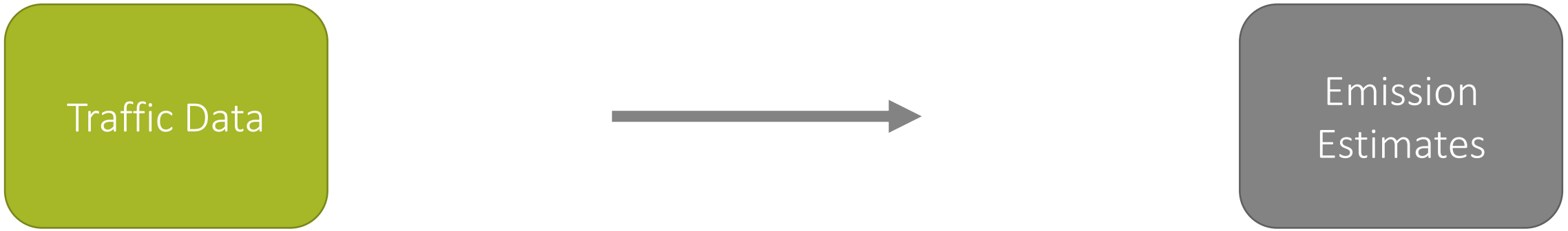


Emission Simulation (MOVES)

US EPA



# Closing the gap in “real time”



# Traffic Data

Travel Times,
Positions,
Vehicle types

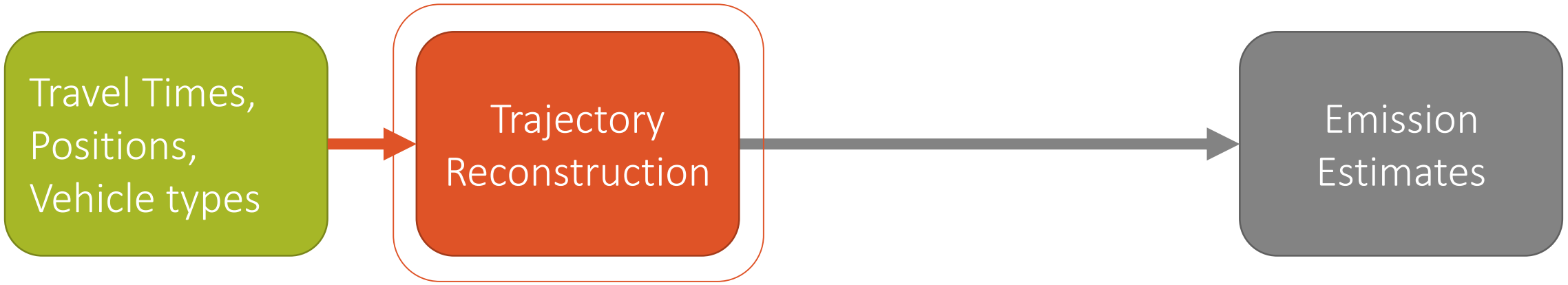
Emission
Estimates

# Traffic Data


## Intersections:
## Vehicle tracking

- Volume counts
- Vehicle types (4 categories)
- Turning movements
- Position & time detection

