modales

Adapting driver behaviour
for lower emissions

Naturalistic trials: Testing the app and training

Dimitri Margaritis – CERTH / HIT

With contributions from:

Andrew Winder – ERTICO

MODALES Final Conference, Brussels, 12 May 2023

Definition of user recruitment process

- Selection questionnaire
- User profile
  - All age groups
  - Different driving routines (rural areas, urban areas, motorways)
- Professional drivers were included in some trial sites
- Vehicles preferred
  - Euro 3 - 6
  - All types of fuel
- Data Privacy management
  - Consent forms
  - Local data management officers
  - Anonymised data: only local partner could identity the user

Ramp-up sites

Barcelona

- 9 users
- App as information collection module only
- No recommendation to drivers available
- No OBD
- Feedback given on aspects of the App

Luxembourg

- 10 users
- OBD + App as information collection module only
- No recommendation to drivers available
- 2nd ramp-up phase with new release of the App

Data collection tools

- MODALES App as data collection module
- OBD Dongles provided to users
- Questionnaires to users
  - Selection / Baseline Questionnaire
  - Interim questionnaire on training video
  - Final questionnaire on driver support App
- Communication channels with local partner
  - Reporting of problems, questions, comments, etc.

Publicity for trial volunteers: example

HOME NOTICIAS DIRECTORIO CALENDARIO ENLACES SUGERENCIAS

ÚLTIMAS NOTICIAS

26 marzo, 2021 Likes:5

Participa al pilot de la nova aplicació de conducció de baixes emissions

Vius a l'Àrea Metropolitana de Barcelona i vas en cotxe habitualment? Participa en el projecte Modales i contribueix a un entorn més net

25 marzo, 2021 Likes:14

Nova vacant disponible

Busquem Tècnic/a de Control de Gestió. Consulta els requisits i inscriu-te si hi estàs interessat/da!

24 marzo, 2021 Likes:30

Analitzarem la xarxa viària d'Andorra

Hem signat un acord amb el Govern d'Andorra per avaluar la xarxa principal de carreteres del país

Large–scale user trials: Phase 1, Baseline

- Equipment:
  - All participants use the App as collection module only
  - Users use an OBD dongle in test sites

- Purpose:
  - Analyse user's driving profile when do not receive any recommendation related to their driving and low emission driving training

Large–scale user trials: Phase 2 treatment

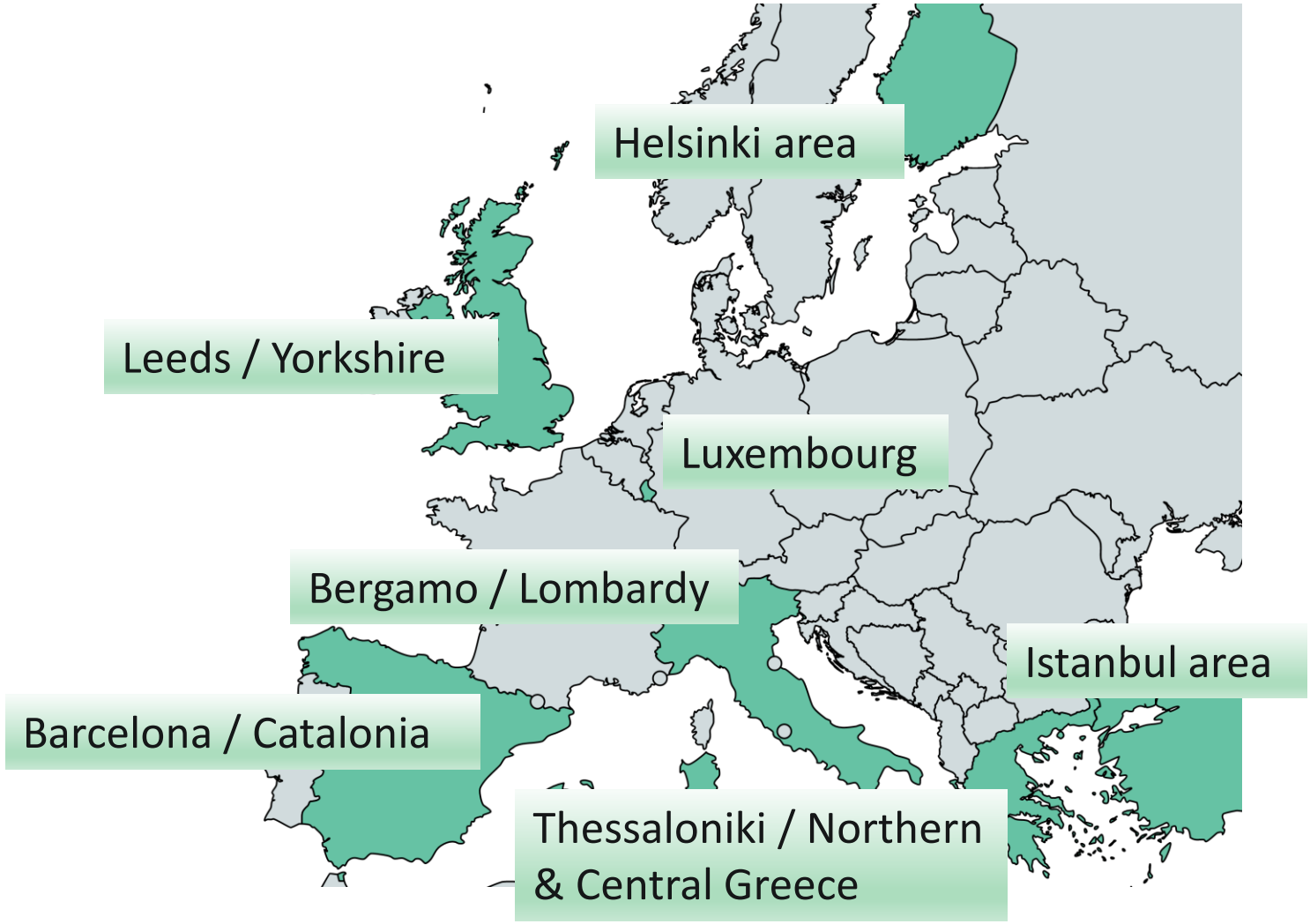
- The users are the same as in the baseline
- Equipment:
  - All participants use the updated App
  - Users used the OBD dongle
  - The App incorporated feedback to drivers
    - Active recommendations while driving
    - Passive recommendations
- Users received training tips and video developed by MODALES
- Purpose:
  - Analyse each user's driving profile when users are receiving training and recommendations on their driving profile
  - Be able to compare how the same users changed its driving profile compared to the baseline

Trial sites

Full trials in 7 European countries

Restricted trials in China
(training/awareness-raising only):

