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Adapting driver behaviour
for lower emissions

Low-emission driving assistant

Dr. Sébastien Faye – Luxembourg Institute of Science and Technology (LIST)

With contributions from:
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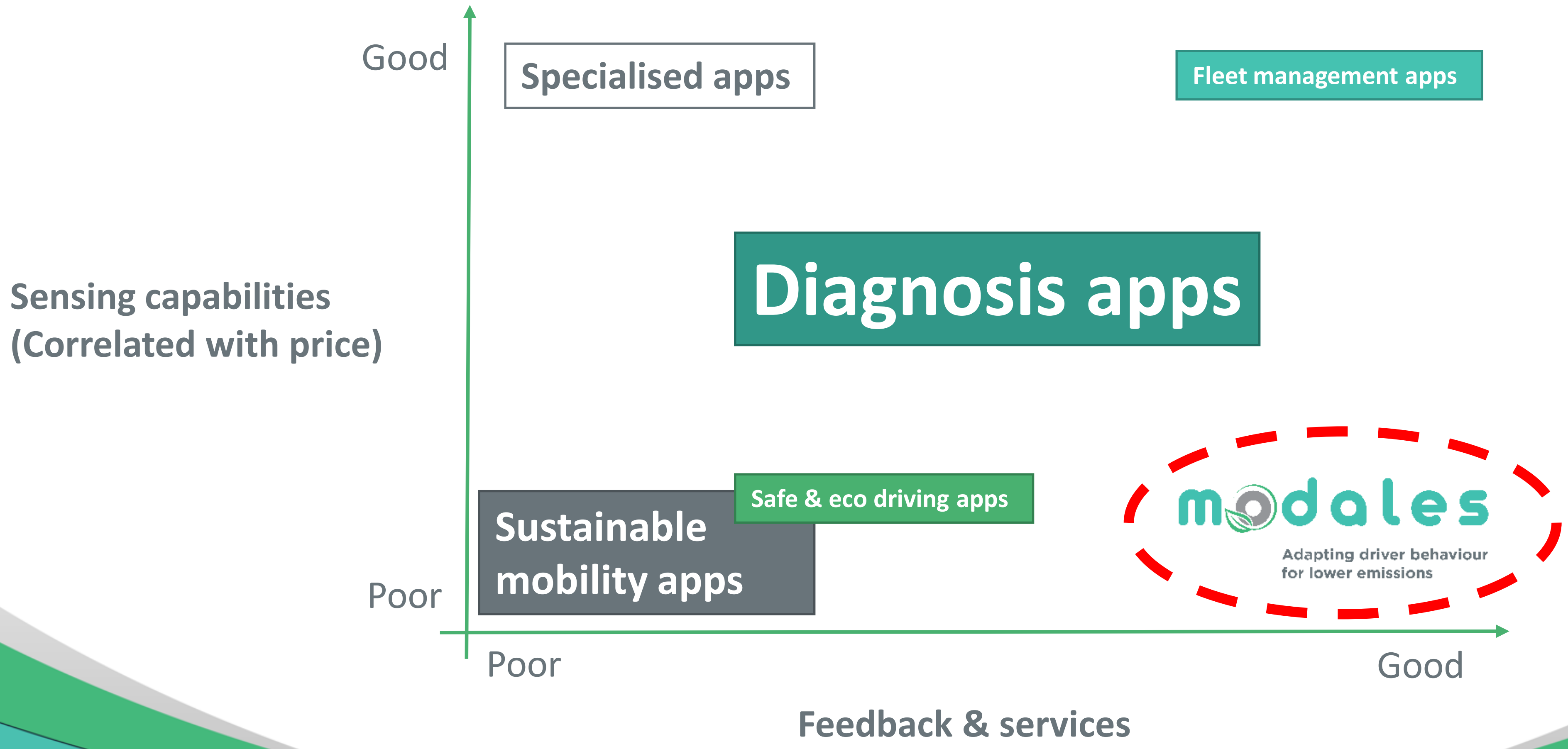
MODALES Final Conference, Brussels, 12 May 2023

Driving application

What's the need?



Overview of the solution

Mobile analytics to understand, assess and guide user's driving choices:

- Module 1 – **In-vehicle data collection** from:
  - Smartphone sensors
  - OBD dongles
- Module 2 – **Data interpretation**:
  - On-device artificial intelligence techniques
  - Privacy-friendly approach

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Overview of the solution

- Module 3 – **Recommendations**:
  - **Active** recommendations:
    - When the user is driving
    - Research prototype → simplified recommendations and HMI, using only the phone sensors
  - **Passive** recommendations:
    - After a trip
    - Complete report, using the phone sensors, OBD data and external web services (e.g., weather, traffic index)

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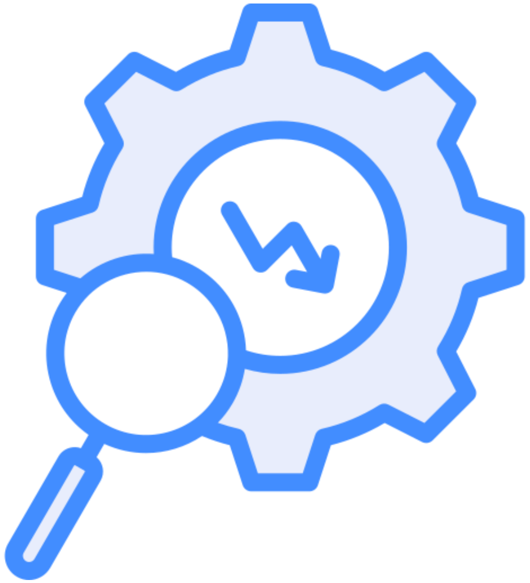
Research challenges

- Learn useful driving indicators from raw data in real time.
- Design a user interface for the journey without compromising safety.
- Build a recommender system.
- Handle different connectivity scenarios.
- Ensure privacy policies.
- Analyse behaviour changes.