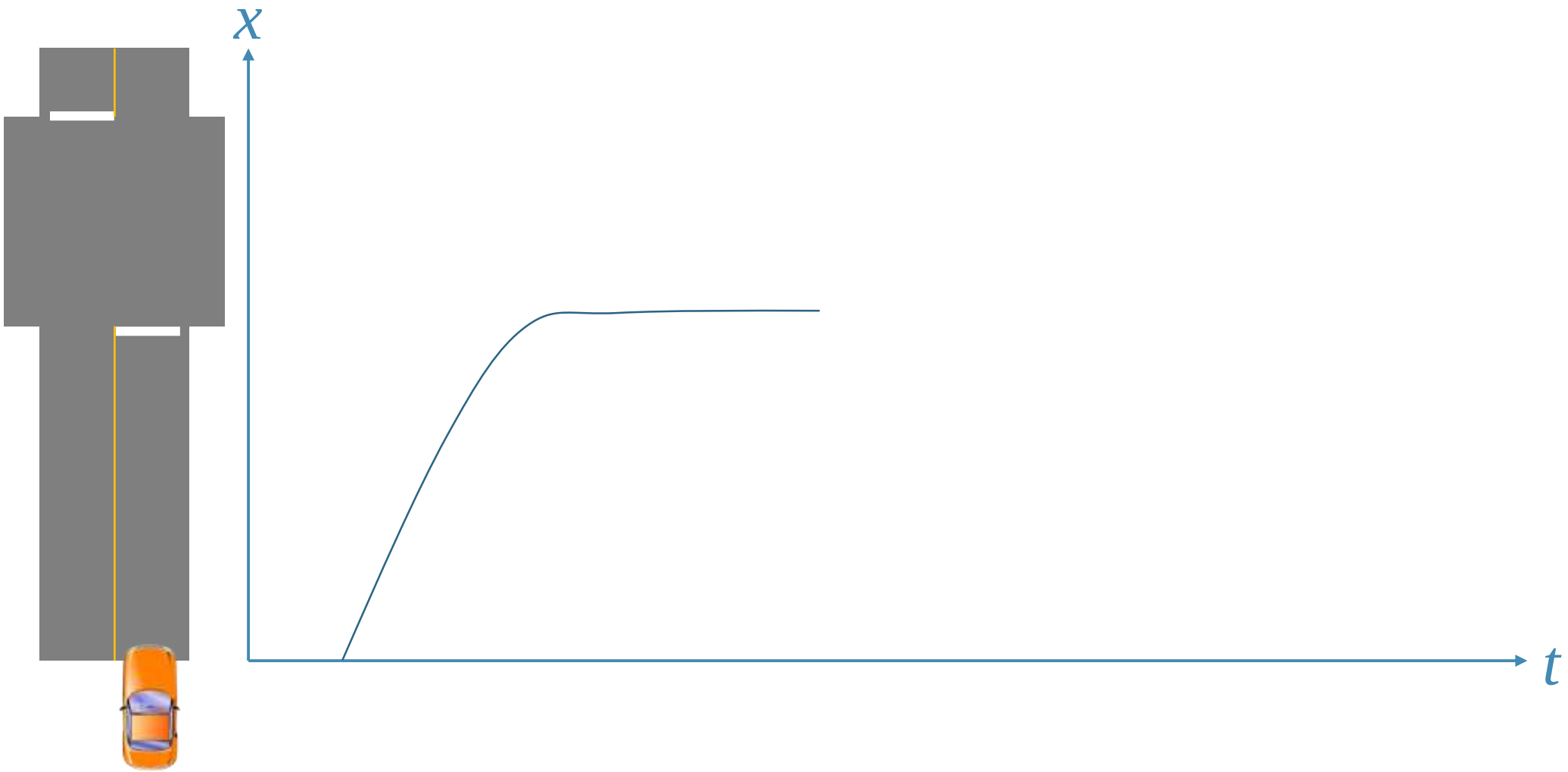
# Modelling Traffic



# Modelling Traffic

Trajectory Reconstruction

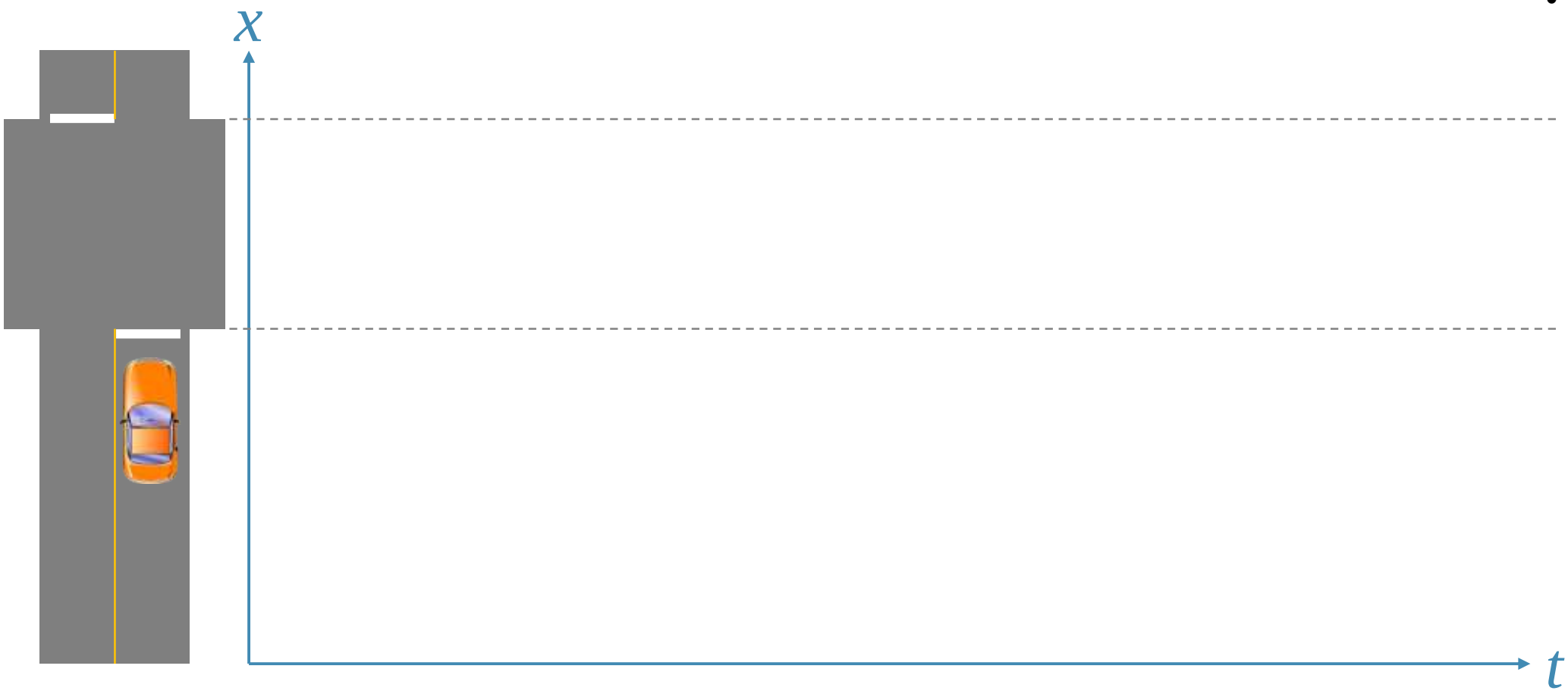
# Vehicle Trajectory Reconstruction



# Vehicle Trajectory Reconstruction

Inputs:

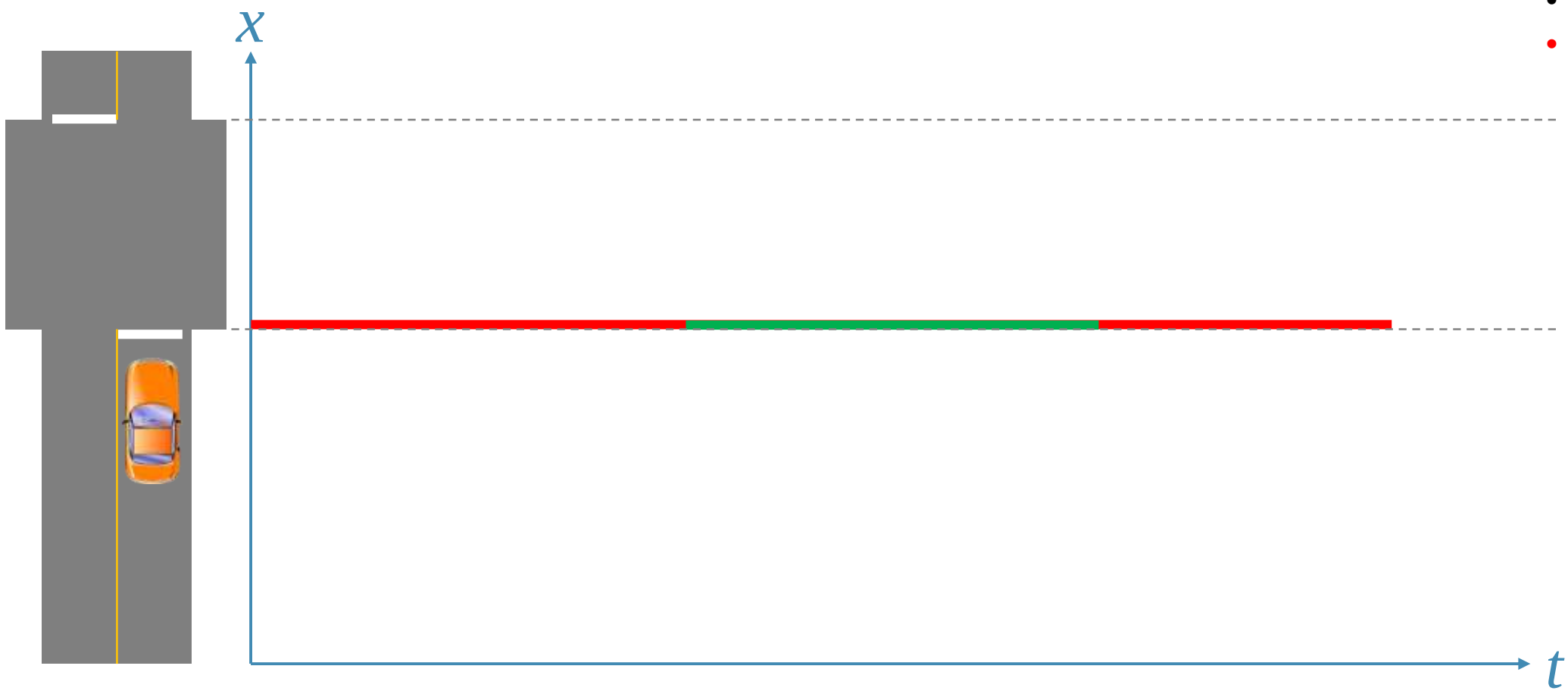
- Road geometry



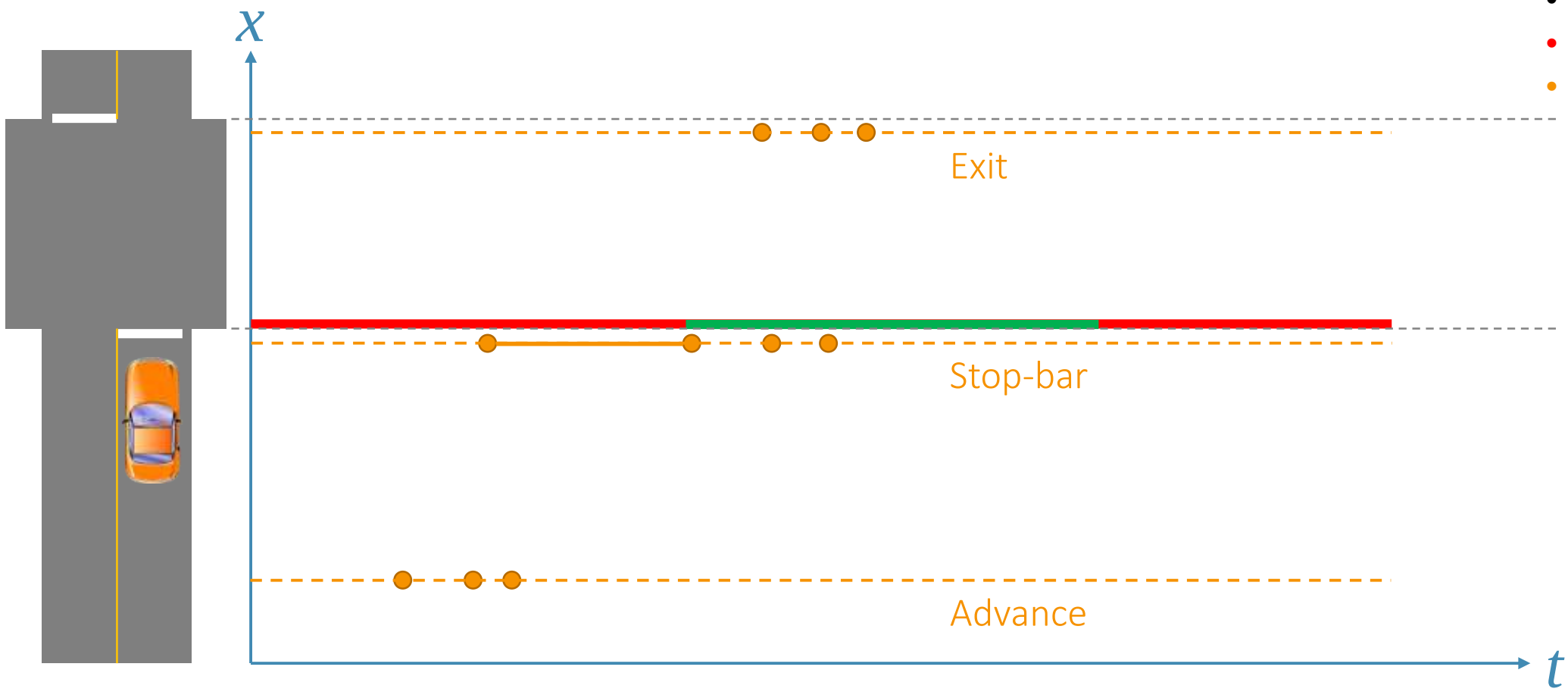
# Vehicle Trajectory Reconstruction

Inputs:

- Road geometry
- Signal timing



# Vehicle Trajectory Reconstruction

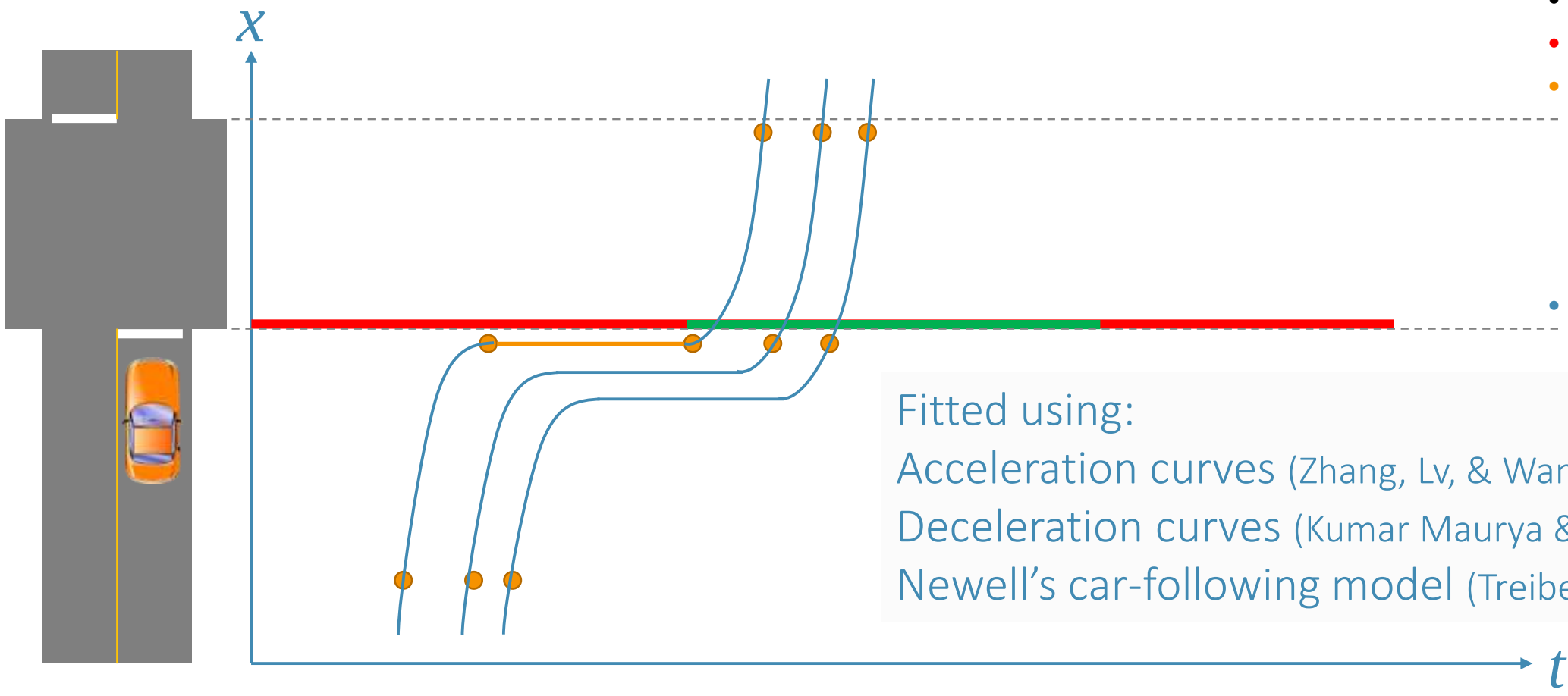



Inputs:

- Road geometry
- Signal timing
- Vehicle detection
  - Advance
  - Stop-bar
  - Exit

Intersection

# Vehicle Trajectory Reconstruction




Inputs:

- Road geometry
- Signal timing
- Vehicle detection
  - Arrive
  - Enter
  - Depart

  Intersection
- Travel Speeds

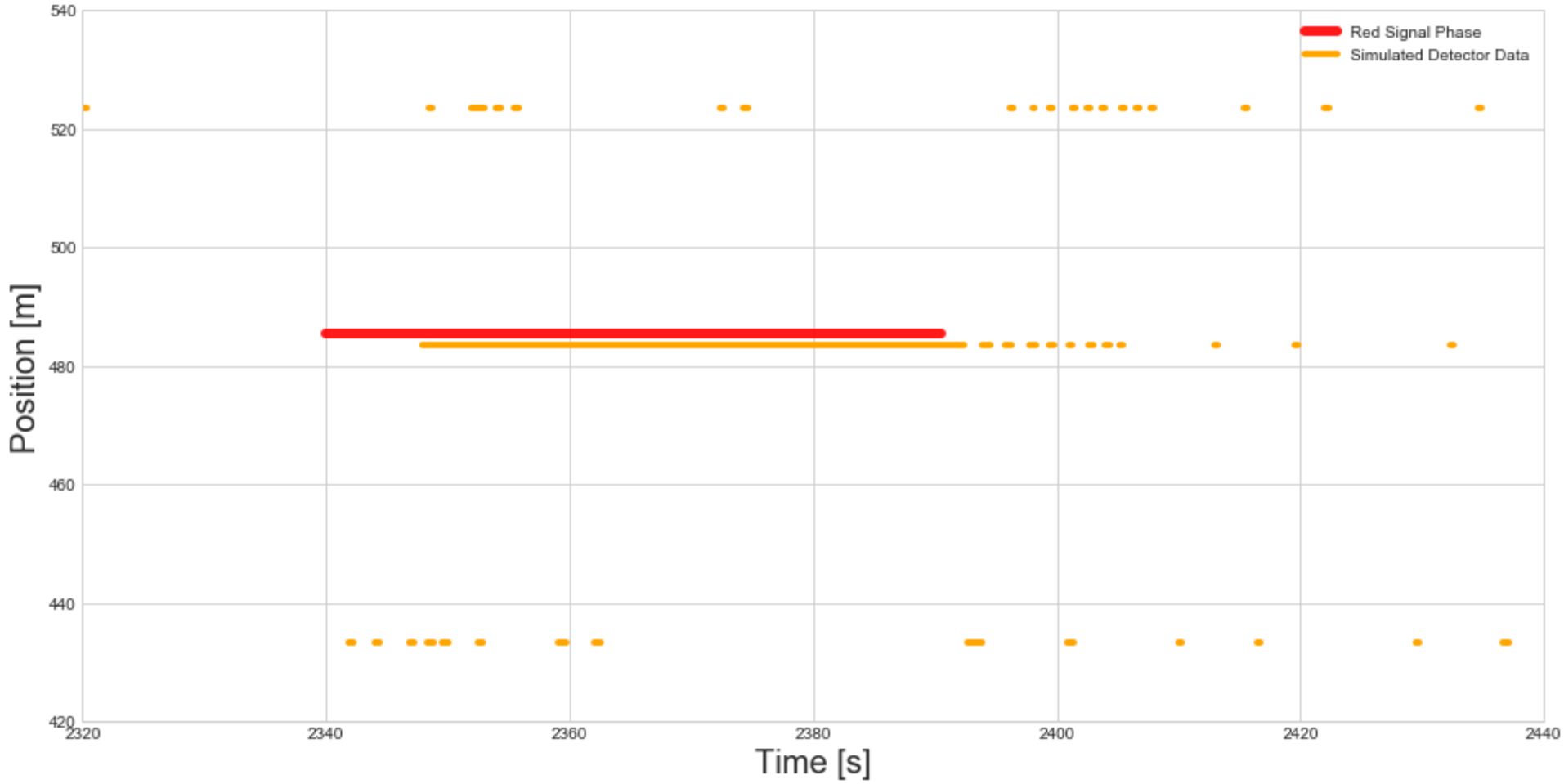
Fitted using:

Acceleration curves (Zhang, Lv, & Wang, 2013)