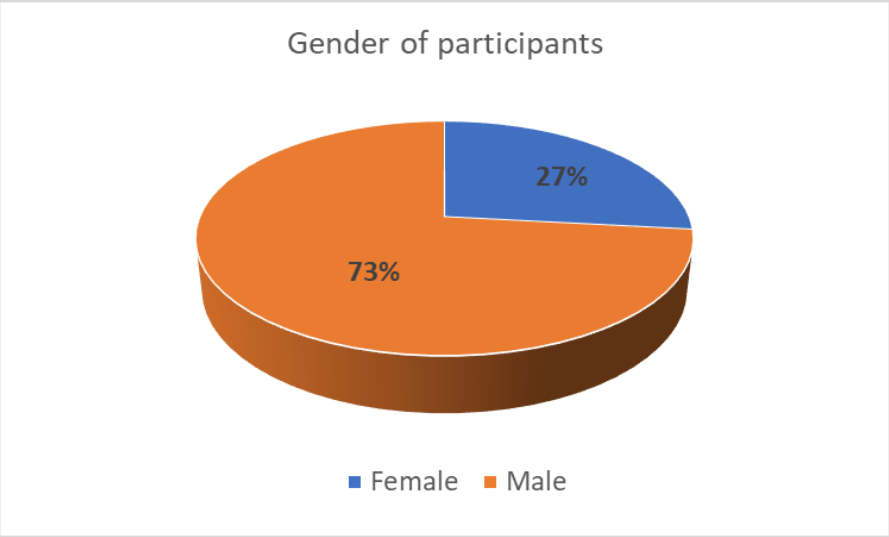
Nanjing

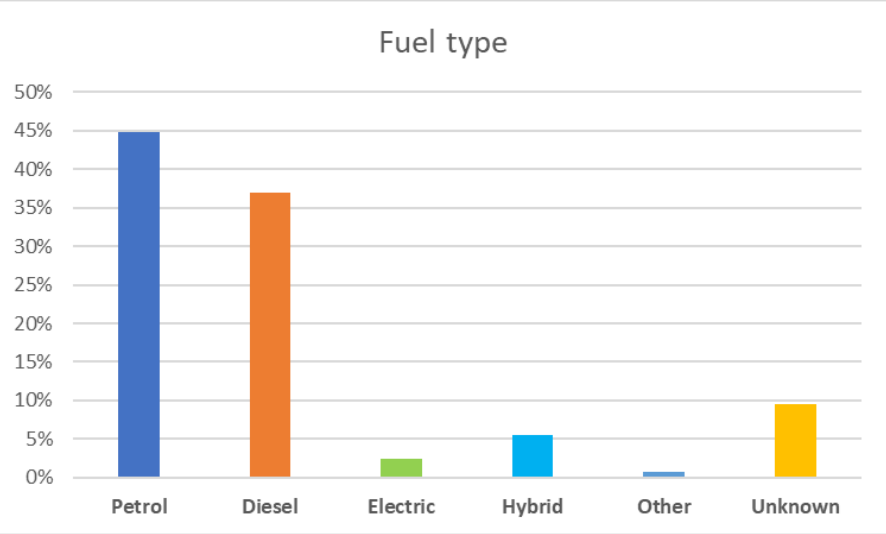


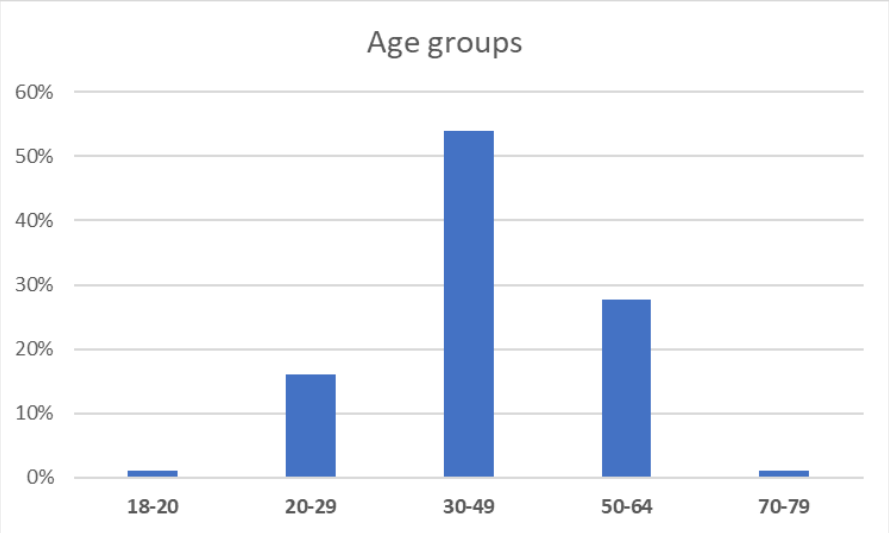
Trial site status

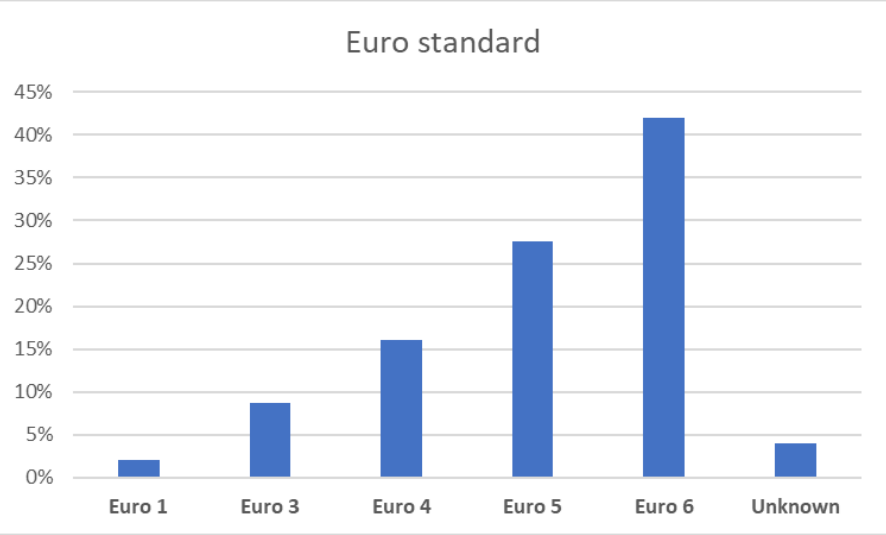
Site location	Number of participants	Specific use cases
Barcelona (ES)	26	• Logistics operator • Taxi drivers • Driving instructors • Young drivers • Coaches, refuse trucks, cleaning trucks drivers • PEMS-equipped vehicles also to be used for before and after trials on fixed route (semi-controlled trial with 2 vehicles in Helsinki)
Bergamo (IT)	11	
Helsinki (FI)	26	
Istanbul (TR)	21	
Leeds (UK)	33	
Luxembourg (LU)	19	
Nanjing (CN)	30	
Thessaloniki (GR)	14	

User/vehicle trial statistics









User trials in China (1/2)

- Background
  - Issues with using the MODALES apps to collect data in China
    - Problem with accessing Google Play Store directly
    - Limited numbers of IOS users
    - Strict rules for cross-border data transfer
- Mitigation plan
  - Used data from questionnaires to assess behavioural changes before/after low emission training
  - Accessed driving data through an online platform

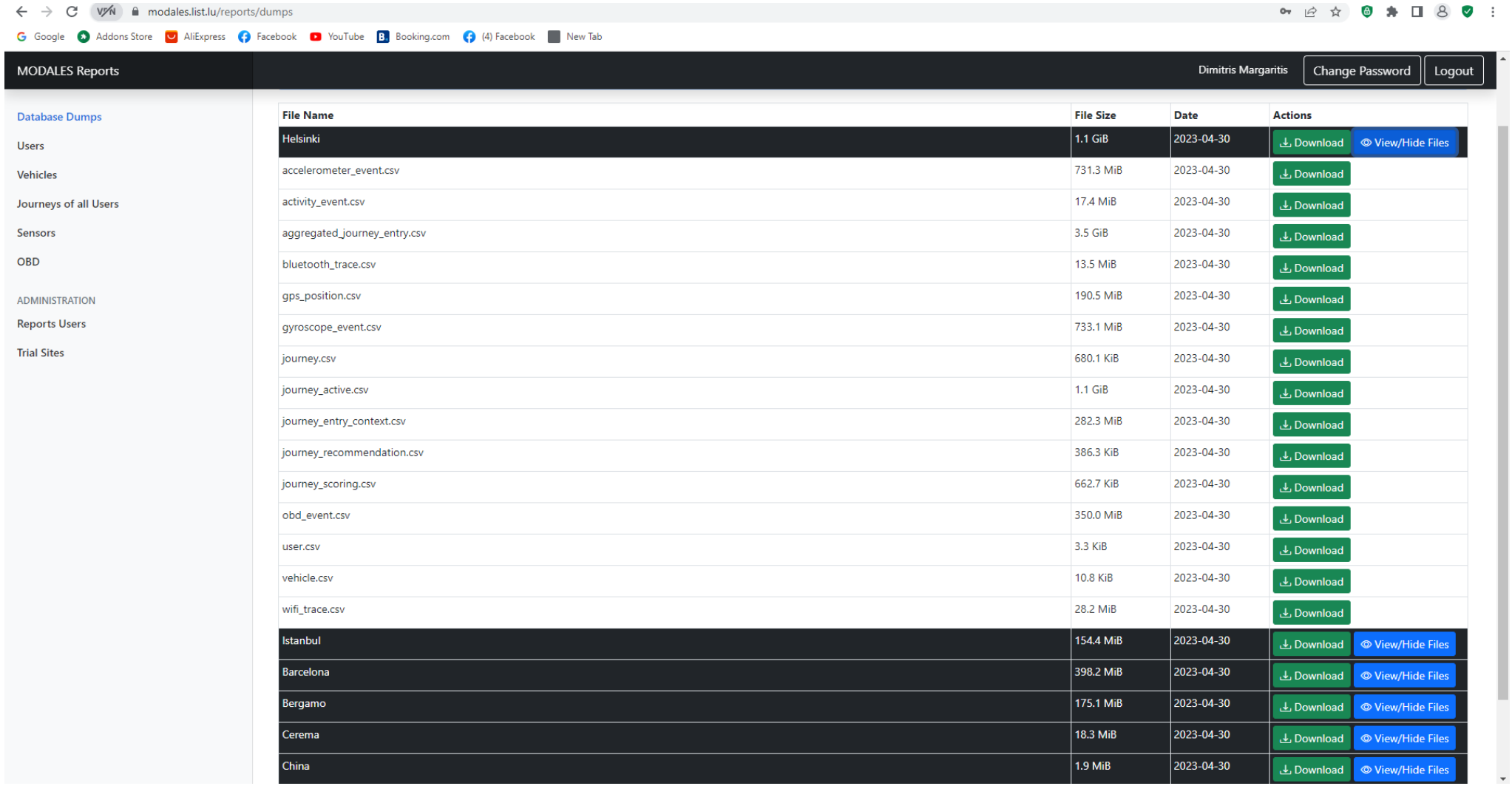
User trials in China (2/2)

- 30 HDVs and drivers

- Type of vehicles:
  - Euro 5 and newer
  - 28 diesel & 2 hybrid

- Driving data collected from:
  - Nanjing Heavy Duty Diesel Vehicle OBD Remote Online Monitoring platform

Monitoring the data collection status



File Name	File Size	Date	Actions
Helsinki	1.1 GiB	2023-04-30	Download, View/Hide Files
accelerometer_event.csv	731.3 MiB	2023-04-30	Download
activity_event.csv	17.4 MiB	2023-04-30	Download
aggregated_journey_entry.csv	3.5 GiB	2023-04-30	Download
bluetooth_trace.csv	13.5 MiB	2023-04-30	Download
gps_position.csv	190.5 MiB	2023-04-30	Download
gyroscope_event.csv	733.1 MiB	2023-04-30	Download
journey.csv	680.1 KiB	2023-04-30	Download
journey_active.csv	1.1 GiB	2023-04-30	Download
journey_entry_context.csv	282.3 MiB	2023-04-30	Download
journey_recommendation.csv	386.3 KiB	2023-04-30	Download
journey_scoring.csv	662.7 KiB	2023-04-30	Download
obd_event.csv	350.0 MiB	2023-04-30	Download
user.csv	3.3 KiB	2023-04-30	Download
vehicle.csv	10.8 KiB	2023-04-30	Download
wifi_trace.csv	28.2 MiB	2023-04-30	Download
Istanbul	154.4 MiB	2023-04-30	Download, View/Hide Files
Barcelona	398.2 MiB	2023-04-30	Download, View/Hide Files
Bergamo	175.1 MiB	2023-04-30	Download, View/Hide Files
Cerema	18.3 MiB	2023-04-30	Download, View/Hide Files
China	1.9 MiB	2023-04-30	Download, View/Hide Files

MODALES training video

Car driver (15 mins)

- Soundtrack: English, French, Italian, Spanish
- Subtitled: Finnish, Greek, Turkish, Chinese

Taxi and LDV driver (15 mins)

- Soundtrack: English. Subtitled: Chinese

HDV driver (15 mins)

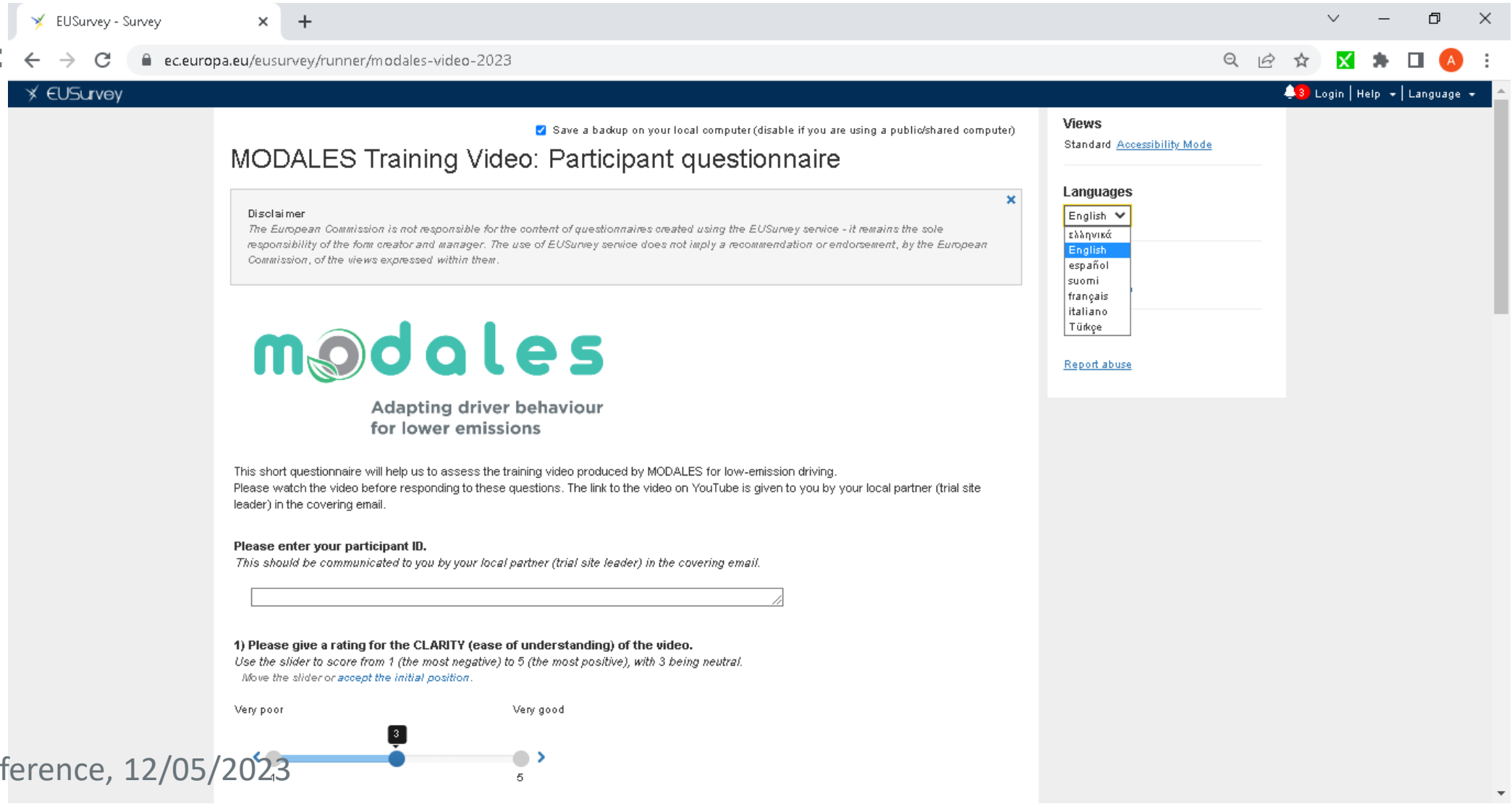
- Soundtrack: English. Subtitled: Chinese