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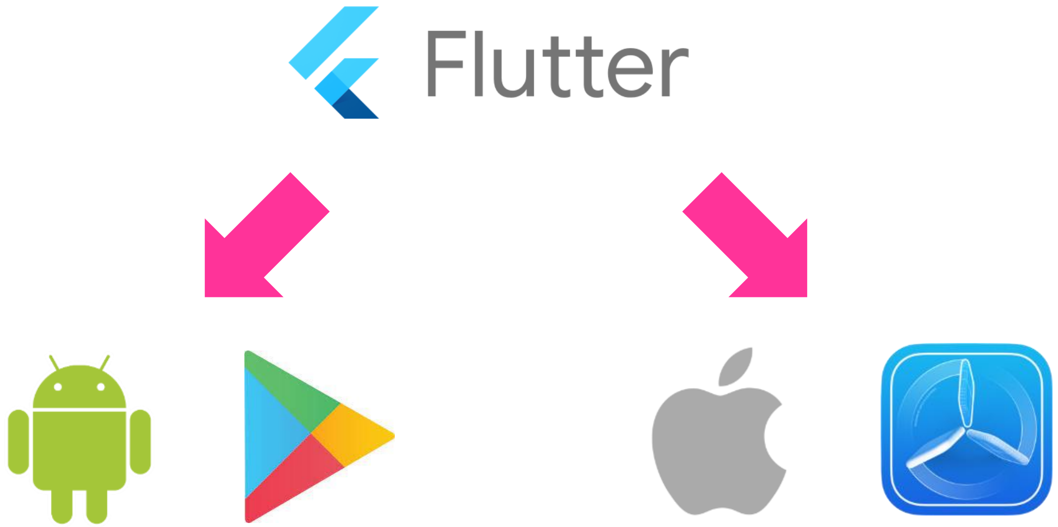
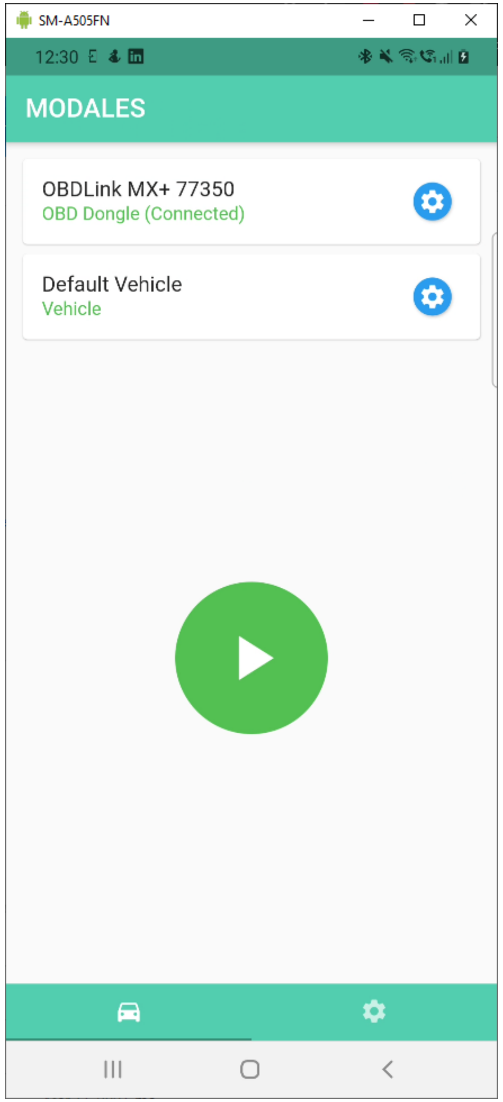
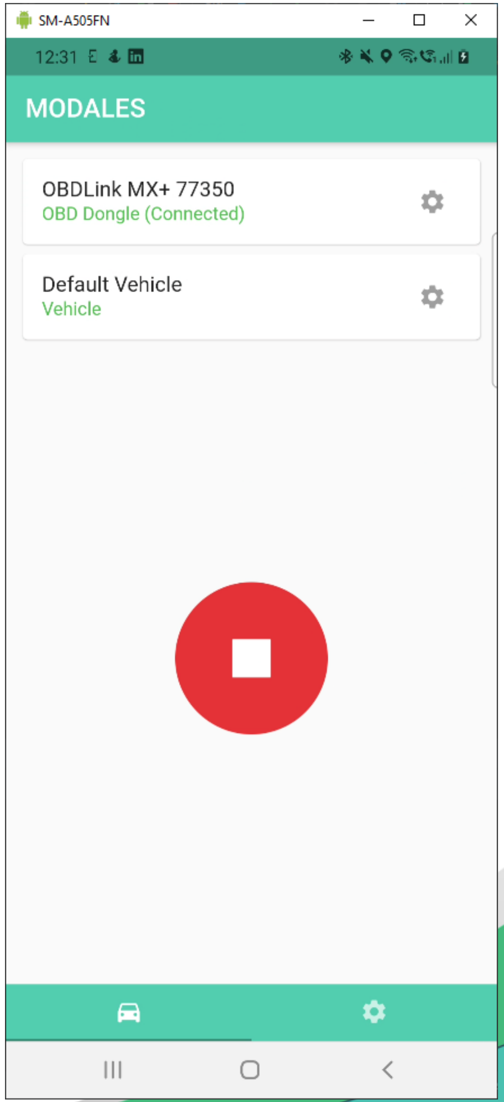
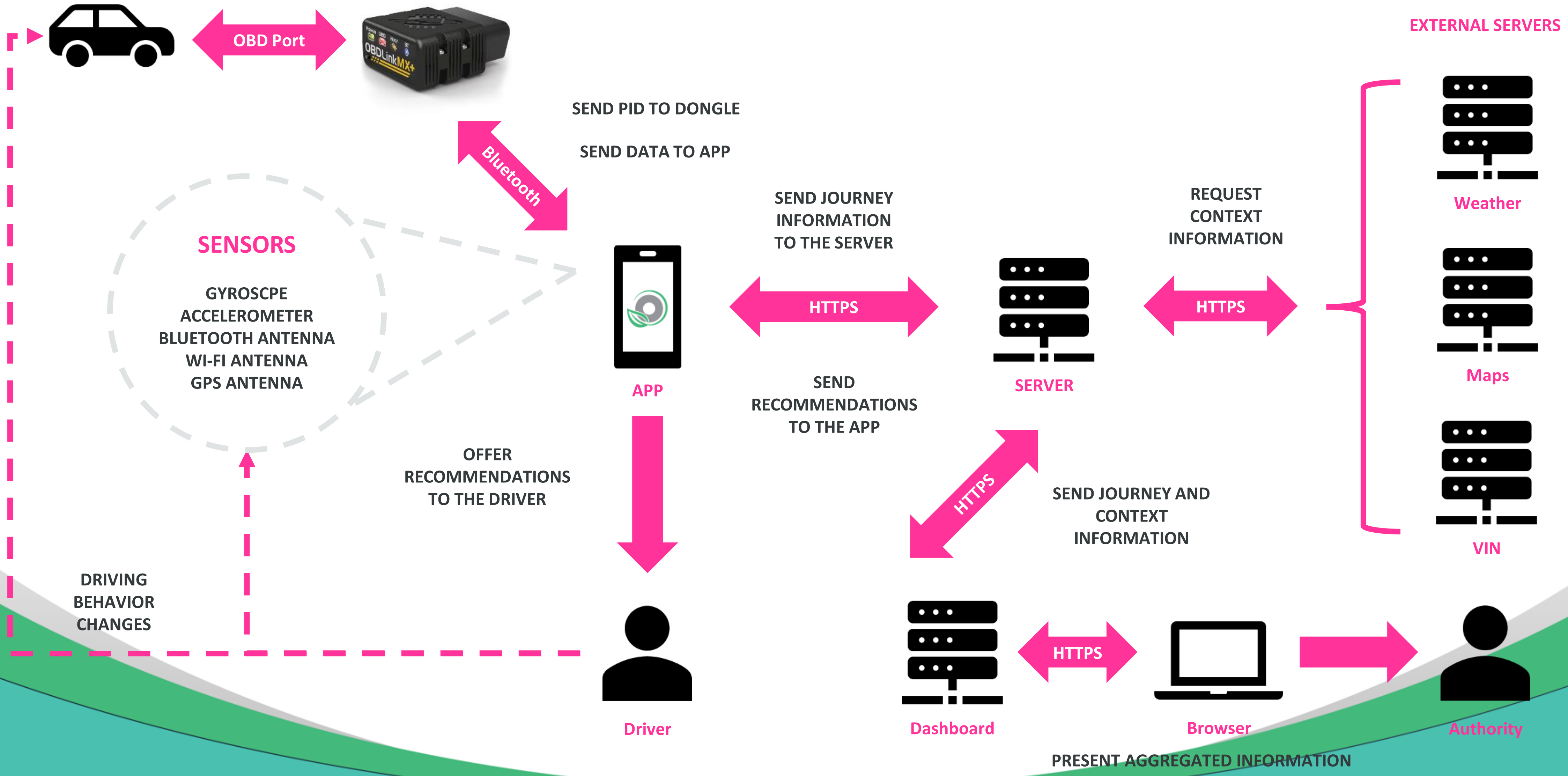
Simple user interface







Architecture overview



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OBD data

More reliable:

- Absolute barometric pressure
- Absolute throttle position
- Accelerator pedal position
- Air flow rate
- Ambient air temperature
- Catalyst temperature
- Engine coolant temperature
- Engine fuel rate
- Engine speed
- Vehicle speed

Less reliable:

- Intake air temperature
- NOx sensor

VINCARIO
Global VIN decoder

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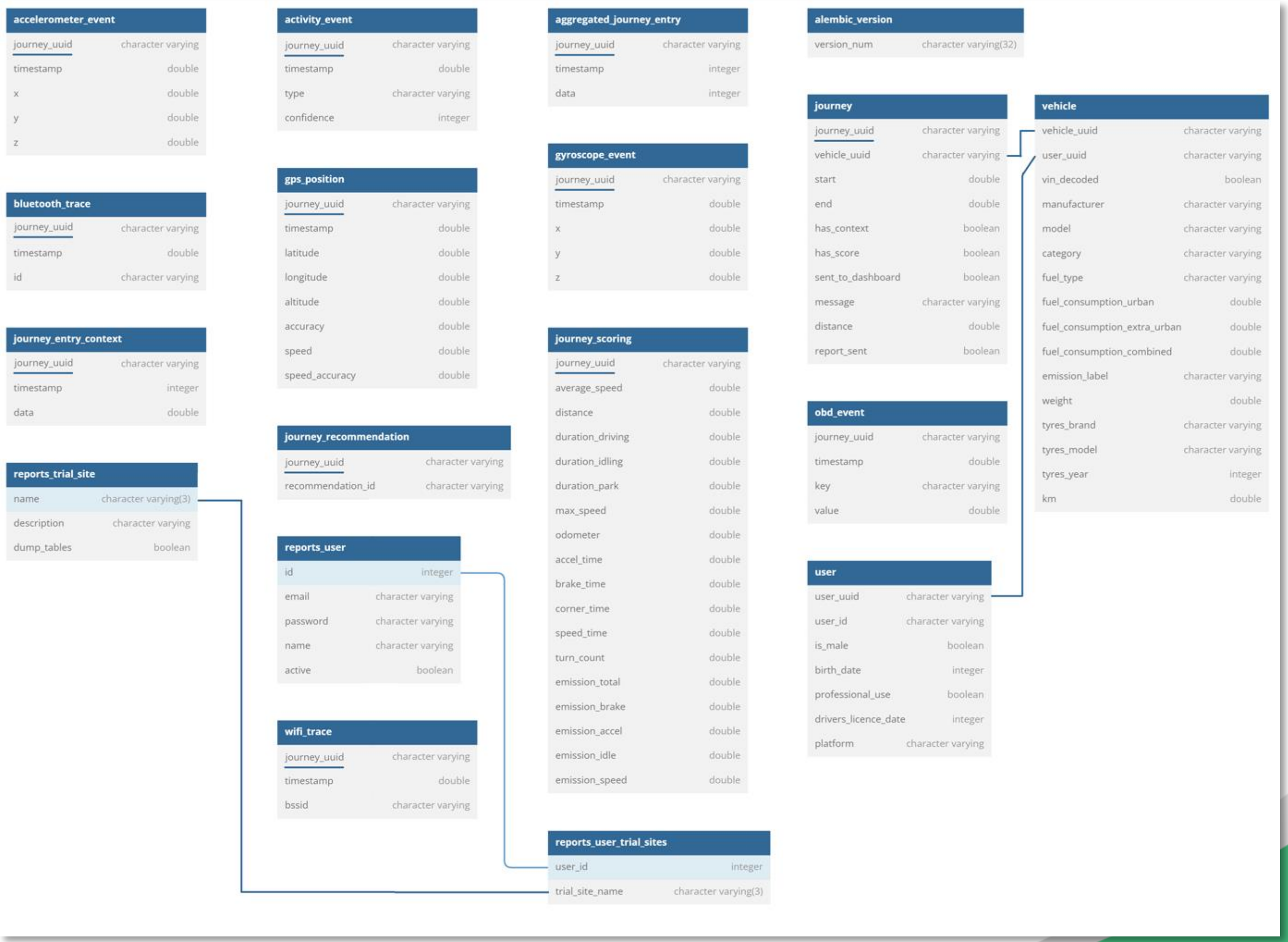
Smartphone data