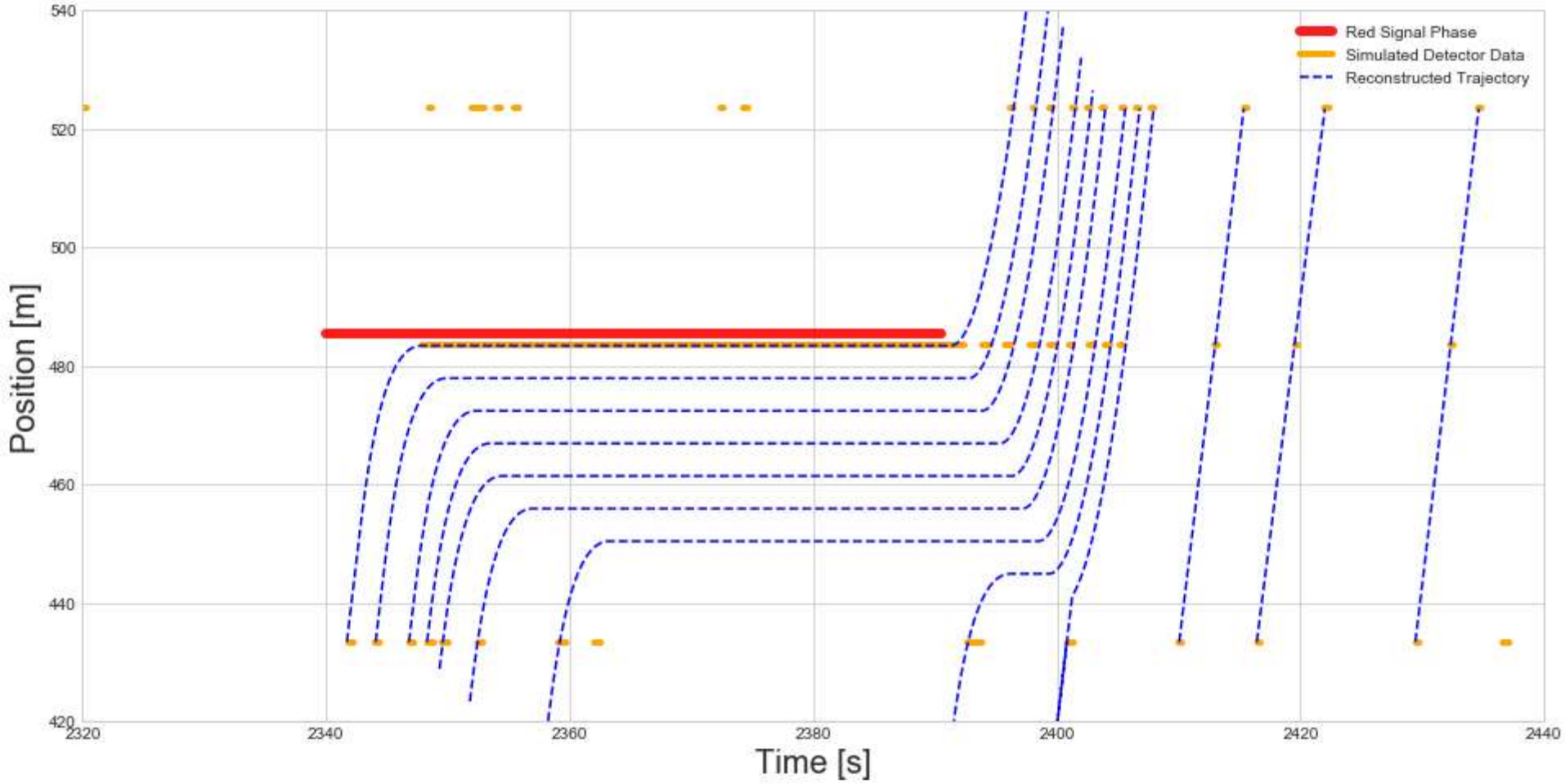
Deceleration curves (Kumar Maurya & Bokare, 2012)

Newell's car-following model (Treiber & Kesting, 2013)

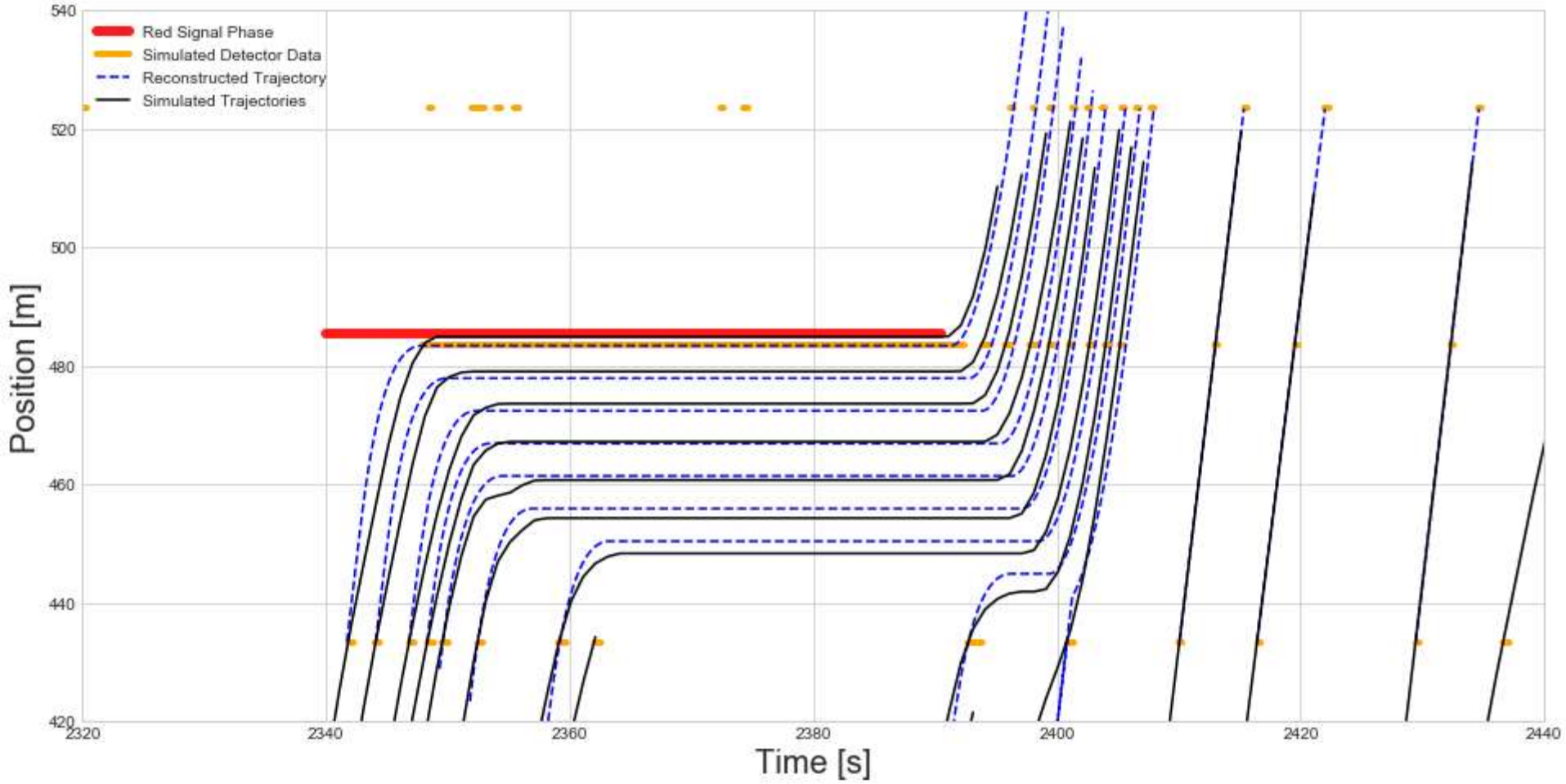
# Trajectory Reconstruction



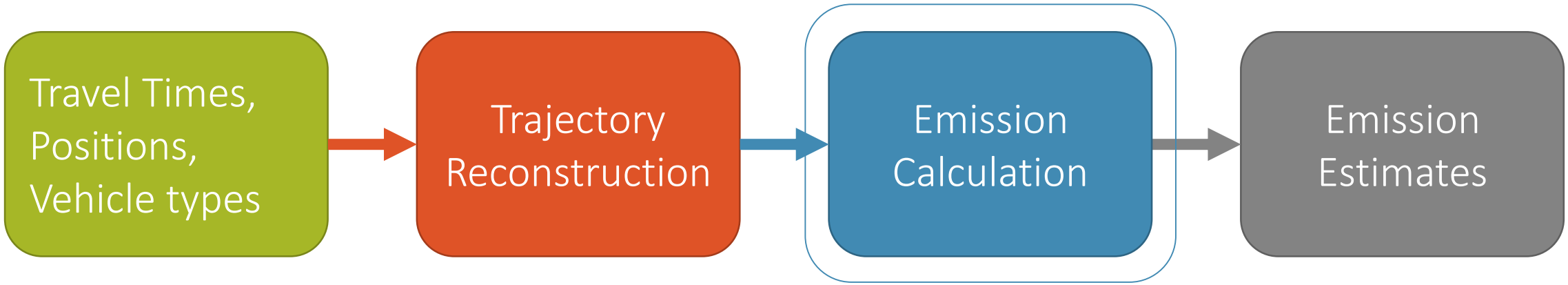
# Trajectory Reconstruction



# Simulated vs. Reconstructed Trajectories



# Calculating Emissions



# Predicting Emissions

Model Form and Inputs

# Predicting Emissions

**How to by-pass the MOVES run?**

Approaches:

1. Calculate **fuel consumption**, apply emission factors
   Using a mechanistic fuel consumption model based on instantaneous speed
   *(Akçelik, Smit, & Besley, 2014)*
2. Calculate **Vehicle Specific Power (VSP)**, apply emission factors
   Using the VSP functions used in MOVES
   *(U.S. Environmental Protection Agency, 2016)*

# 1. Predicting Emissions: Fuel Model

$$Fuel\ Consumption\ \times Emission\ Factors = Emission\ Estimates$$

$$Fuel\ Consumption = f\left(\begin{matrix} Speed \\ Acceleration \end{matrix}, Vehicle\ Mass, Calibrated\ Parameters\right)$$

Vehicle Trajectories

Based on Vehicle Type

(Akçelik et. al., 2014)

$Emission\ Factors$ — Regression using results generated by MOVES

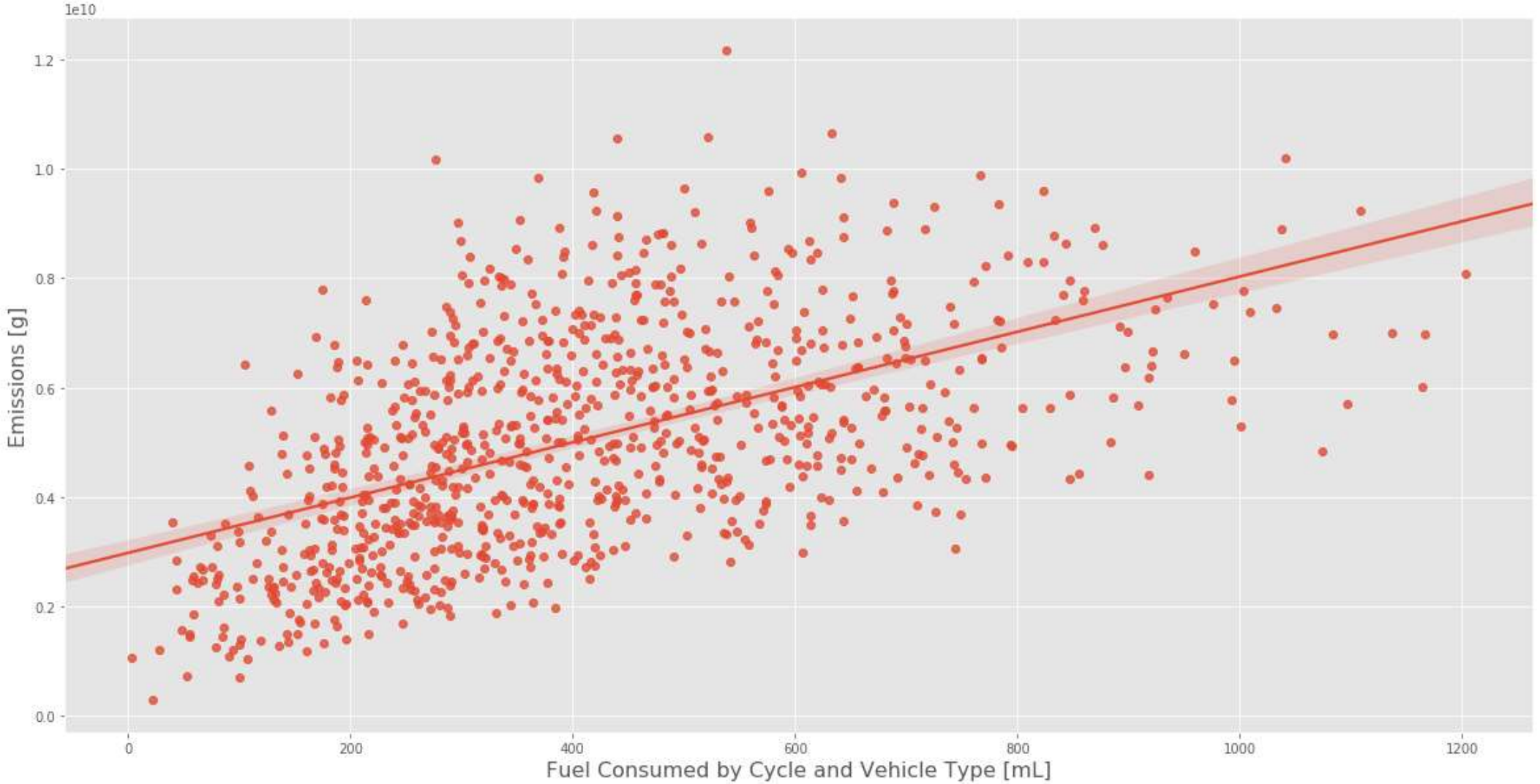
# Determining Emission Factors

Use results from MOVES to perform regressions

Aggregation level for sample points:

- Spatially:
  - *Road segment*
- Temporally:
  - *Signal cycles*

# 1. Emissions vs. Fuel Consumption



# 2. Predicting Emissions: VSP (Vehicle Specific Power)

$$VSP \times Emission\ Factors = Emission\ Estimates$$

$$VSP = f\left(\begin{array}{c} Speed \\ Acceleration \\ Vehicle\ Mass \\ Calibrated\ Parameters \end{array}\right)$$

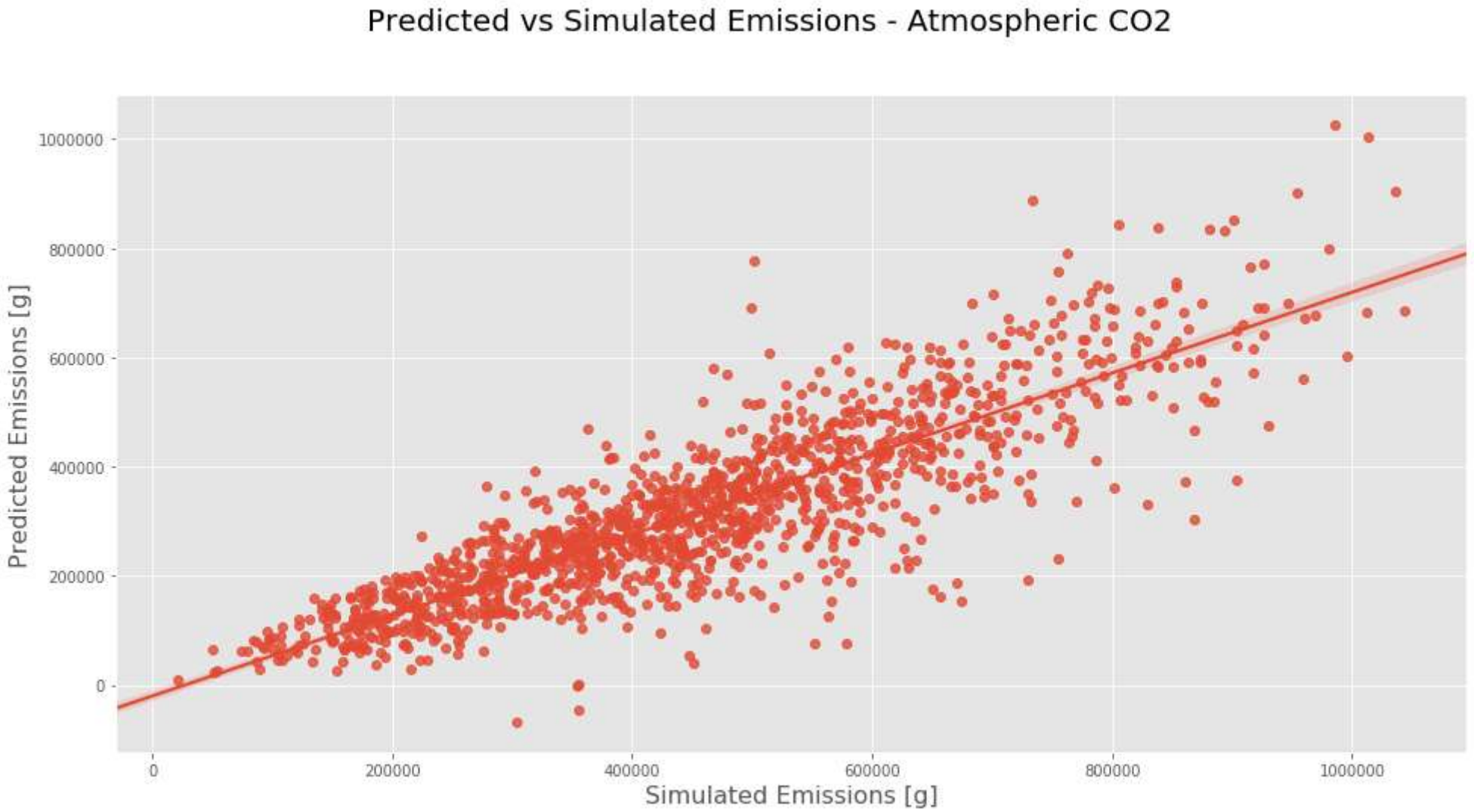
Speed, Acceleration — Vehicle Trajectories