Feedback from the MODALES training video

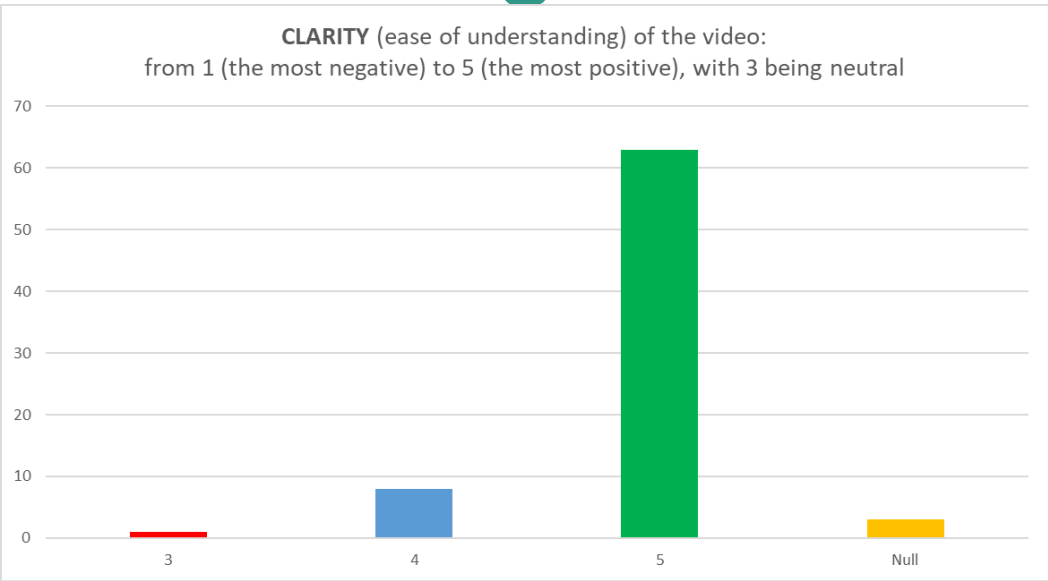
Short online questionnaire (7 questions) https://ec.europa.eu/eusurvey

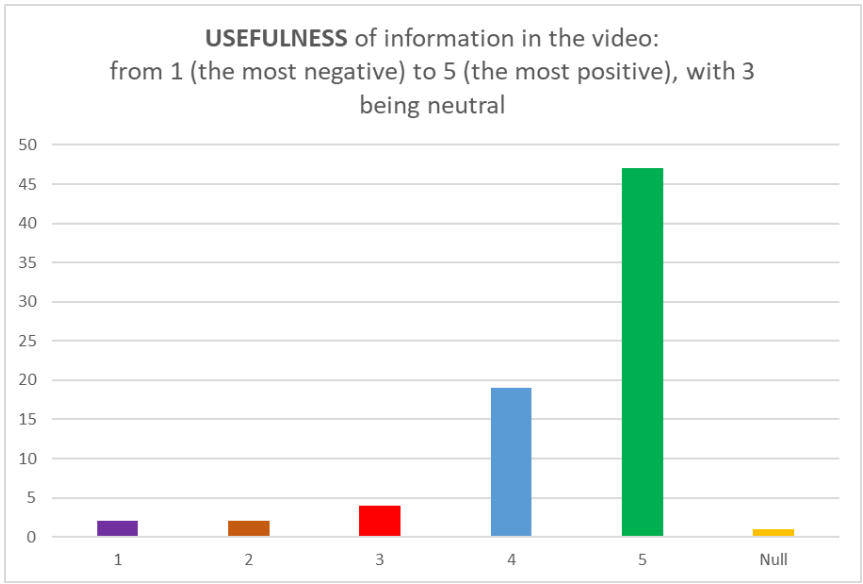
82 respondents:

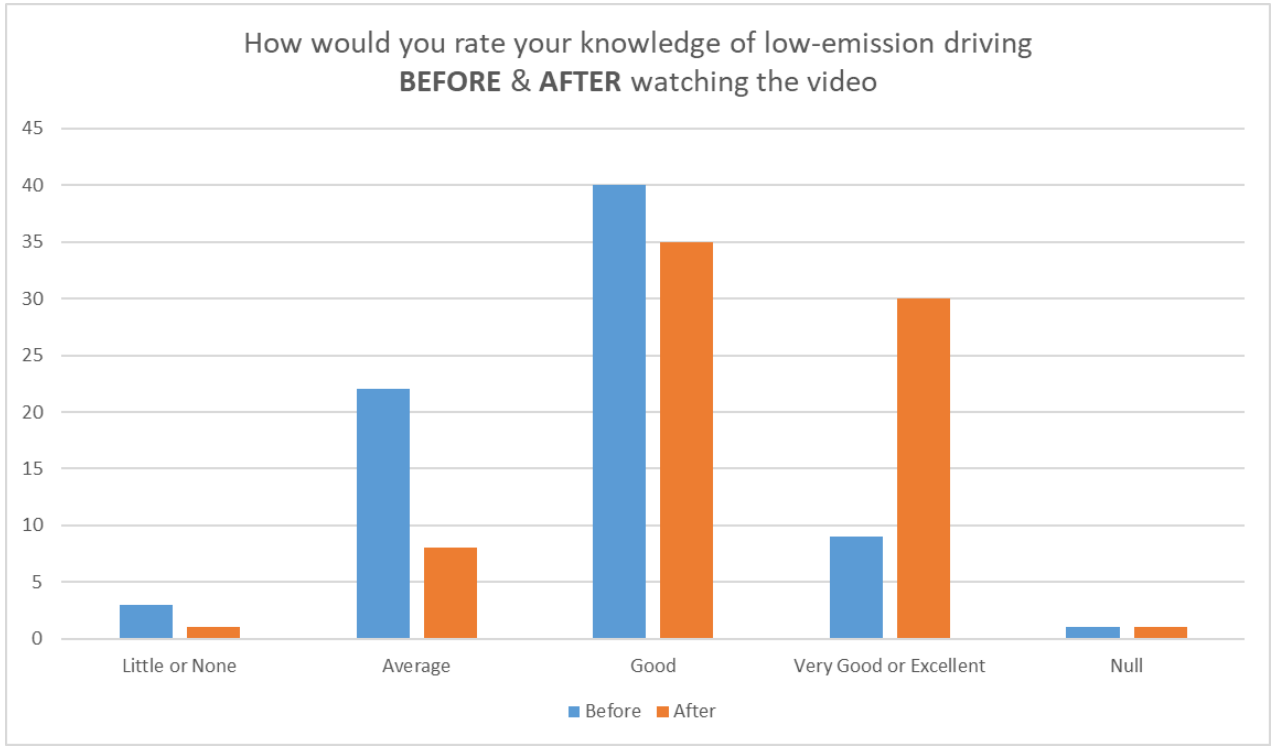
- CN: 20
- ES: 9
- FI: 11
- GR: 12
- IT: 9
- LU: 5
- TR: 8
- UK: 8



Training Video: assessment results







Adapting driver behaviour for lower emissions

www.modales-project.eu

MODALES project

Thank you

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Adapting driver behaviour for lower emissions

Trial results

Prof Haibo Chen – Institute for Transport Studies, University of Leeds (LEEDS)

With contributions from the partners of the following trial sites:

Leeds: Dr Ye Liu, Dr Said Munir – LEEDS

Istanbul: Prof Orhan Alankus, Dr Sina Alp – OKAN

Bergamo: Dr Mara Leonardi – Brembo

Luxembourg: Cindy Guerlain, Dr Sébastien Faye – LIST

Helsinki: Rasmus Pettinen – VTT

Barcelona: Christoph Vollath – RACC

Thessaloniki: Dimitris Margaritis – CERTH

Nanjing: Dr Ying Li – DYNN; Prof Tiezhu Li – SEU

MODALES Final Conference, Brussels, 12 May 2023

Aim & Objectives

- *Q1: Did the MODALES low-emission training and education change the driving behaviours of the participants?*
- *Q2: What KPIs were used to measure the behavioural change?*
- *Q3: What were the influencing factors that affected the change?*

Were the trial results reliable / representative (i.e. was the observed change consistent with drivers' perceived change)?

- Sources of uncertainty: poor data quality (e.g. accuracy, adequacy), wrong data selection/pre-processing methods, wrong users!

Main criteria for data selection/pre-processing

- No negative or zero speeds;
- Quality assurance of phase 2 data first (phase 2 << phase 1);
- Exclusion of users who didn't generate any data in phase 2;
- Like-for-like journeys from both phases (i.e. the same route with similar travel time, cross-correlation/convolution for part of the journey).

- Suitable for limited data available, in terms of the number of journeys, total travel distance, total travel time.

Driving behaviour KPIs, influencing factors and emissions calculation

- ***Main parameters & KPIs related to driving behaviour, based on WP3:***

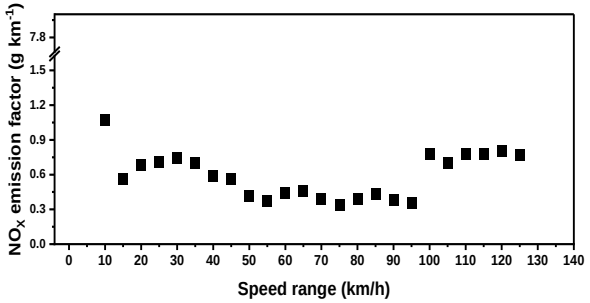
Emission	Parameters	KPIs
Exhaust	Acceleration	% of >0.9 m/s^2 or upper quartile of the site-specific baseline, average
	Speed	% of outside 20~50 km/h, average
Brake	Deceleration of braking	% of >1.0 m/s^2 or upper quartile, average
	Initial speed	upper quartile, average
Tyre	Acceleration	% of outside -1.0 m/s^2 ~ +0.9 m/s^2, average
	Acceleration on a curve	% of outside -1.0 m/s^2 ~ +0.9 m/s^2, average
	Initial speed	upper quartile, average
Combined	Journey score	Distribution, average, % extreme scores etc

- ***Influencing factors:*** road type, user type, vehicle type, gender, age, experience *etc*.
- ***Emissions:*** calculated using the equations (or emission factors) derived in WP3, and new score-emission corelation equation developed by Okan

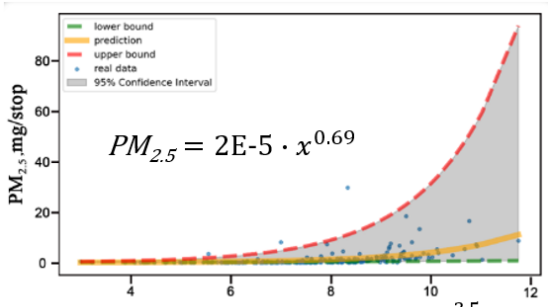
How did we calculate exhaust and non-exhaust emissions from driving behaviour KPIs?