Raw driving data:

- Accelerometer
- Gyroscope
- Wi-Fi and Bluetooth traces
- User activity (in vehicle or not)
- Manual inputs from the user
- GPS (stored temporarily)

Extended data:

- Scores, journeys, …



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Database - Context information

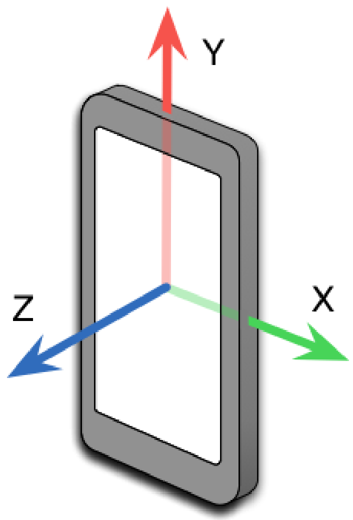
Weather:
- humidity
- temperature
- total snow
- visibility
- wind speed

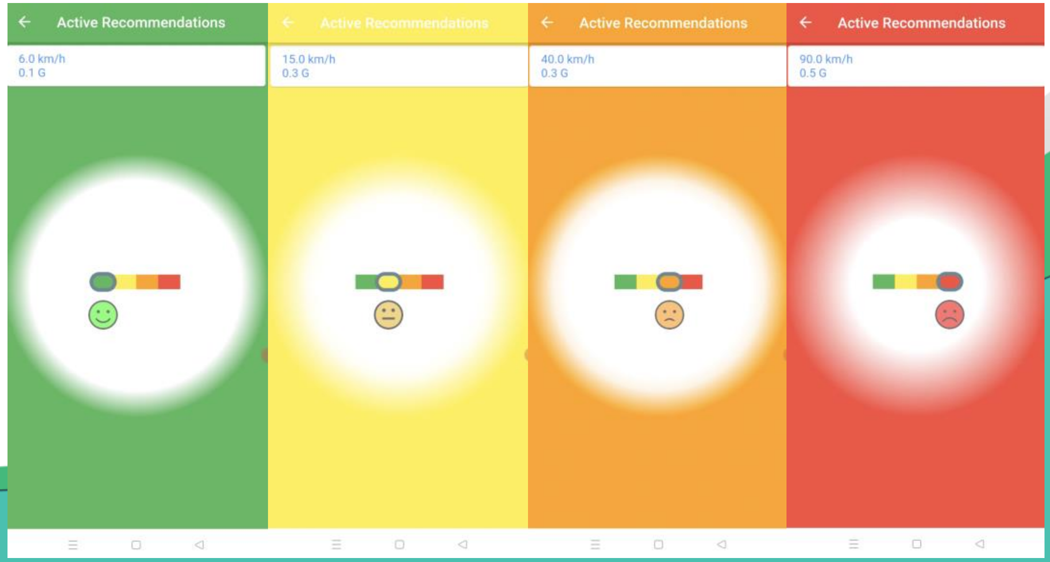
Traffic:
- historical average speed
- historical free flow speed
- historical jam factor
- historical traversability
- real-time confidence
- real-time traffic speed

Road:
- average roughness category
- curvature
- distance to intersection
- functional class
- has end of no overtaking sign
- has no overtaking sign
- has pedestrian crossing sign
- has stop sign
- has traffic signal
- has yield sign
- heading
- intersection category
- international roughness index
- is bridge
- is intersection
- is long haul
- is ramp
- is roundabout
- is tunnel
- is urban
- lane category
- radius
- road type
- slope
- speed category
- speed limit
- speed limit trucks

Active recommendation

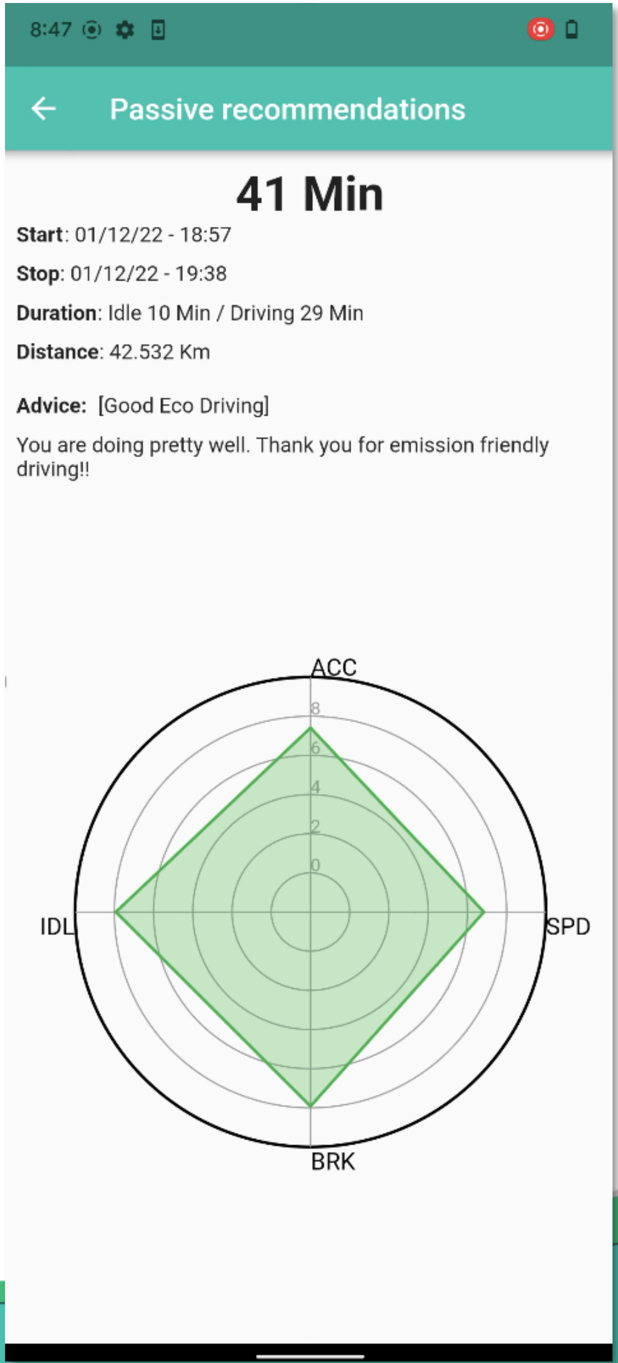
- **Real-time** display with colour codes, proportional to the acceleration.
- Based on accelerometer data





