



**UDRIVE**

European Naturalistic  
Driving Study

# **Eco-driving webinar WP 4.5**

Veerle Heijne (TNO)

# Schedule webinar Eco-driving

14:00 Introduction to eco-driving + Q&A

14:15 Data description and analysis plan + Q&A

14:30 Preliminary results + Q&A

- Driving conditions
  - Road type
  - Congestion
- Personal driving style
  - Free-flow velocity
  - Braking
  - Gear shifting

14:50 Conclusions and planned activities



# UDRIVE

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## Introduction to UDRIVE & eco-driving

# UDRIVE project

- Natural behaviour in natural surrounding
  - No experimental interventions
  - Insight look over the shoulder of the driver
- Most work packages study safety
- WP 4.5: eco-driving analysis by TNO

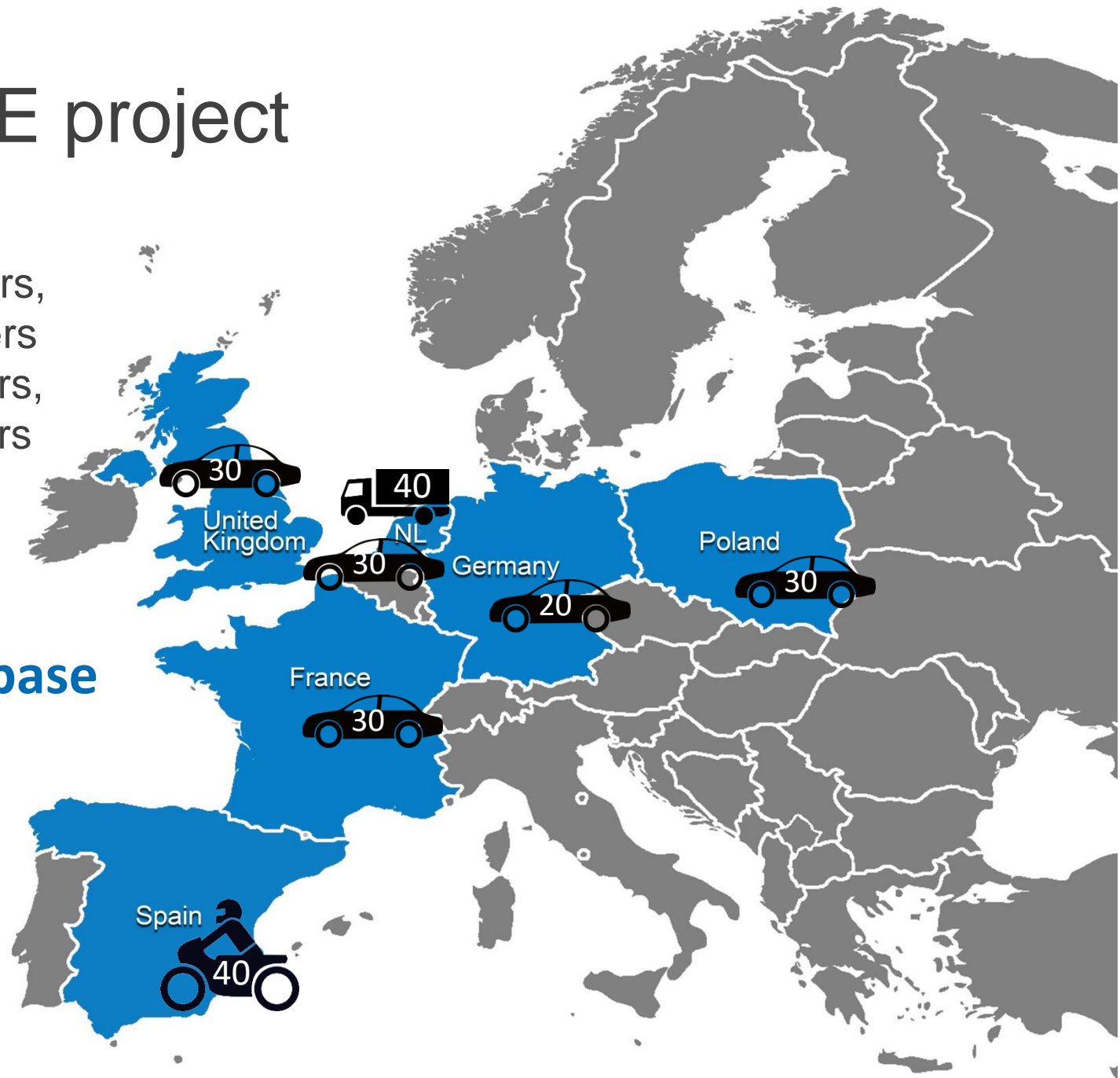
# UDRIVE project

Data collected:

car: 13 200 hours,  
125 drivers  
truck: 6 000 hours,  
41 drivers

One DAS

One Database



# Introduction to eco-driving

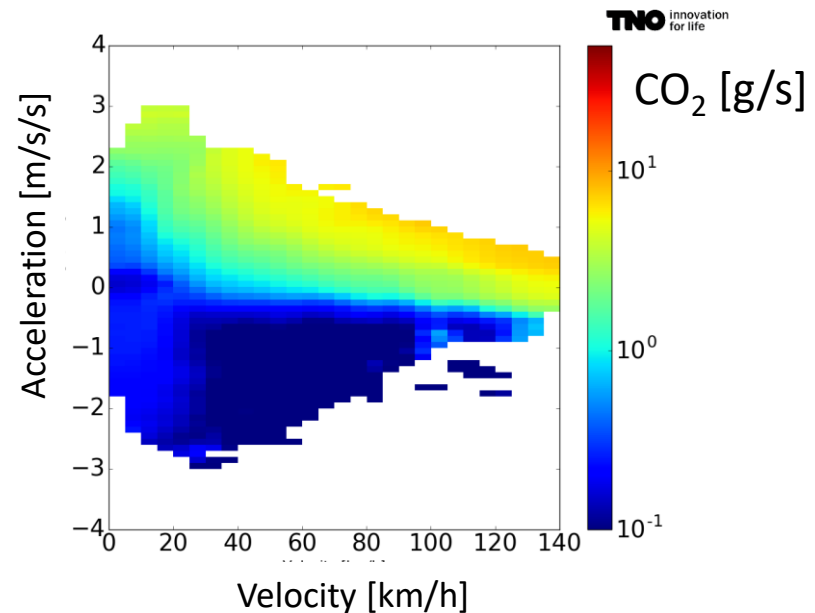
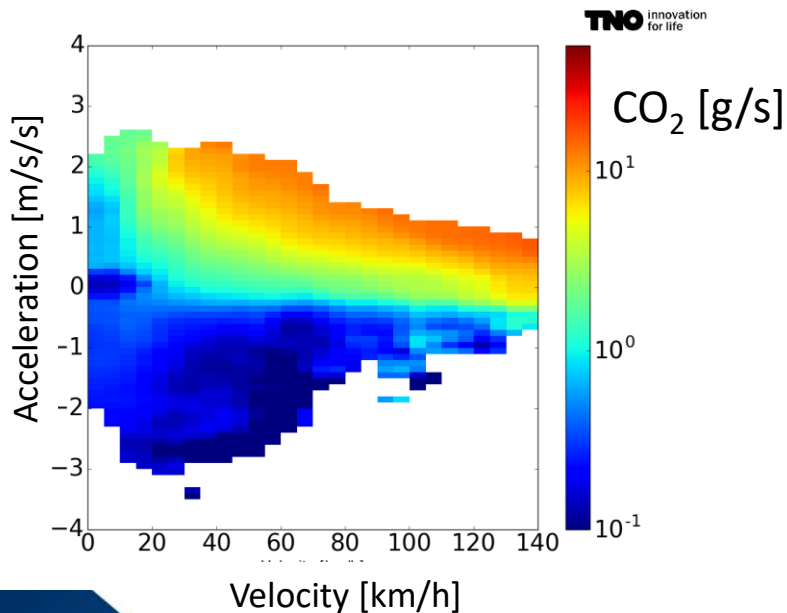
- Up to 40% difference in fuel consumption between drivers, due to:
  - Personal driving style
  - Vehicle condition
  - Infrastructure
  - Congestion

# Introduction to eco-driving

- Golden rules of eco-driving
  1. shift gear up quickly
  2. drive with a lower engine rpm
  3. smoothen speed profiles
  4. increase usage of engine brake
  
- High fuel consumption:
  - High engine speeds
  - Non-constant velocity (high dynamics)
  - Losing energy with braking

# When do emissions occur?

- v-a dependency of emissions for two Euro-6 vehicles
- Always high fuel consumption at high velocity and high acceleration