Driving behaviour to exhaust emissions

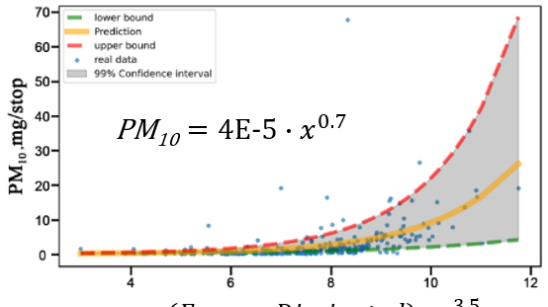
Speed range (km/h)	$a > 0.9$ m/s² (%)	NOx
5-10	x%	1.08+23.59(x-0.03)
10-15	x%	0.57 +12.37(x-0.03)
15-20	x%	0.69 +15.05(x-0.03)
….		
120-125	x%	0.77 +16.80(x-0.03)
>125	x%	0.79 +17.24(x-0.03)



Driving behaviour to brake wear



$$x = (Energy\ Dissipated) \cdot v_1^{3.5}$$

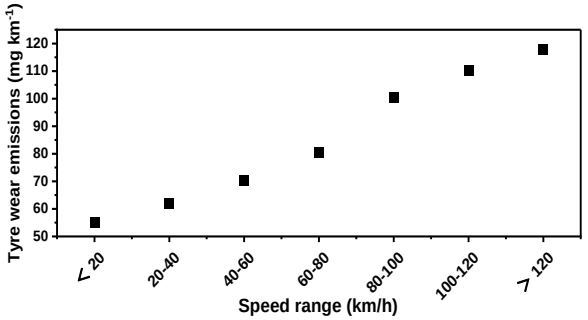


$$x = (Energy\ Dissipated) \cdot v_1^{3.5}$$

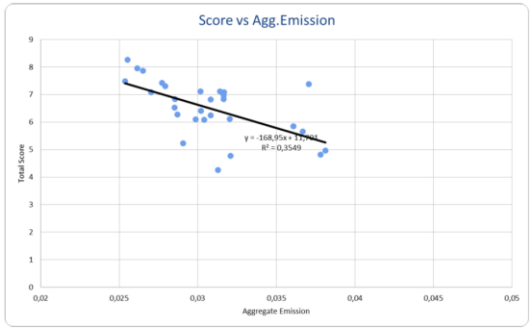
$$Energy\ Dissipated = \frac{1}{2} m(v_1^2 - v_2^2)$$

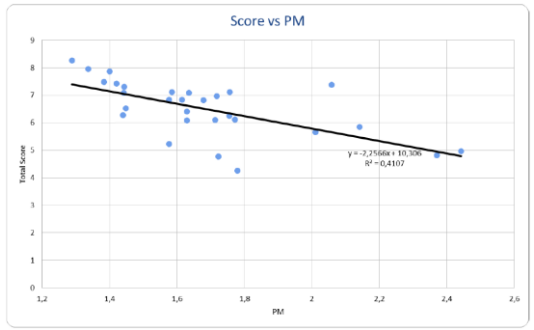
Driving behaviour to tyre wear

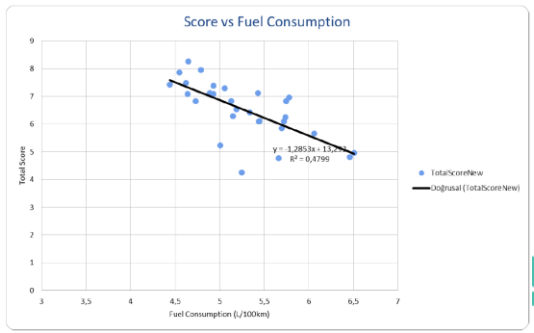
Speed range (km/h)	Average a (m/s²)	Tyre wear
<20	x	55.11+272.8(x-0.2)
20-40	x	61.93 +306.6(x-0.2)
40-60	x	70.33 +348.1(x-0.2)
….		
100-120	x	117.9 +583.7(x-0.2)
>120	x	124.9 +618.3(x-0.2)



Journey scores to combined emissions







Data is analysed by:

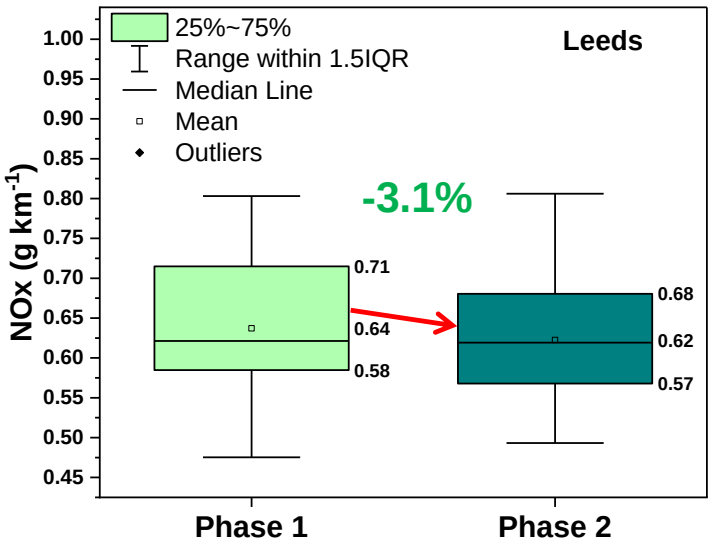
- …road type (3)
- …emission type (4)
- …site (8 countries)
- …driving behaviour KPI (>5)
- …air pollutant (>3)
- …vehicle type (4)
- …user type (3)

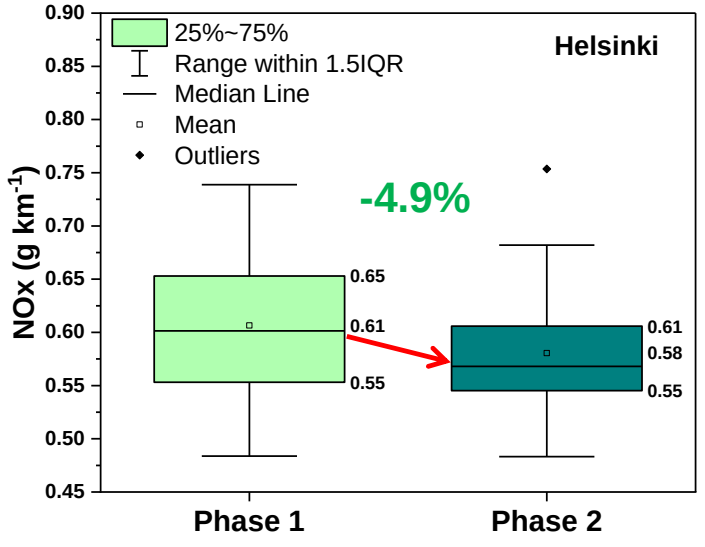
Large number of figures or tables

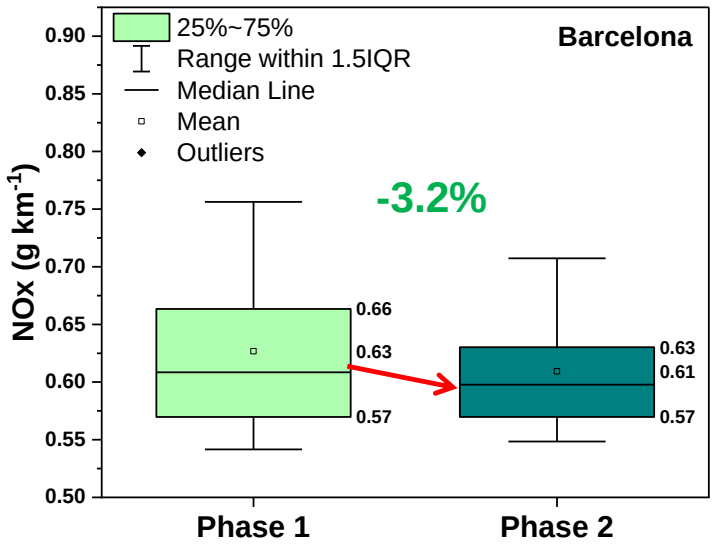
- … vehicle age
- … user age, experience, gender etc.

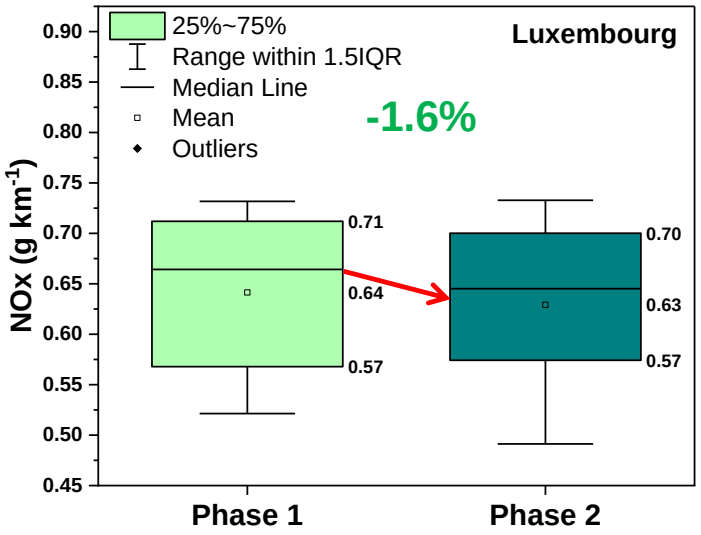
Today's presentation focuses on main findings & top-level issues.

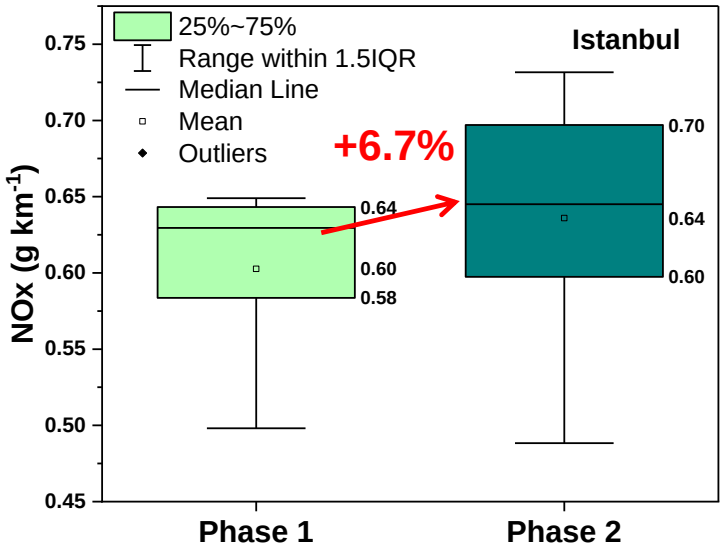
Exhaust emissions – before and after training