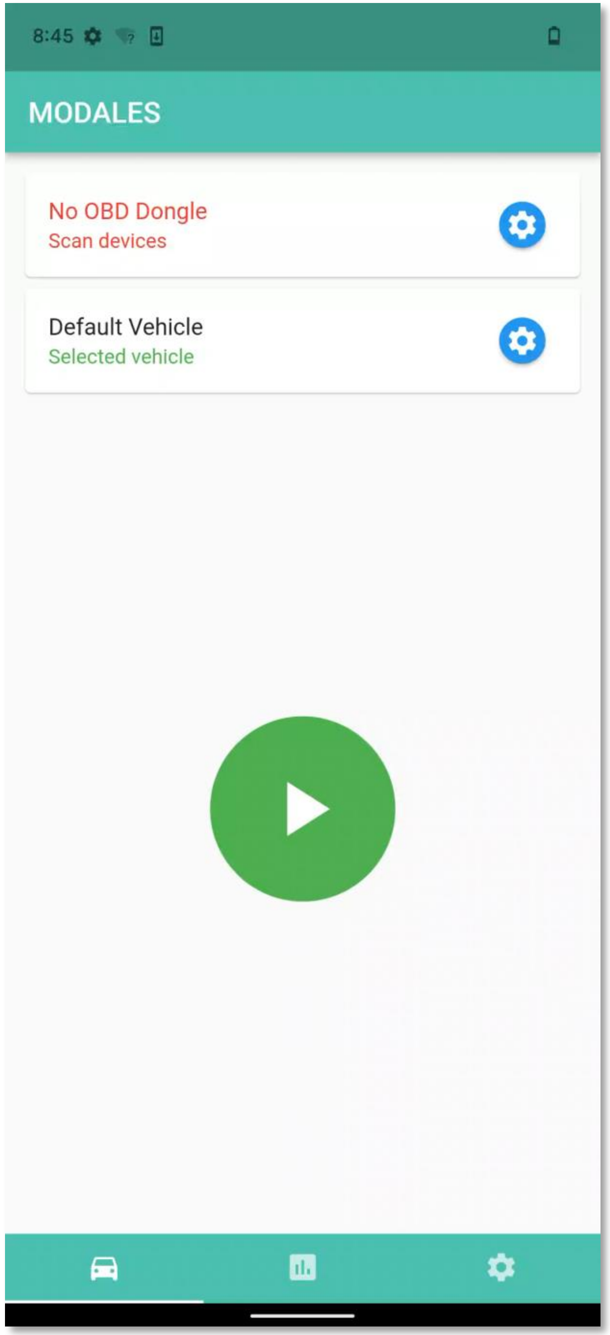
Passive recommendation

- Delivered to the user **after his/her driving session**.
- Four **scores** generated.



Demo

08:51
4°c
20.5
20.5
MENU
3D
Rechercher...
AUTO
MODALES

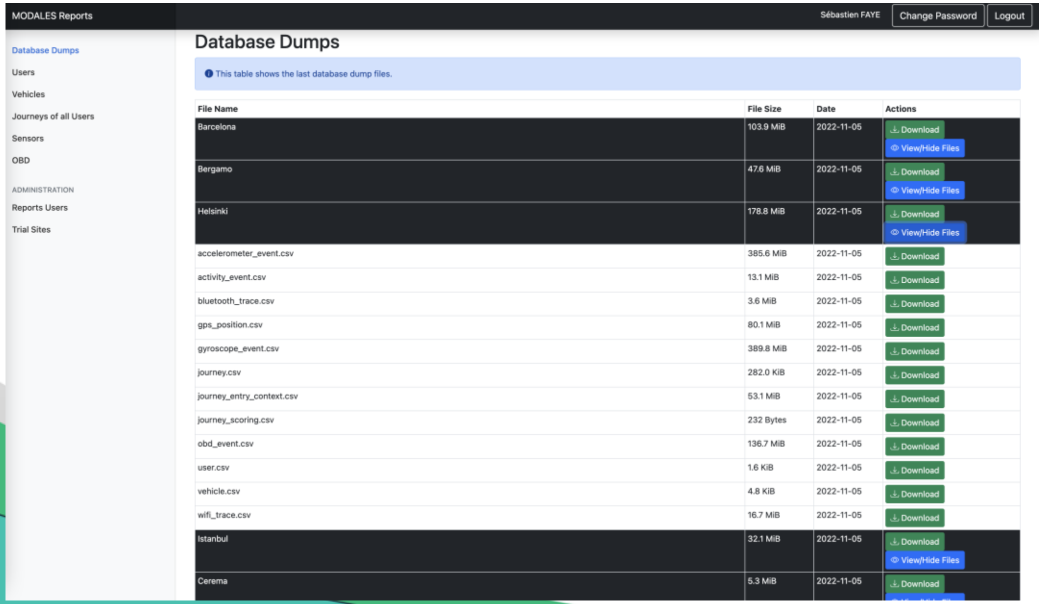

8:45
MODALES
No OBD Dongle
Scan devices
Default Vehicle
Selected vehicle

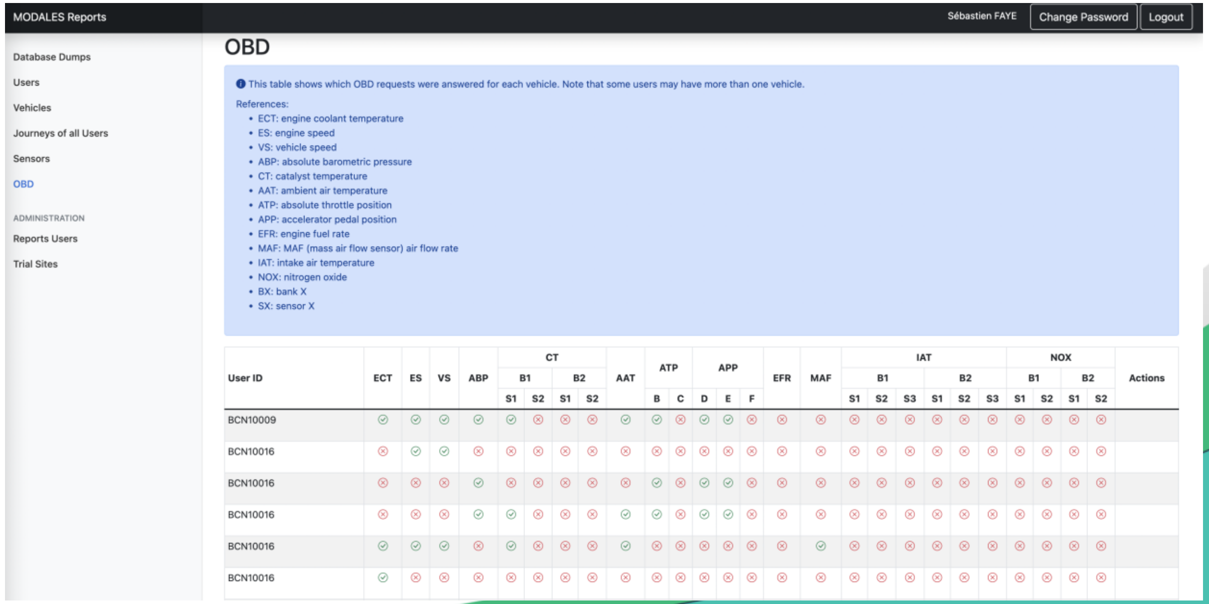

08:52
4°C
20.5
20.5
Rue du Grand Chemin (Rurange-lès-Thionville)
199m
MENU
3D
Rechercher...
AUTO
Active Recommendations
LIST
SRC
ENGINE
START
STOP

Internal reporting platform

T5.3: Internal reporting platform

- Data sharing with partners
- Data filtering and following: evolution of the data collection and the participation for each trial site