Vehicle Mass — Based on Vehicle Type

Calibrated Parameters — (US EPA, 2014)

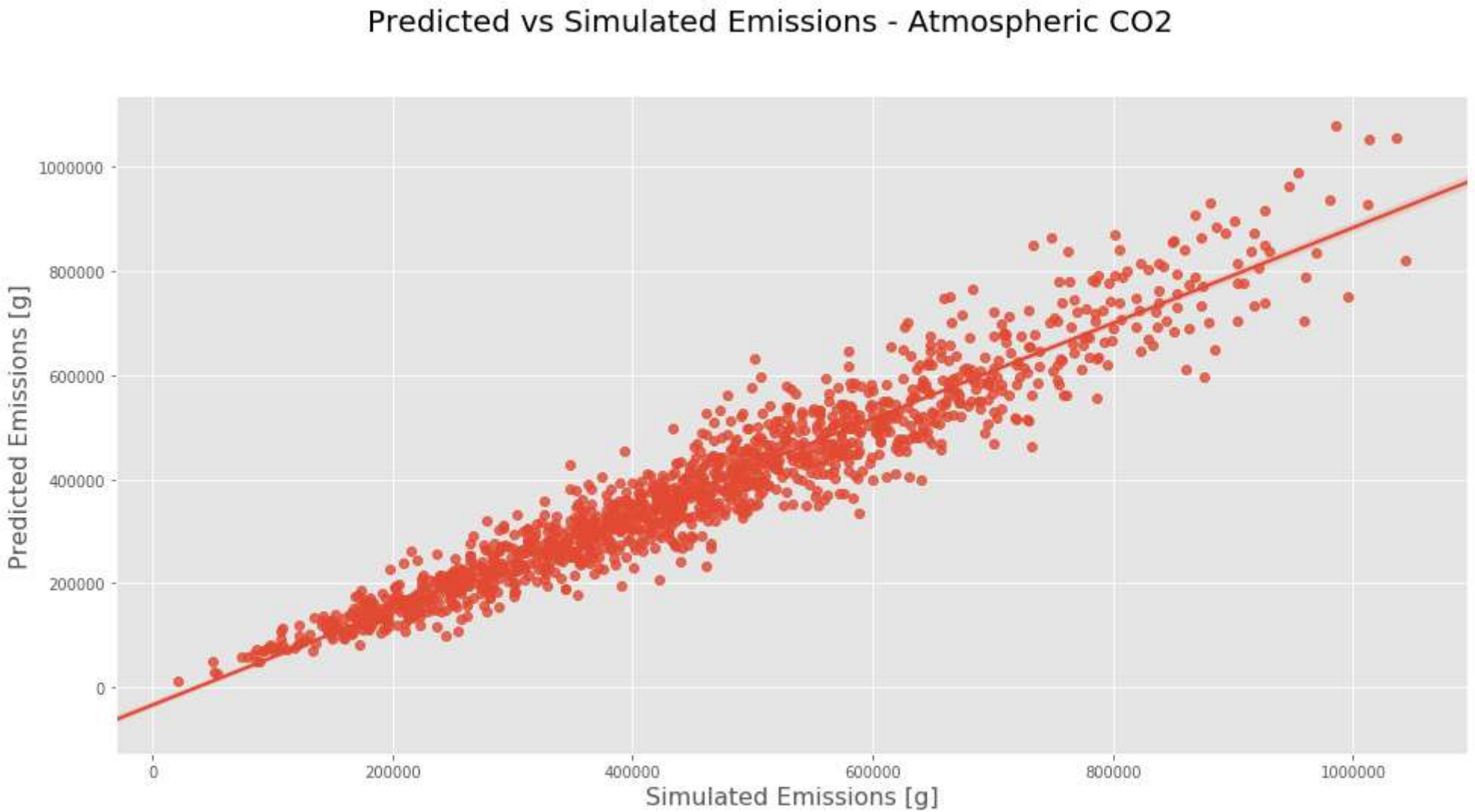
$Emission\ Factors$ — Regression using results generated by MOVES