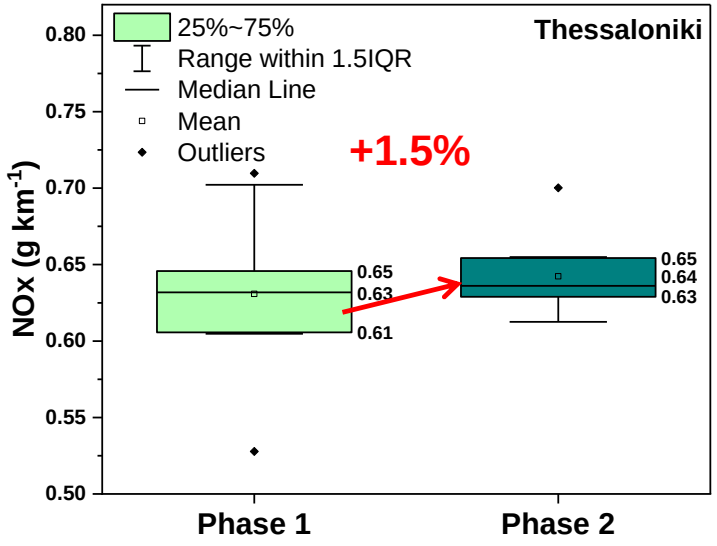








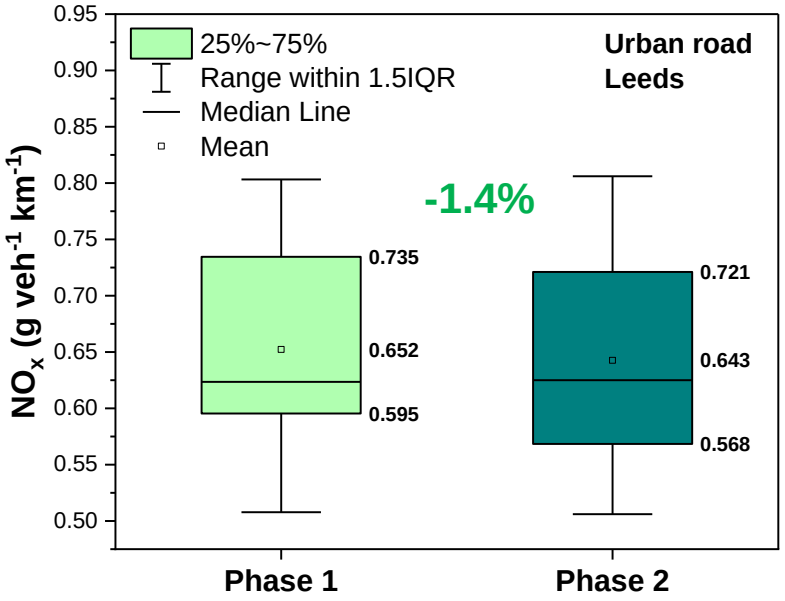


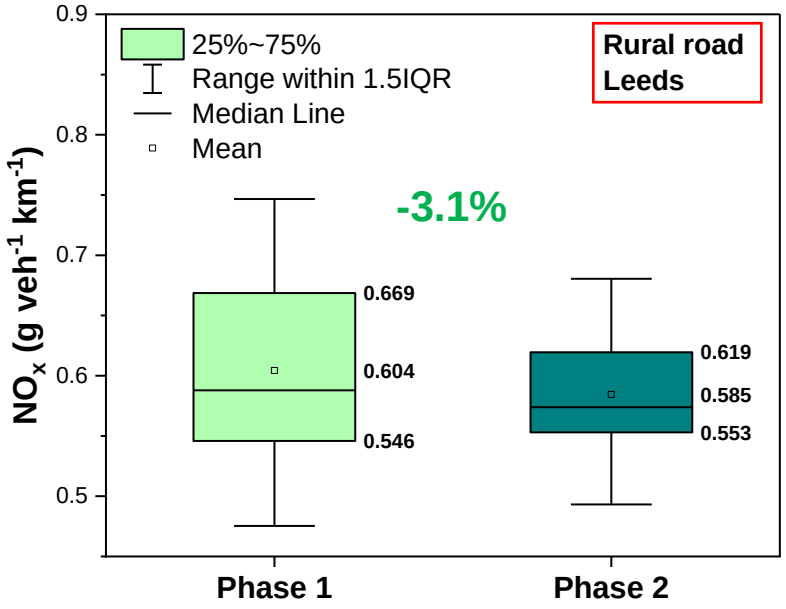


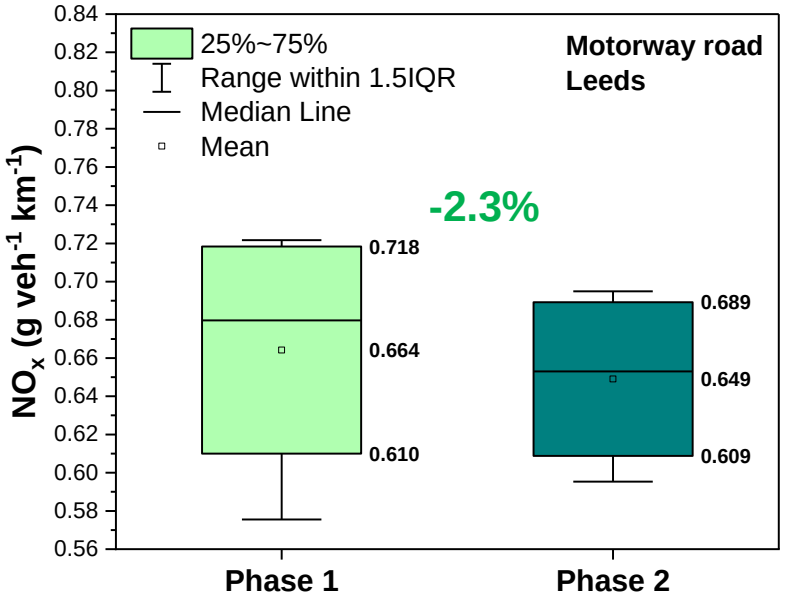
Exhaust emissions (NO_x) – best vs worst performance

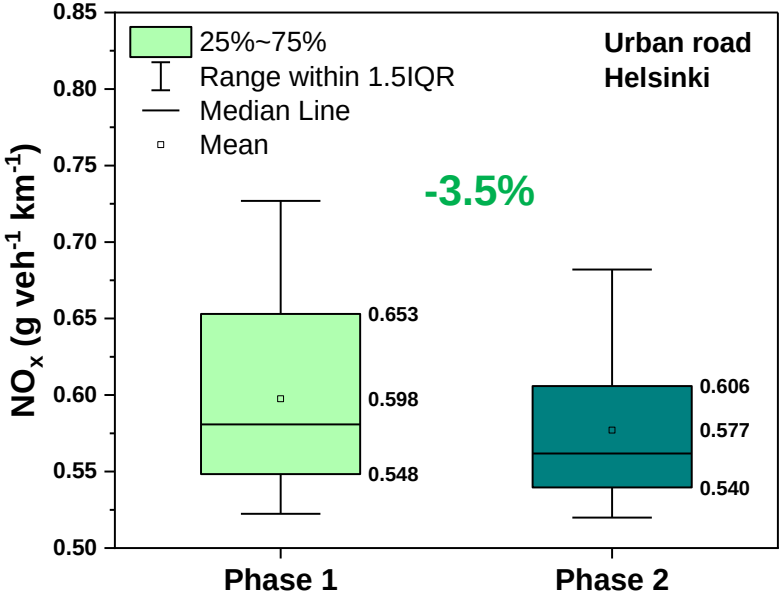
Site	Best	Worst
Leeds	-6.1%	+2.3%
Helsinki	-10.9%	+2.9%
Barcelona	-4.9%	0.0%
Luxembourg	-4.5%	+2.9%
Istanbul	-1.8%	+7.0%
Thessaloniki	-1.8%	+6.0%