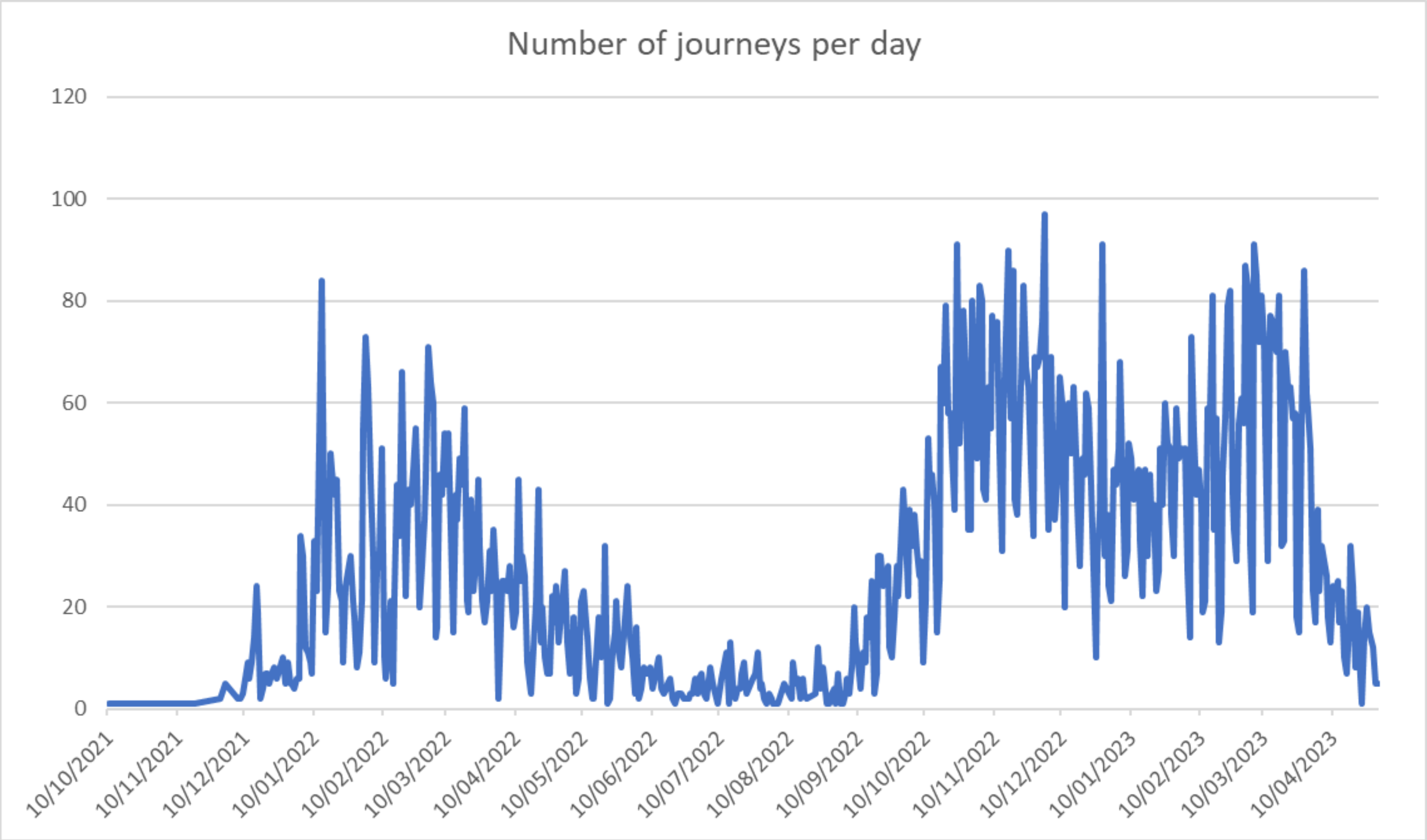




Data collected & lessons learned

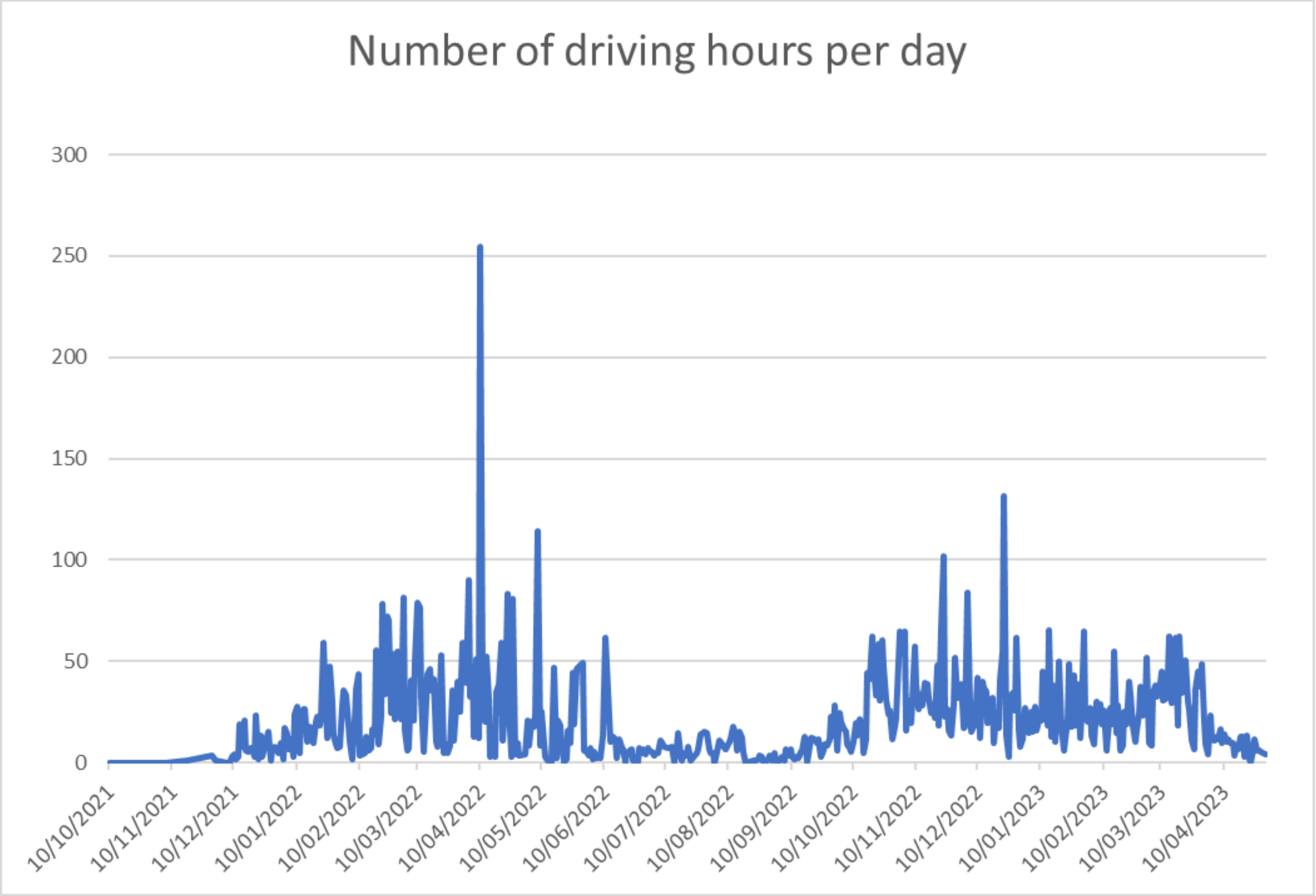
Some statistics…

Total journeys:
14 618



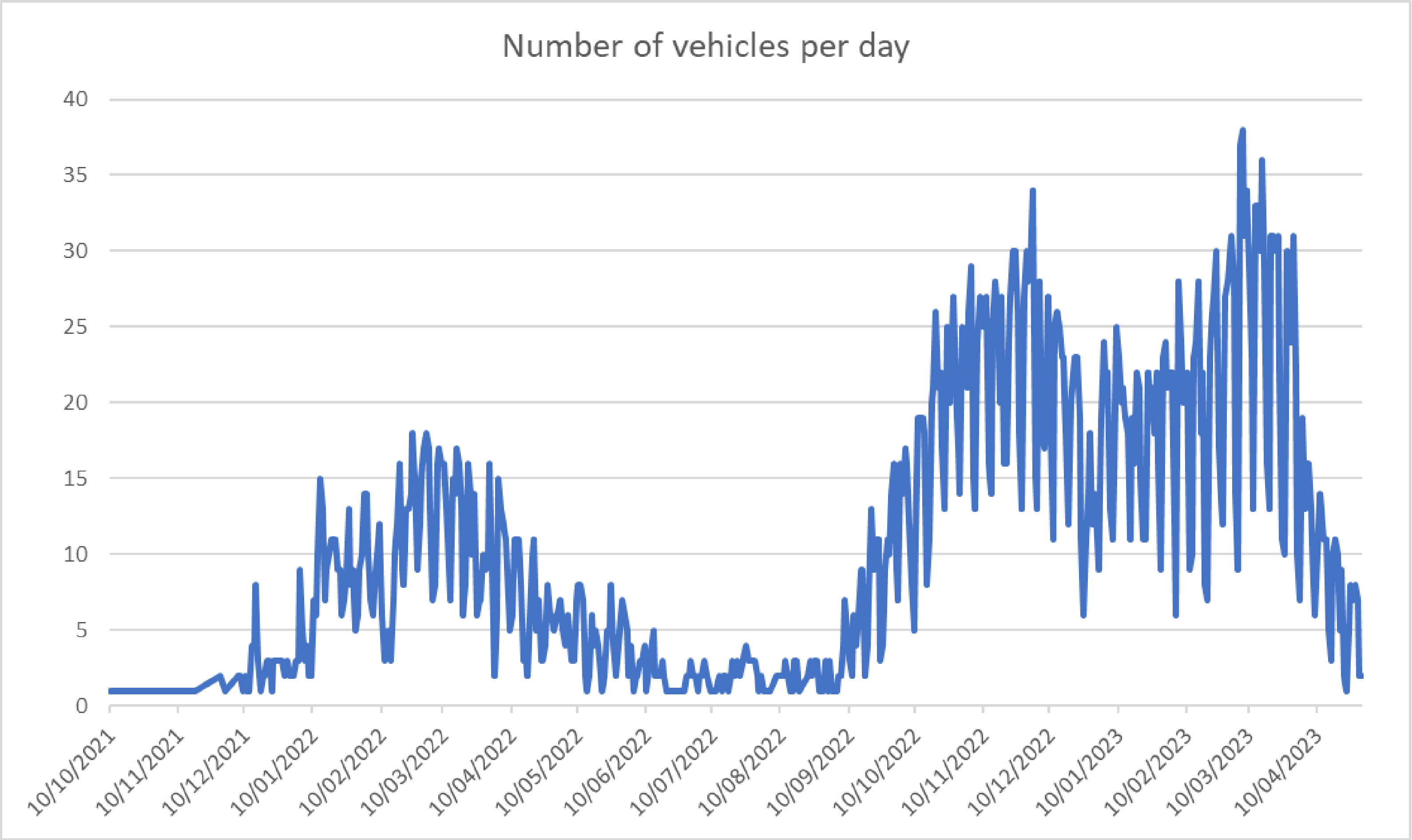
Some statistics…

Peak: **250 hours** recorded in a day



Some statistics...