# 2. Prediction using VSP



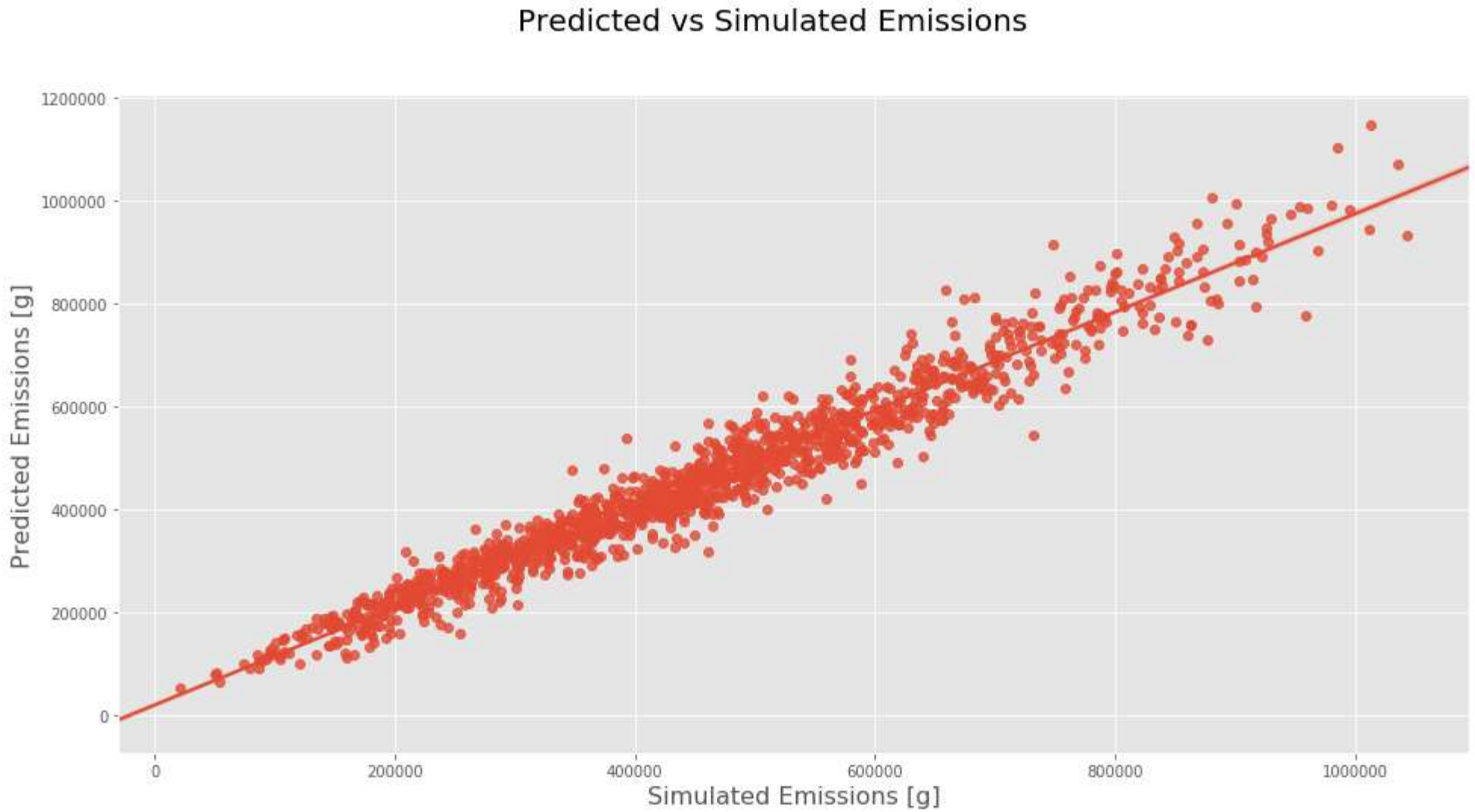

MAPE = 32%

# 2. Prediction using VSP & volume




MAPE = 18%

# 2. Prediction: VSP, volume, speed bins

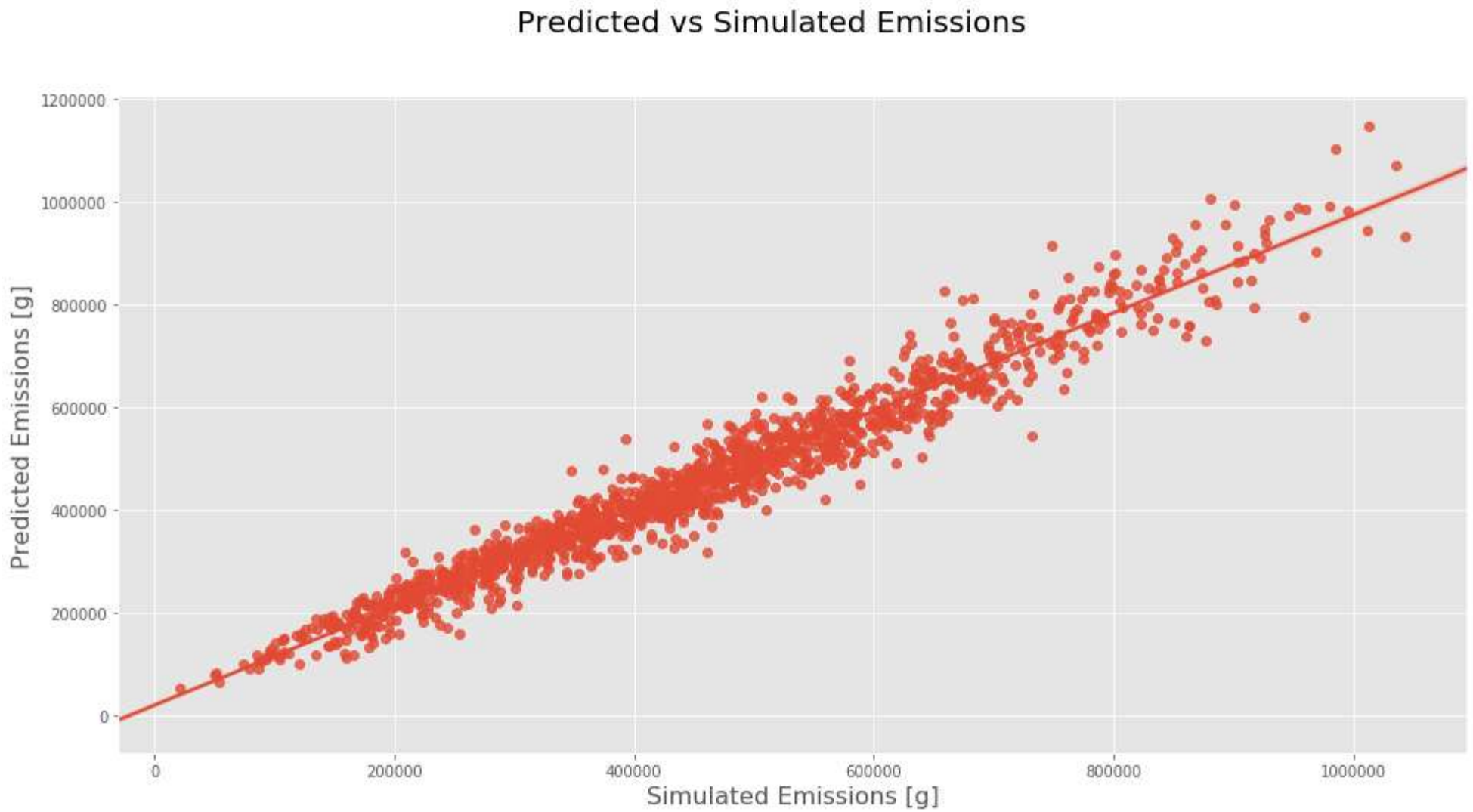



MAPE = 8%

# Greenhouse Gases

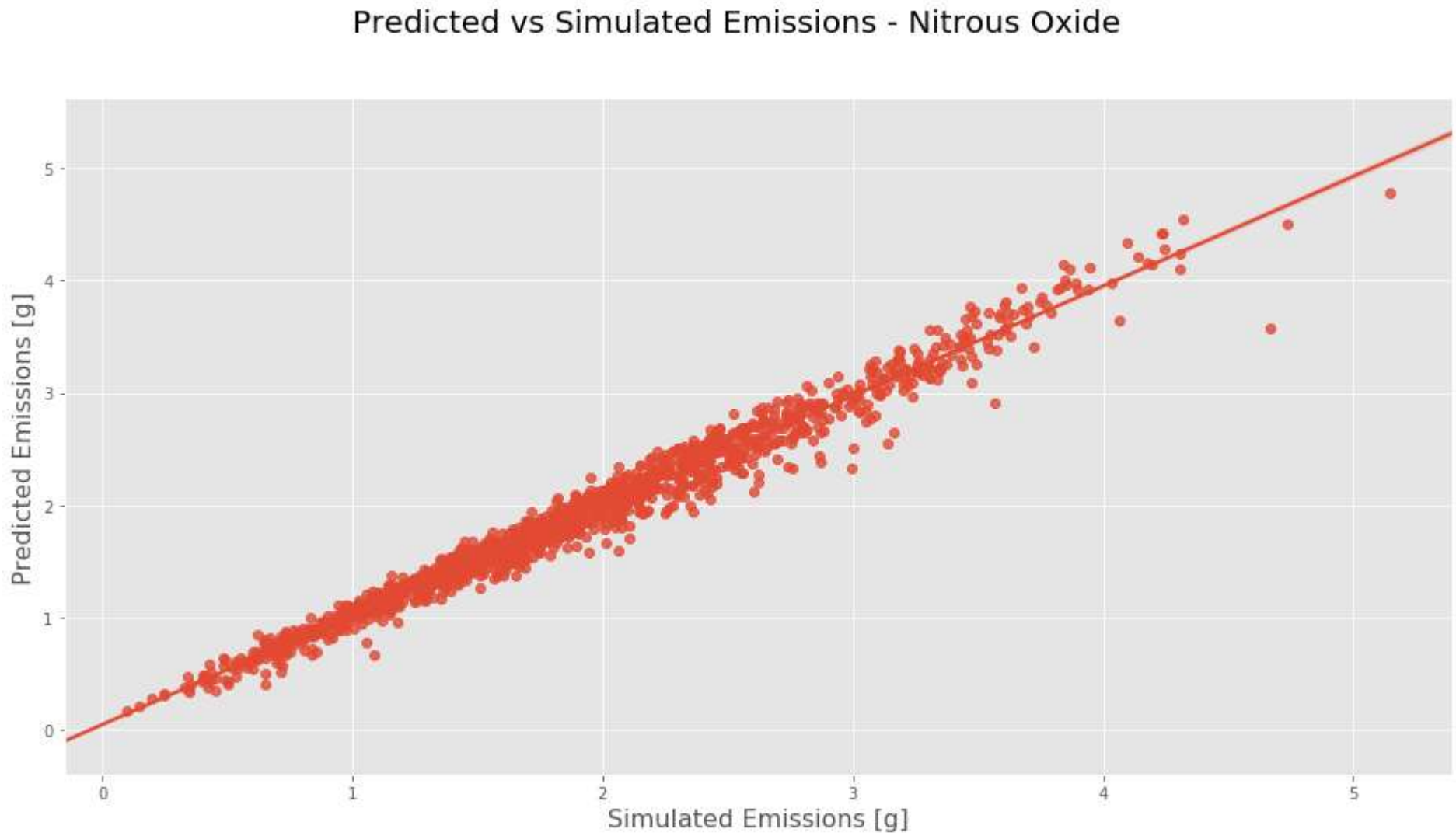
Comparing the prediction approach for different gases