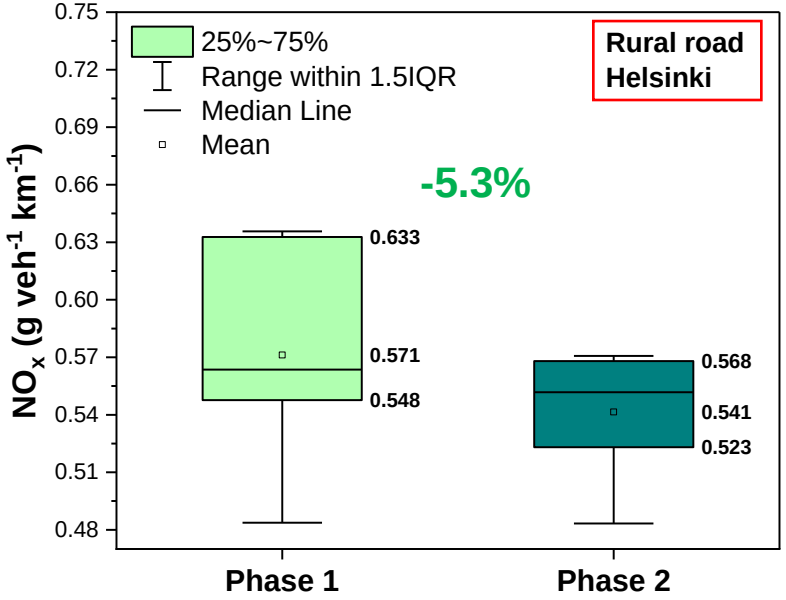
Exhaust emissions – by road type

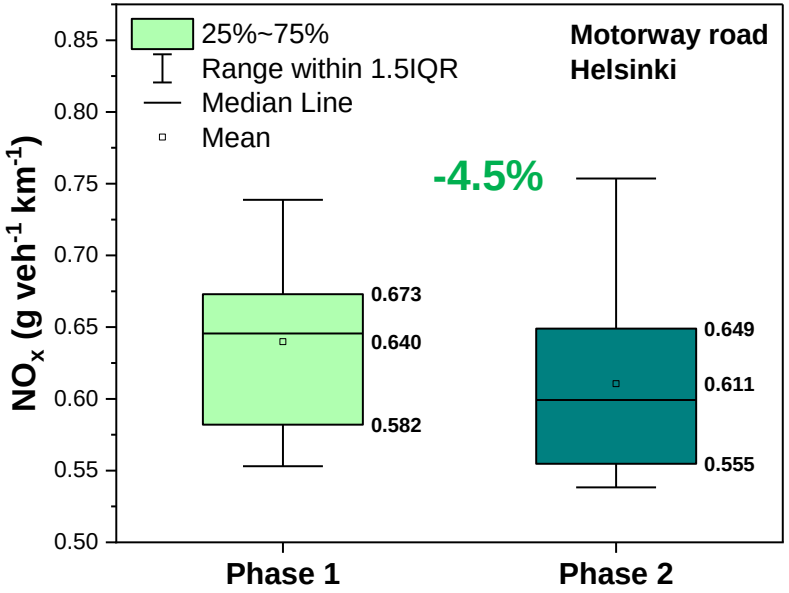




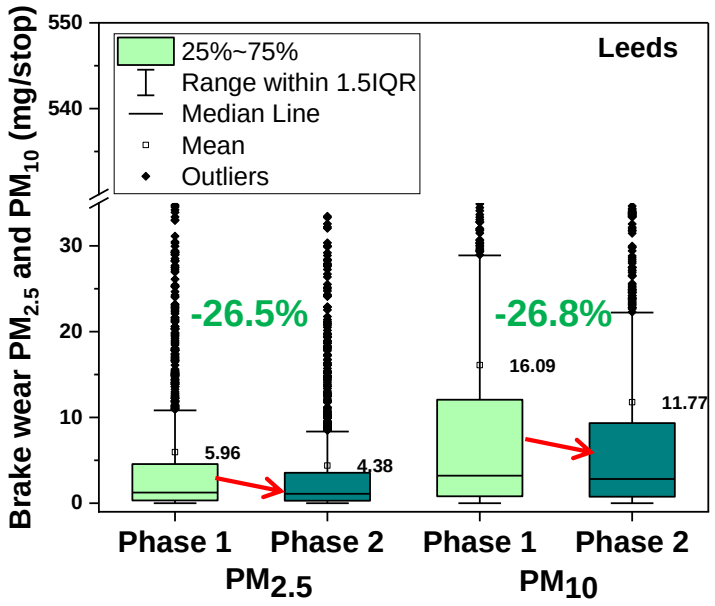


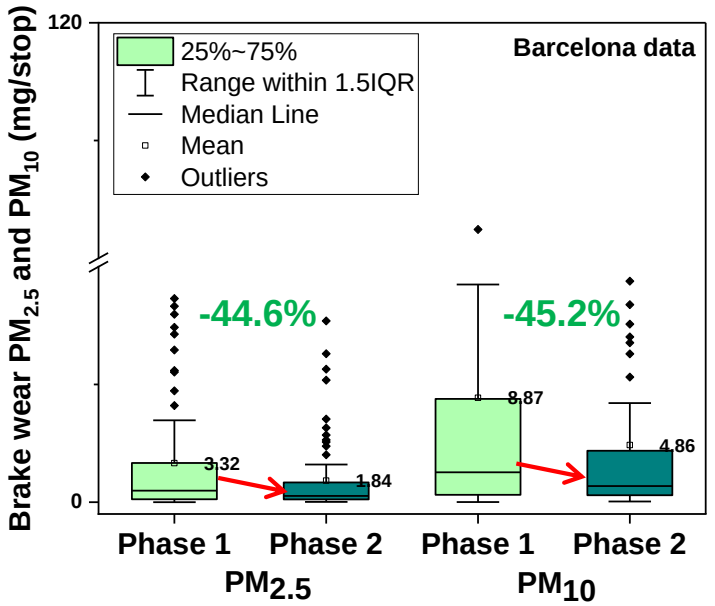


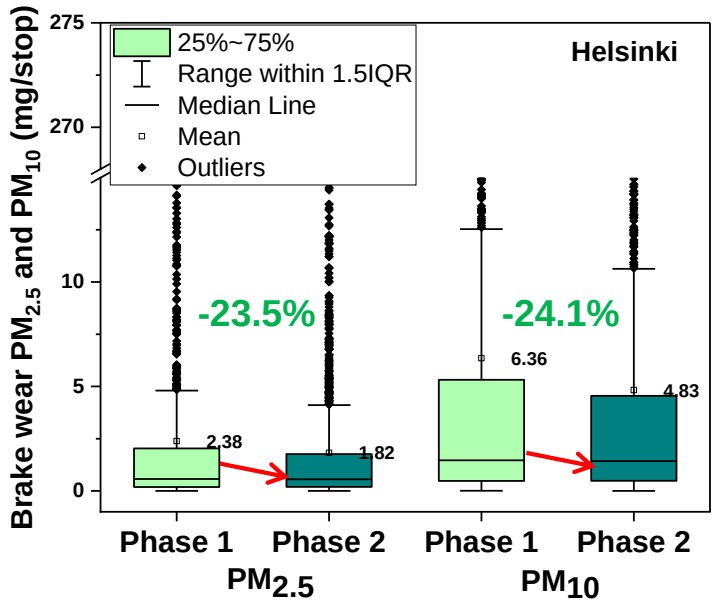


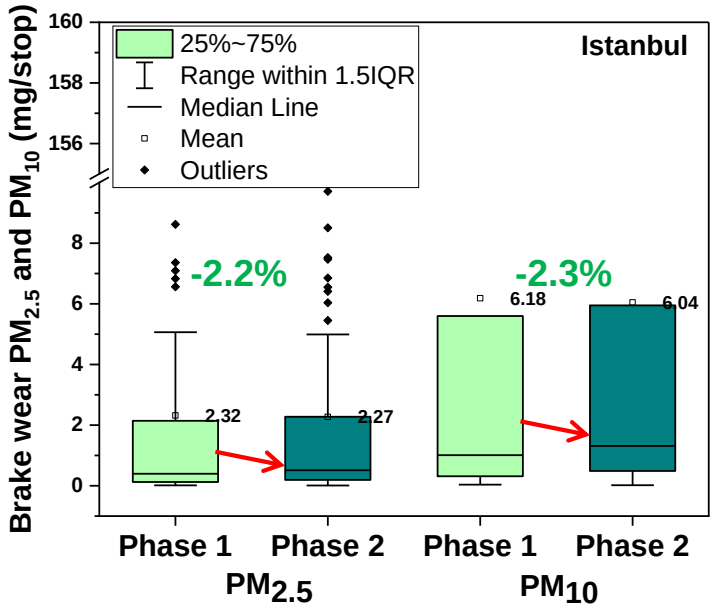


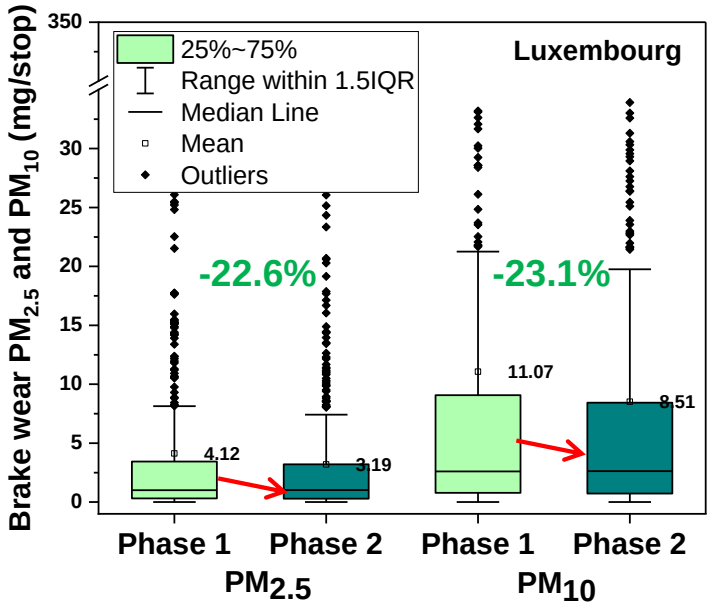
Brake wear ($PM_{2.5}$, PM_{10}) – before and after training

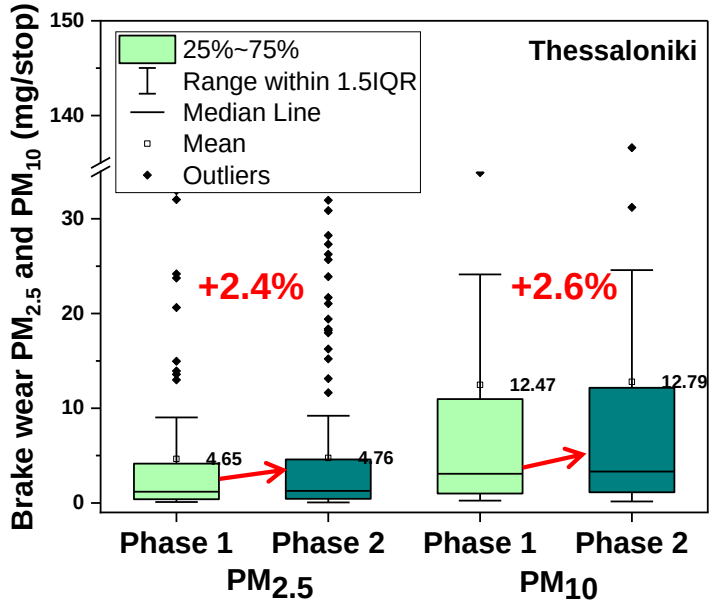








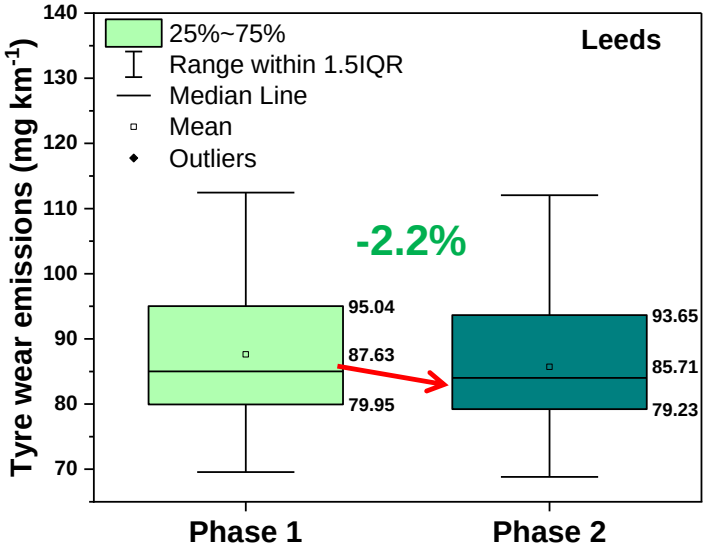


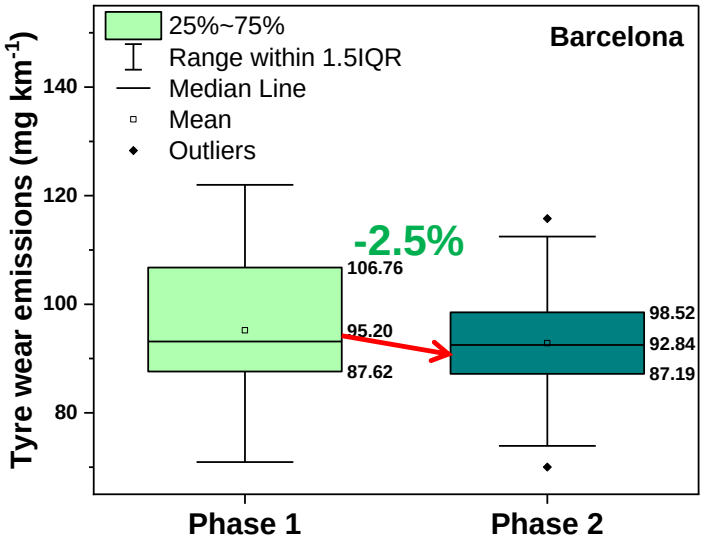


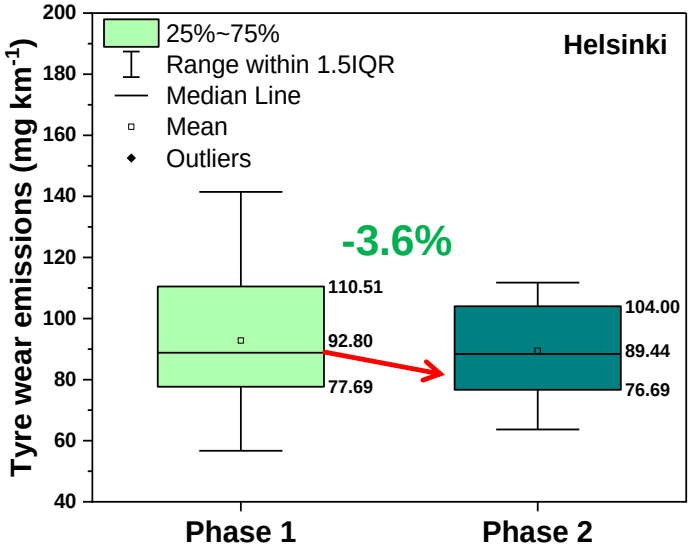
Brake wear ($PM_{2.5}$) – best vs worst performance

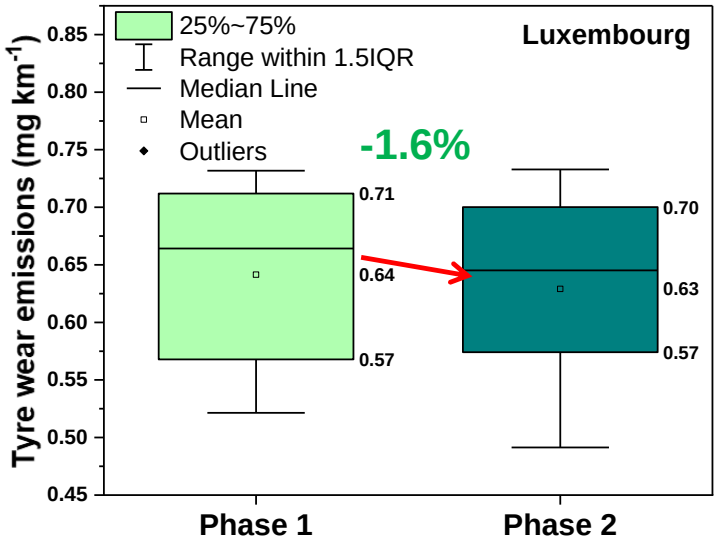
Site	Best	Worst
Leeds	-41.3%	-7.1%
Helsinki	-64.4%	-10.0%
Barcelona	-31.4%	-7.6%
Luxembourg	-36.0%	-3.3%
Istanbul	-37.8%	-1.3%
Thessaloniki	-33.8%	+4.8%