Total vehicles:
359



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Users' feedback

1. **Data transfer** and **connectivity** not easy to manage from an end-user perspective.
   - Multiple countries, with connectivity constraints, and asynchronous data transfer.
   - Solution: more flexibility in the configuration of the mobile app, but difficult to manage.
2. **OBD integration**.
   - Not all PIDs are available
   - Difficult for the end-users to manager an additional device.
   - Solution (not implemented): rely on car manufacturer data solutions.
3. **Start** and **stop** of the mobile app.
   - Users are forgetting
   - Solution: implementing an automatic start/stop solution.
4. Issues with the **graphical interface** on some phones.
   - Difficult to manage all phones and OS.
5. Specific issues with **iOS**.
   - Difficult to manage all phones and OS.

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LinkedIn MODALES project

Thank you

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Scoring Algorithm Methodology

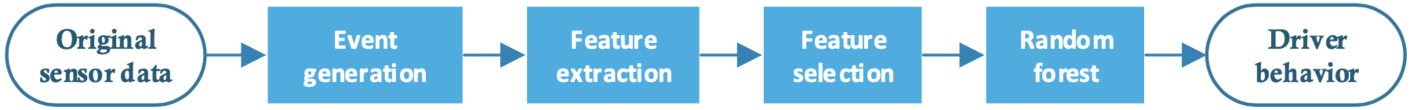
Orhan Alankuş
Istanbul Okan University

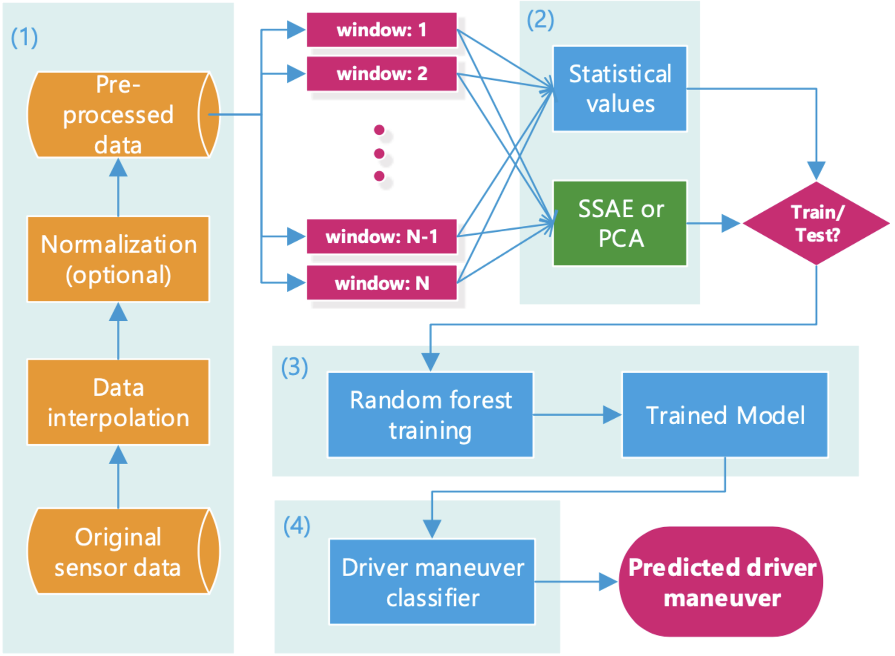
MODALES Final Conference, Brussels, 12 May 2023

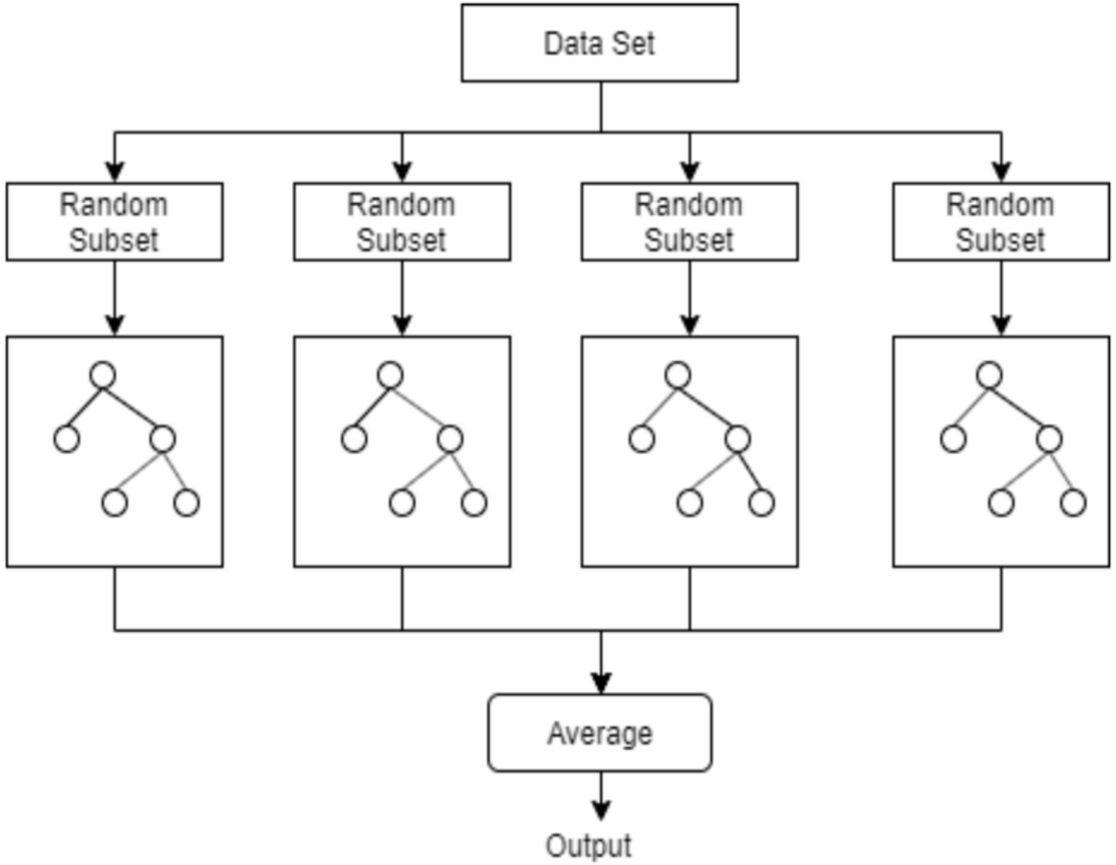
Scoring System

- An integrated system for «Driver Support Application»
- It is necessary to have a system that gives a methodology to determine the correlation between driving style and the emissions
- The emission correlations must include CO_2, NO_x and PMs including that of from tires and brakes
- Driving style parameters are selected as v.a and RPA (Relative Positive Acceleration) in line with EU regulation 2018/1832
- The system must be flexible as to be applicable for different type of vehicles and engines