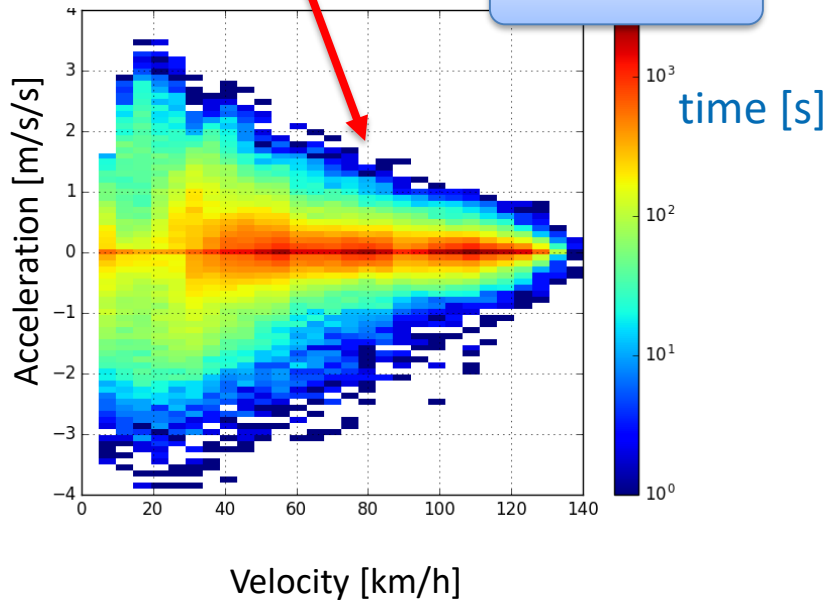
[R11177 “NO<sub>x</sub> emissions of fifteen Euro 6 diesel cars: Results of the Dutch road vehicle emission testing program 2016”, Heijne et.al.]



- v-a distribution per driver determines emissions

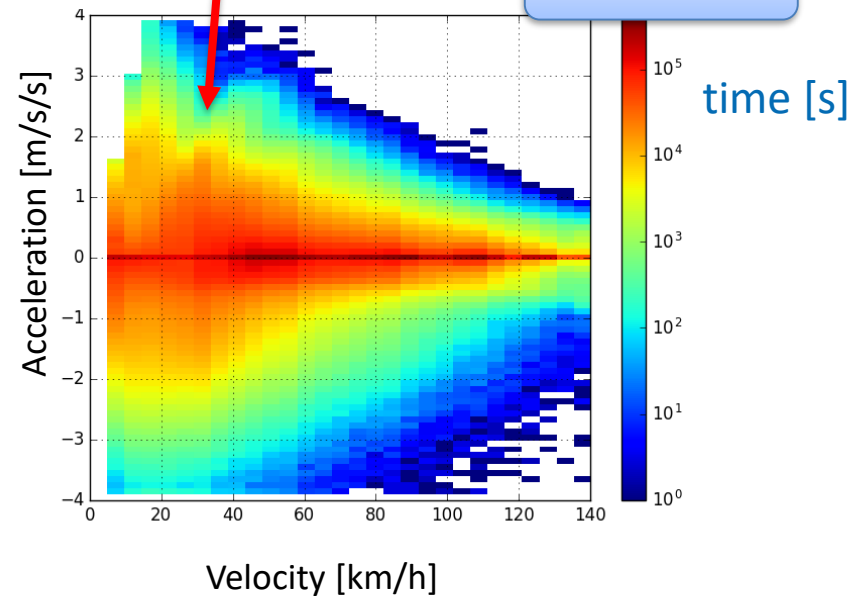
More rural / motorway?

one driver



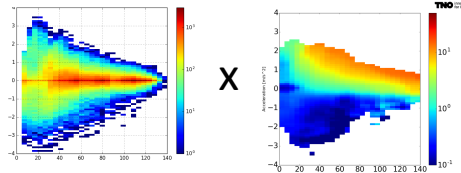
More urban?

all drivers



$$\text{CO}_2 \text{ [g]} = \text{time [s]} \times \text{CO}_2 \text{ [g/s]}$$

$$\text{CO}_2 \text{ [g]} =$$



# Eco-driving research objectives

- Define driving styles that correlate with reduced fuel consumption
- Assess fuel consumption reduction potential from eco-driving, for different parts of the driver population
  - Define driving styles that correlate with fuel consumption based on driving pattern
  - Identify different driver groups based on driving style
  - Correlate driver characteristics (and safe driving) with driving style
  - Assess impact of driving styles on fuel consumption, using external fuel consumption data
  - Assess eco-driving potential for drivers
  - Assess large-scale eco-driving potential, recommend steering mechanisms

# Eco-driving research questions

- RQN5.4: When do drivers **brake** and is it necessary to brake in each instance?
- RQN5.2a: How much do drivers **deviate from the speed limit** in free flow situations?
- RQN5.2b: Why do drivers deviate from the speed limit in free flow situations?
- RQN5.6: Do drivers **shift gear** to avoid high engine speeds and high fuel consumption?
- RQN5.5: Is eco-driving an observable characteristic of **certain drivers**?
- RQN5.3: Is eco-driving and **safe driving** correlated?