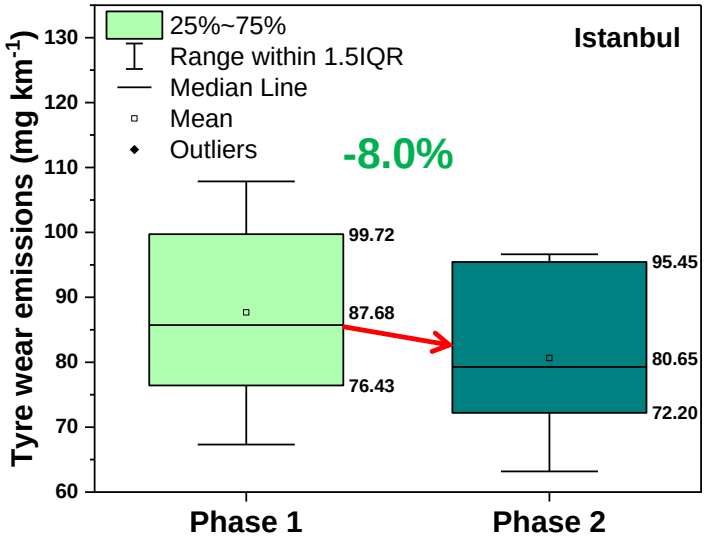
Tyre wear – before and after training

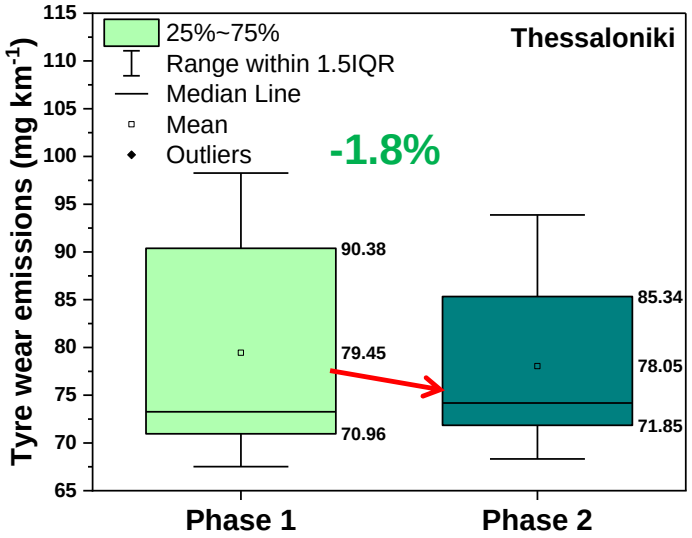








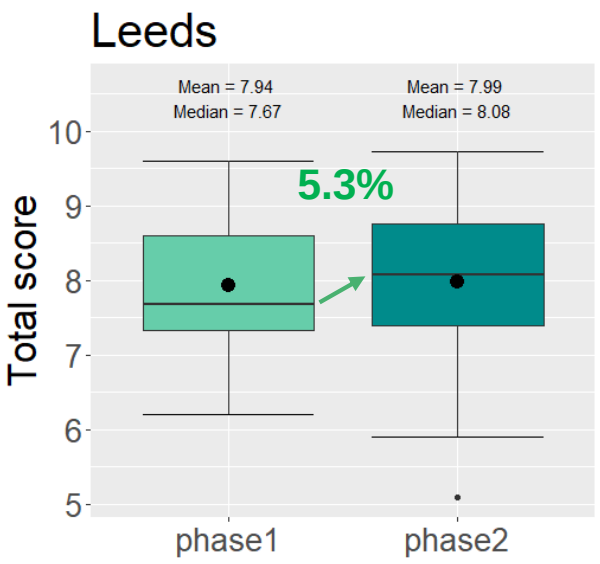


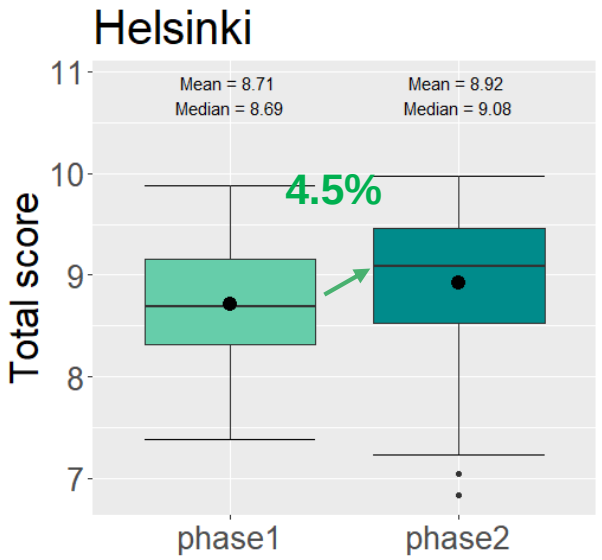


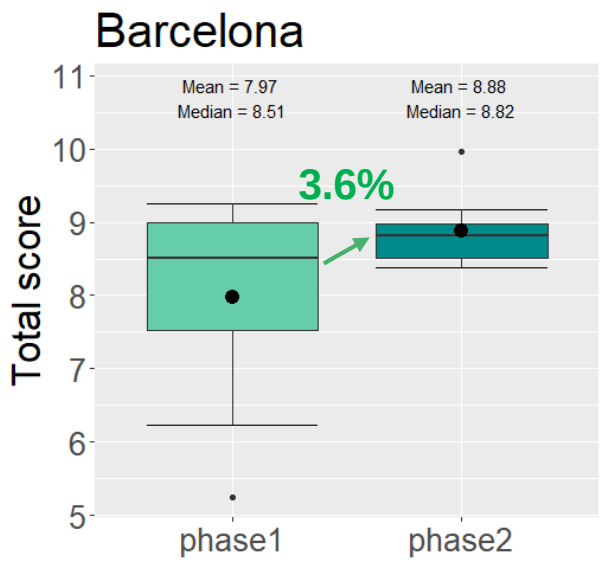
Tyre wear (mg/km) – best vs worst performance

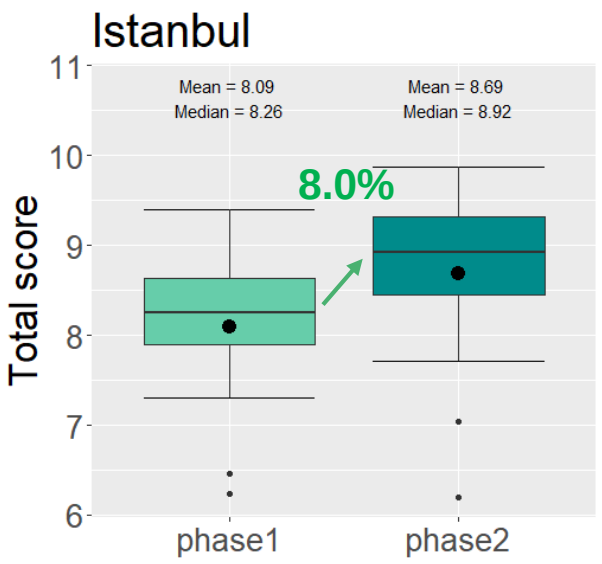
Site	Best	Worst
Leeds	-6.0%	+2.3%
Helsinki	-14.9%	+4.4%
Barcelona	-7.1%	+1.7%
Luxembourg	-5.5%	+1.2%
Istanbul	-11.3%	-4.5%
Thessaloniki	-4.2%	+0.2%