# $CO_2$


Predicted vs Simulated Emissions
Predicted Emissions [g]
Simulated Emissions [g]
0
200000
400000
600000
800000
1000000
1200000

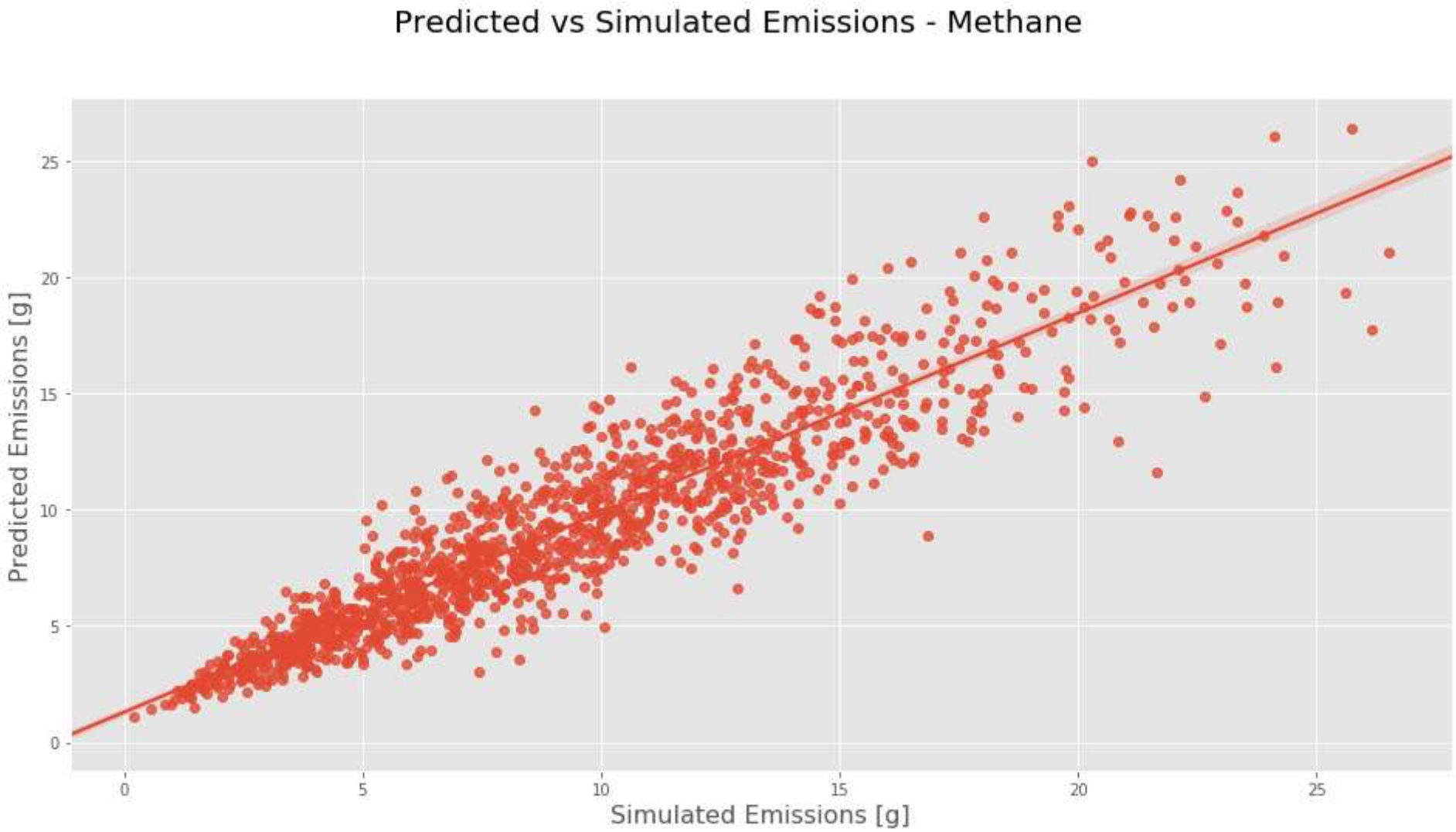
MAPE = 8%

# $N_2O$


Predicted vs Simulated Emissions - Nitrous Oxide
Predicted Emissions [g]
Simulated Emissions [g]
0
1
2
3
4
5

MAPE = 5%

# $CH_4$


Predicted vs Simulated Emissions - Methane
Predicted Emissions [g]
Simulated Emissions [g]
0
5
10
15
20
25

MAPE = 19%

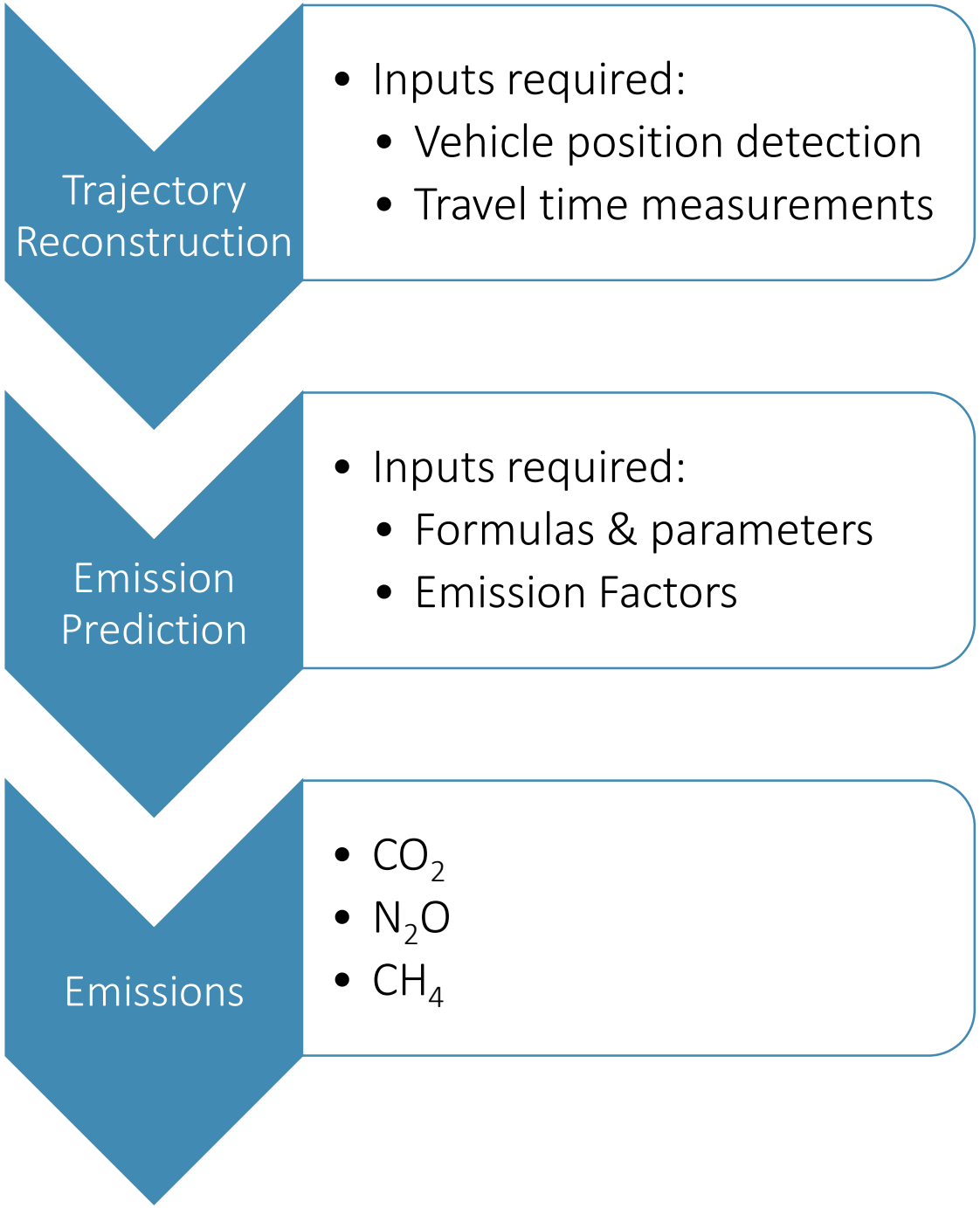
# Conclusion

A method for emission estimation was developed.

- Can be performed in real time.
- Uses currently available traffic data.
- Better for relative comparisons than estimating absolute values of emissions

More research to be done in terms of

- Refining the process / models
- Generalizability



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