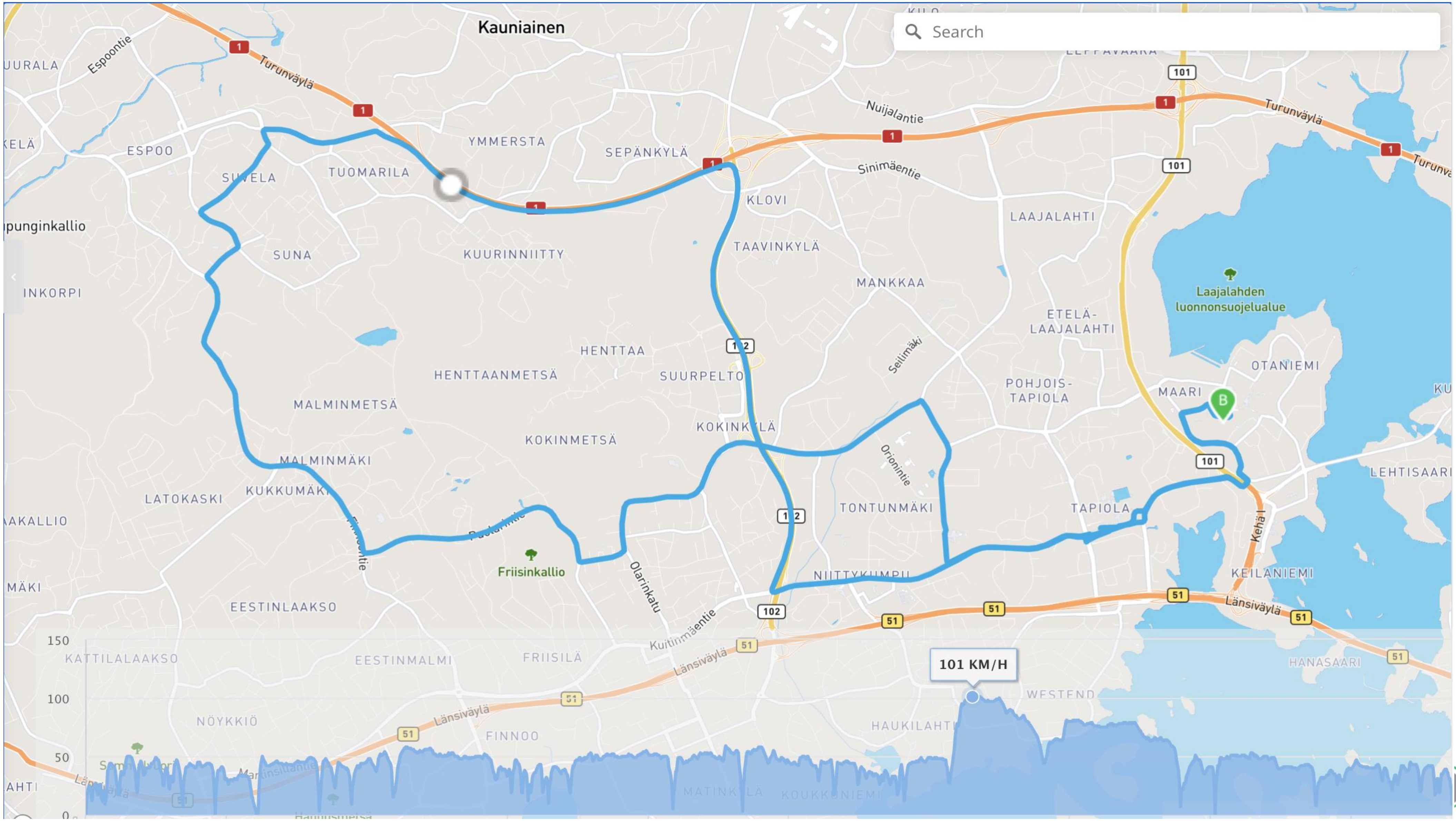
Event Detection



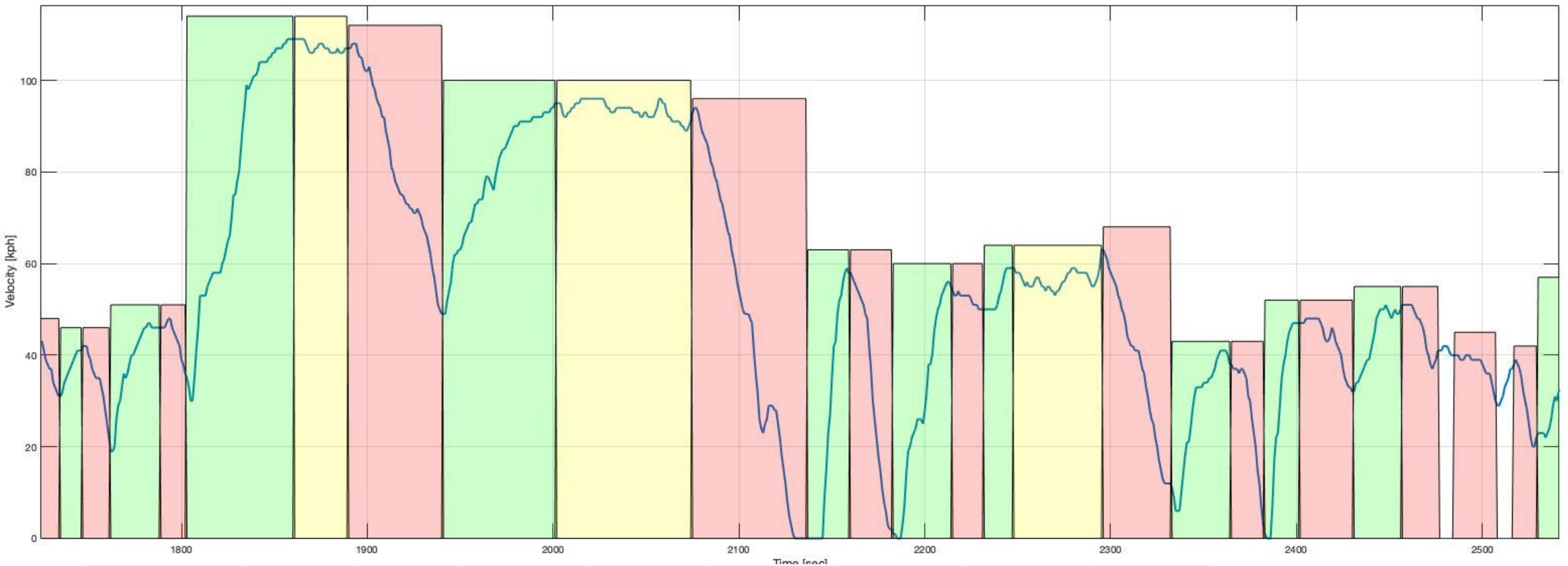




21PE060_DriverG-Run#1



21PE059_DriverG-Run#1



Distance(m)	Fuel(kg)	Nox	PM2.5	PM10	Acc Score	Brk Score	Spd Score	Total Score
30710	50%	9%	14%	27%	87	60	100	82

MC

Multi-Objective Optimization and Aggregate Emission Value

- Using Air Quality Index Standards and Cost of emissions on human health weight parameters for multi-objective optimization has been determined
- Brake and Tyre emissions are calculated and added to the PMs and training tables have been created using VTT data

Fuel consumption	NO2	PM10	PM2.5
0,50	0,09	0,14	0,27

For Brake:

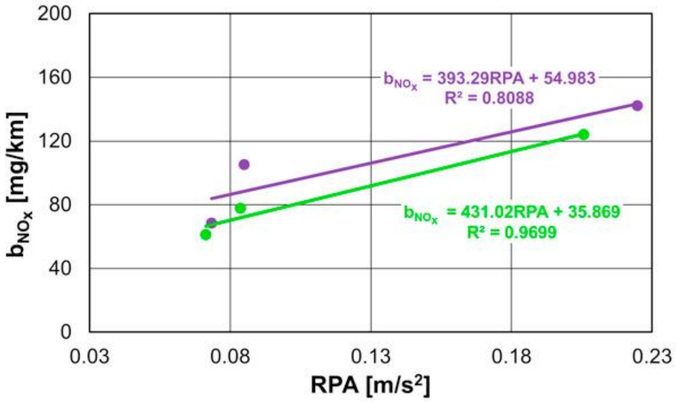
$$m = \rho V_w = \varphi K \frac{F_N \rho L}{3} = \frac{K \rho \varphi M}{6Nk}(v_1^2 - v_2^2) \quad \begin{cases} \varphi=1 & T_{pad} < 200°C \\ \varphi=1.8 & 200°C \leq T_{pad} \leq 250°C \\ \varphi=5.6 & T_{pad} > 250°C \end{cases} \quad \text{(Eq. 4-10)}$$

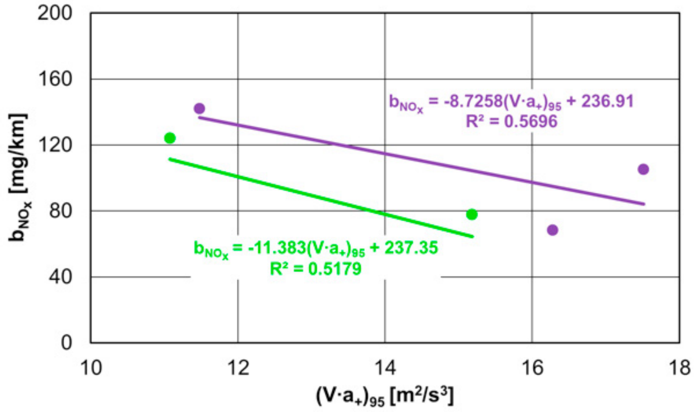
For Tyre :

$$m_T = \varphi k_1 (w)^{k_2} BD$$

$$w = \frac{P(t)}{\varphi NBL}$$

Scoring Threshold Values Through Lit. Survey and Training





Thres. (g)	Velocity (kph)												
	0	10	20	30	40	50	60	70	80	90	100	110	120
Acceleration	0.30	0.30	0.25	0.25	0.25	0.20	0.20	0.20	0.20	0.15	0.15	0.15	0.15
Deceleration	-0.50	-0.50	-0.50	-0.25	-0.25	-0.25	-0.25	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
Left Turn	0.35	0.35	0.35	0.35	0.30	0.30	0.30	0.25	0.25	0.25	0.20	0.20	0.20
Right Turn	-0.35	-0.35	-0.35	-0.35	-0.30	-0.30	-0.30	-0.25	-0.25	-0.25	-0.20	-0.20	-0.20