# Q&A

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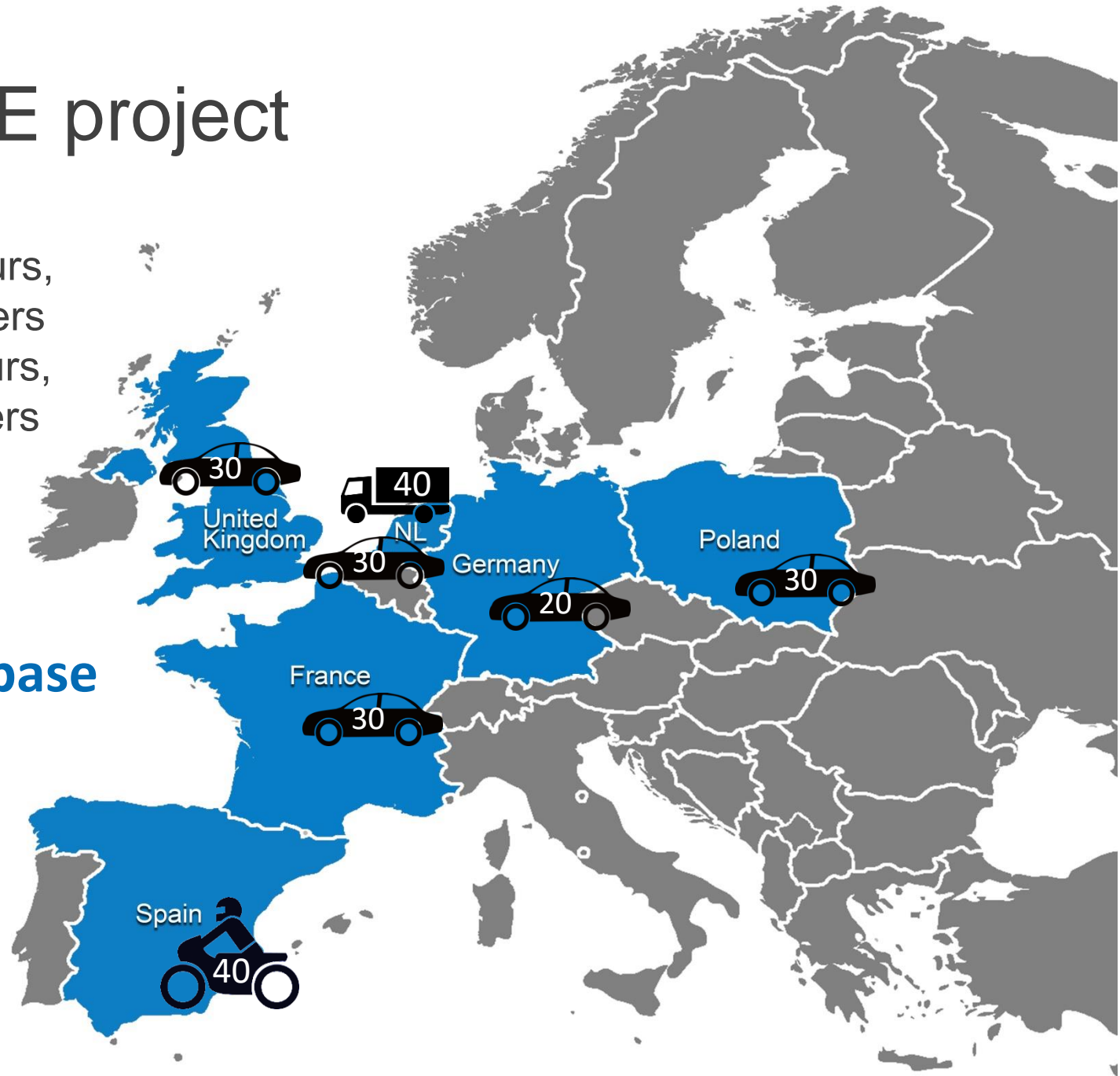
## Data description and analysis plan

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# Vehicle types

3 cars types:

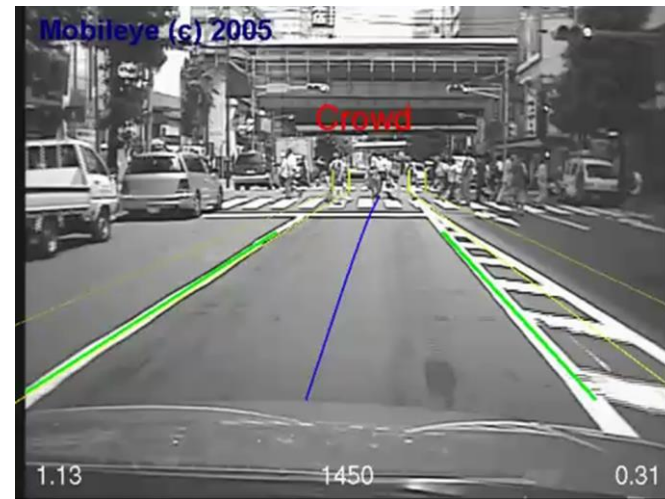
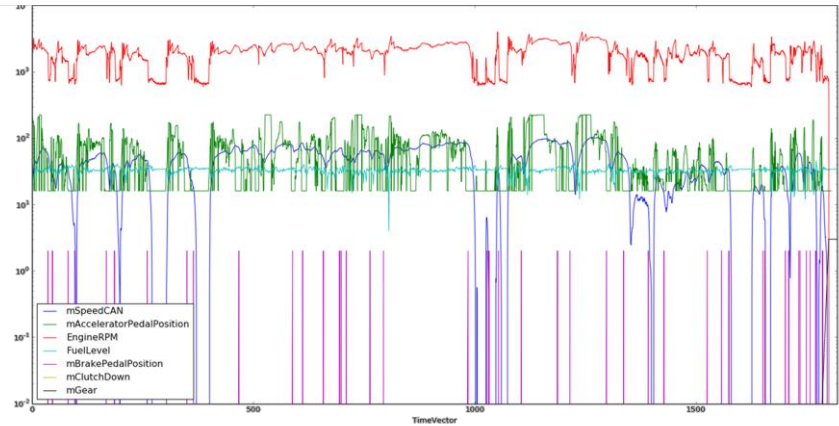
- Renault Clio 3 (small car)
- Renault Clio 4 (small car)
- Renault Mégane 3 (Medium-sized family car)

1 PTW type: Piaggio Liberty

2 Truck types: Volvo, medium sized for city deliveries

# Data description

- CAN signals
  - Velocity
  - RPM
  - ...
- Mobile Eye
  - Surrounding objects position and velocity
- Video
- MAP matching
  - Speed limit
  - Road type
  - Intersection type
- Derived signals from users
  - Derived road type
  - Derived headway





# Data description

- Natural behaviour in natural surroundings
- Using **continuous signals** instead of Safety-Critical-Events
- Not all variables are well-documented and available
  - road inclination, lane width
- Some variables can be derived from other signals
  - headway, braking energy, curvature, gear, road type

# Eco-driving in UDRIVE

- **Infrastructure and congestion** will have largest influence on fuel consumption
- Only the **bandwidth of personal style** is the bandwidth of eco-driving
- **Decouple** the reasons for good/bad eco-driving behaviour:
  - personal style
  - congestion/other road-users
  - road infrastructure
  - vehicle type

# Research questions

- RQN5.4: When do drivers brake and is it necessary to brake in each instance?
  - recognizing bends, junctions, traffic lights (map data and accelerometer)
  - headway, lane width (mobile eye), road gradient
  - brake pedal signal (from CAN), braking energy, gear, engine speed
- RQN5.2a: How much do drivers deviate from the speed limit in free flow situations?
  - velocity and acceleration
  - lateral acceleration, bends
  - junctions, traffic lights, speed limits
- RQN5.2b: Why do drivers deviate from the speed limit in free flow situations?
  - speed limits (map data)
  - headway distance (mobile eye)
- RQN5.6: Do drivers shift gear to avoid high engine speeds and high fuel consumption?
  - engine speed, gear position, clutch engaged signals (CAN)
  - acceleration (accelerometer)
- RQN5.5: Is eco-driving an observable characteristic of certain drivers?
  - Ecodriver parameter, driverID and characteristics (questionnaire)
- RQN5.3: Is eco-driving and safe driving correlated, through increased anticipation of road infrastructure and traffic situations?
  - SCE information from other WPs, ecodriver parameter

# Analysis plan

- Study parameters related to research questions
- Decouple driving conditions and personal driving style
- Determine average driving style, and residual per driver
- Cluster drivers by common characteristics and driving style
- Define 'eco-driving score' based on driving style parameters
- Evaluate potential of eco-driving from differences between driver groups and corresponding fuel consumption

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