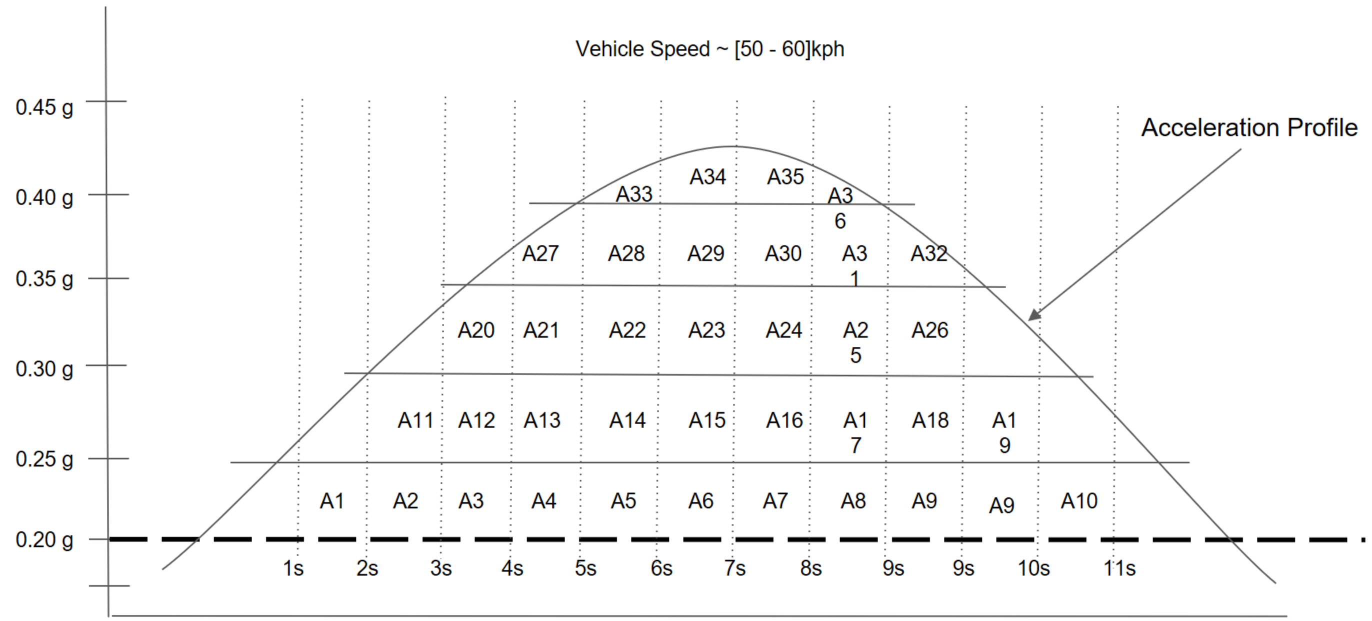
Karolina Kurtykaa, Jacek Pielechaa, “ The evaluation of exhaust emission in RDE tests including dynamic driving conditions “ (13th International Scientific Conference on Sustainable, Modern and Safe Transport (TRANSCOM 2019)

Score Calculation

```
var accCarRanges = []float64{0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50}
```

RPA Effect

Sample Threshold & Penalty Coefficient Calculation




```
var accCarFactors = [][]float64{
    {0.00, 0.00, 0.00, 3.00, 5.00, 7.00, 9.00, 12.00},      /*   0-10  penalties */
    {0.00, 0.00, 0.00, 3.00, 5.00, 7.00, 9.00, 12.00},      /*  10-20  penalties */
    {0.00, 0.00, 3.00, 5.00, 7.00, 9.00, 12.00, 15.00},     /*  20-30  penalties */
    {0.00, 0.00, 3.00, 5.00, 7.00, 9.00, 12.00, 15.00},     /*  30-40  penalties */
    {0.00, 0.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00},    /*  40-50  penalties */
    {0.00, 3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00},    /*  50-60  penalties */
    {0.00, 3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00},    /*  60-70  penalties */
    {0.00, 3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00},    /*  70-80  penalties */
    {0.00, 3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00},    /*  80-90  penalties */
    {3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00, 21.00},   /*  90-100 penalties */
    {3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00, 21.00},   /* 100-110 penalties */
    {3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00, 21.00},   /* 110-120 penalties */
    {3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00, 21.00},   /* 120-180 penalties */
}
```

Penalty Point Calculation:

Penalty Factor=(A1+A2+...+A10) * 3 + (A11+A12+...+A19) * 5 + (A20+A21+...+A26) * 7 + (A27+A21+...+A32) * 9 + (A33+A21+...+A36) * 11

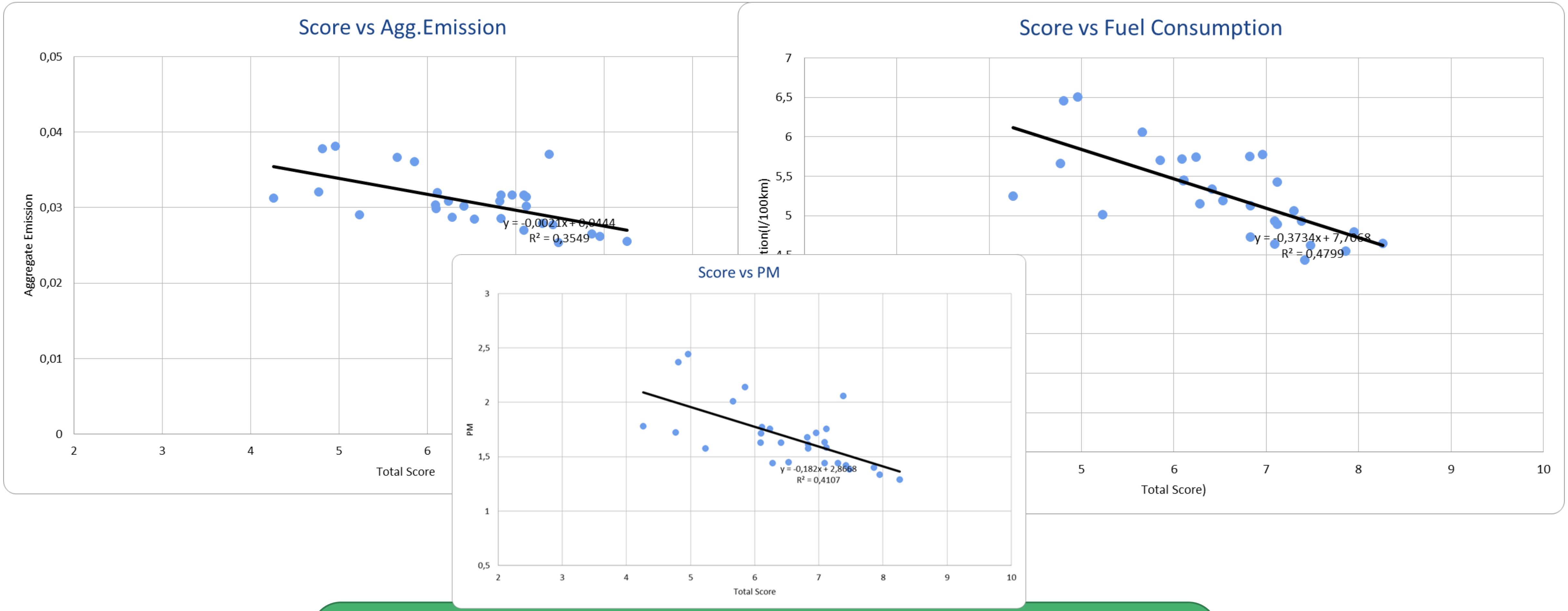
SCORE = 100-(Penalty Factor/total acceleration time)*100

Recommendation System

- GOOD_ECO_DRIVING = "You are doing pretty well.... "
- ORANGE_ACCELERATION = "You seem to accelerate quite frequently......"
- RED_ACCELERATION = "You seem to accelerate harshly or aggressively......."
- ORANGE_DECELERATION = "You seem to brake quite hard........"
- RED_DECELERATION = "You seem to brake very harshly......."
- ORANGE_SPEEDING = "Your driving is quite fast on occasions......."
- RED_SPEEDING = "Your driving is often at excessive speeds.........."

- Orange is if your score is between 70-90
- Red is if your score is less than 70

Correlations



Results show that an improvement of the score by 20% brings a reduction of 18,6% in fuel consumption, 27,8% in PMs and 23,8% in aggregate emissions for the score range given in the graphs.

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THANK YOU

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