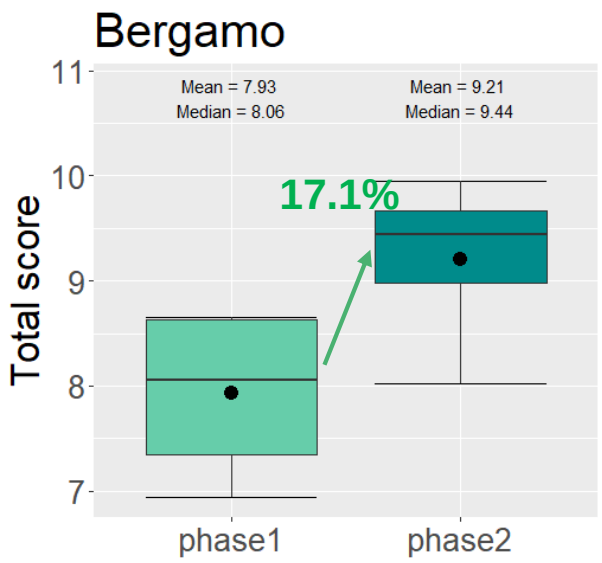
Combined emissions vs journey scores

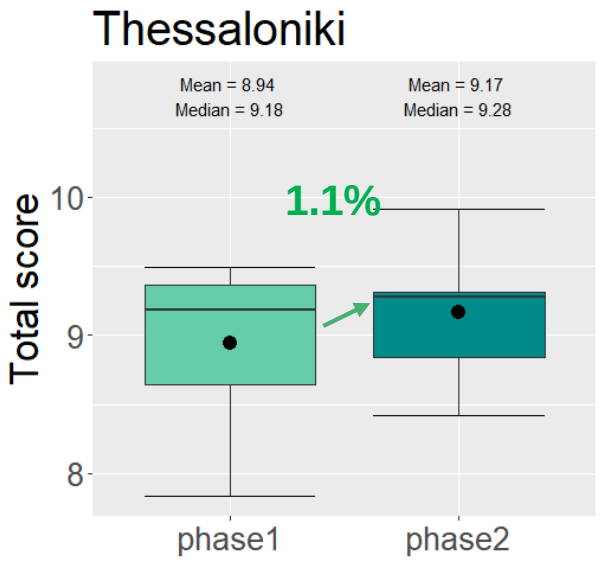


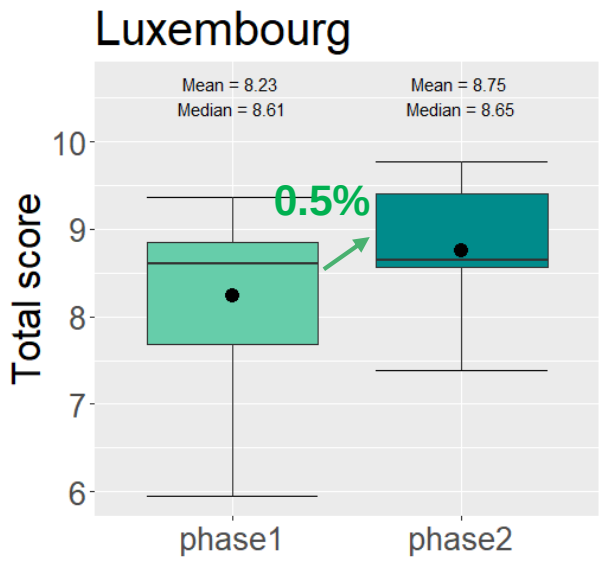












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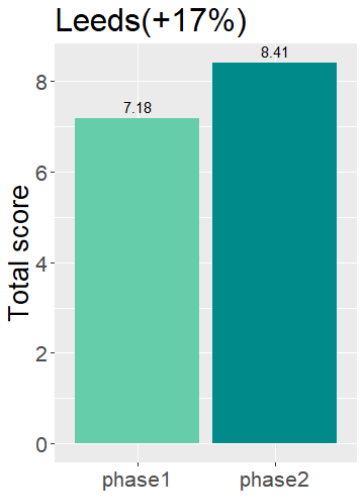
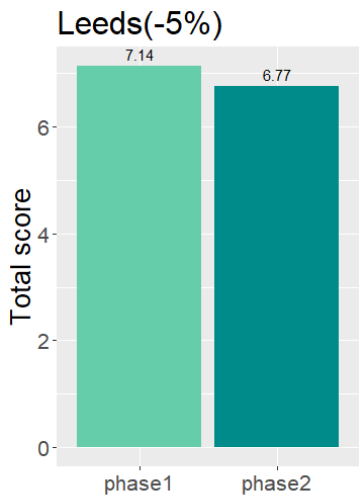
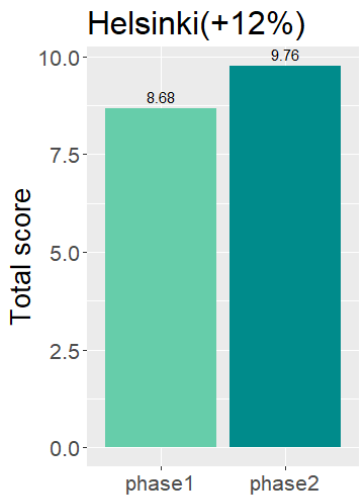
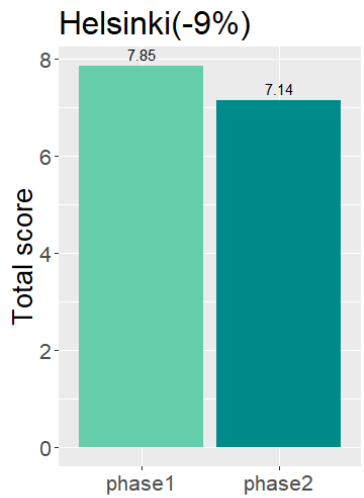
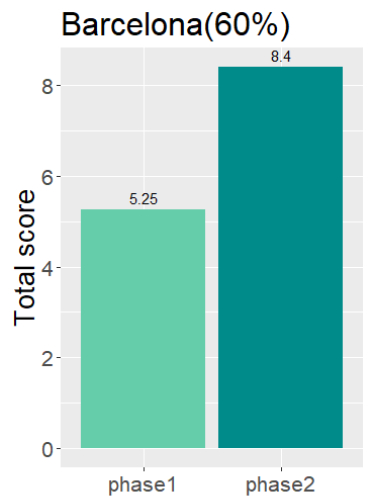
Combined emissions – best vs worst performance

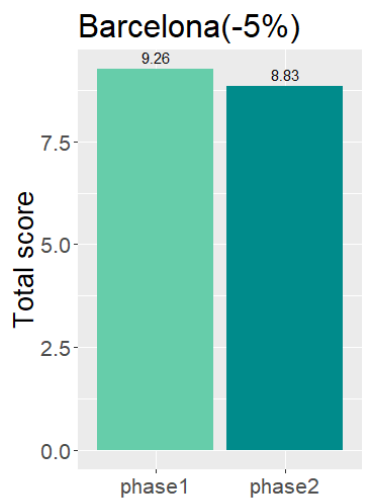


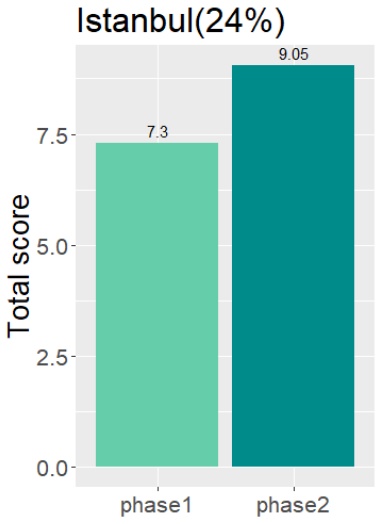


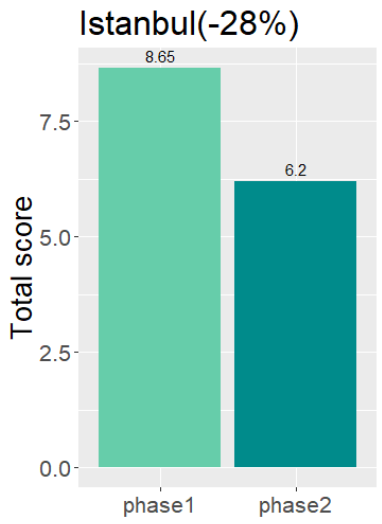


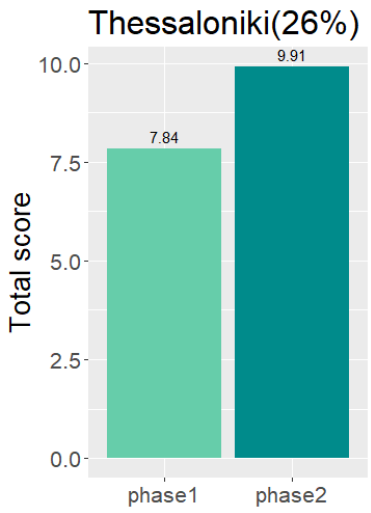


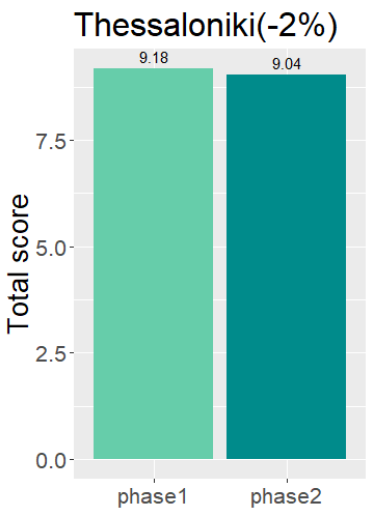


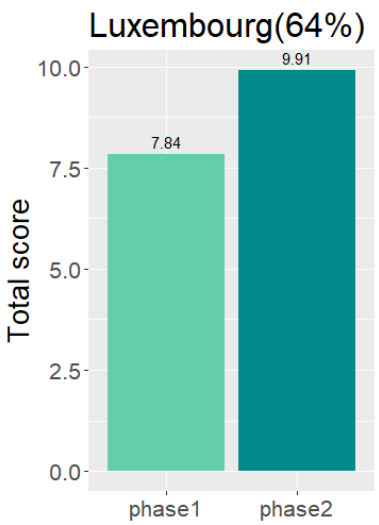


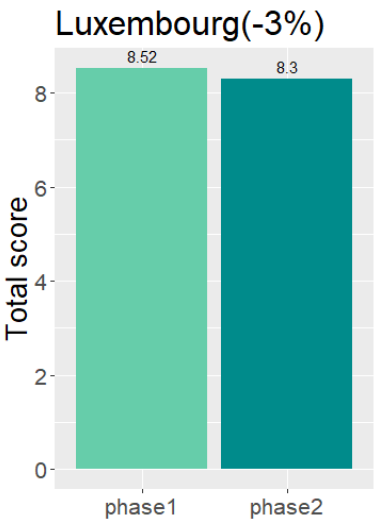












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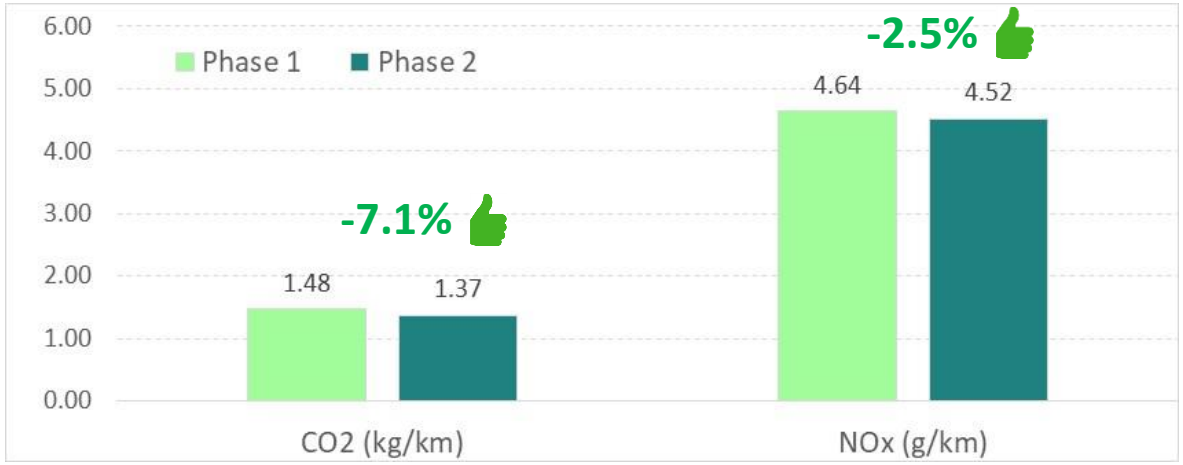
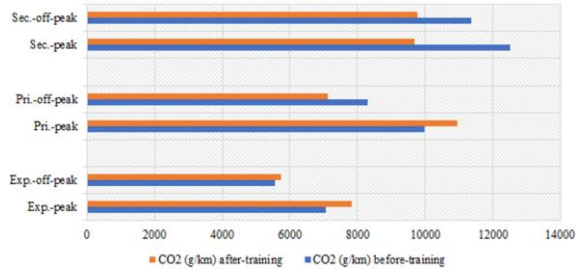
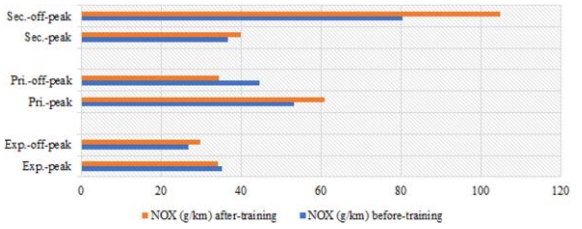
Trial results from Nanjing (China)

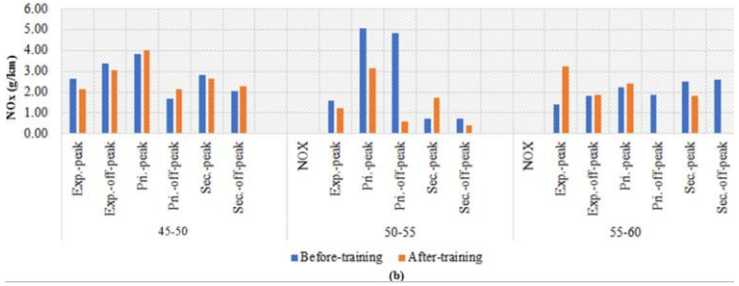


By Road Type

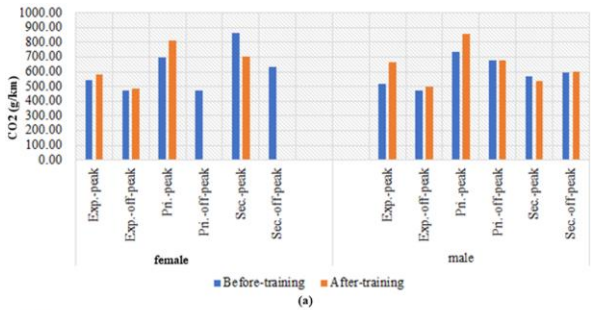


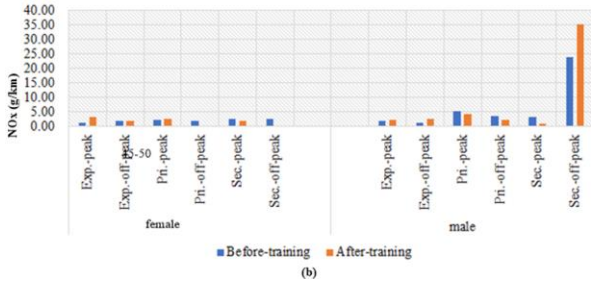


By Age

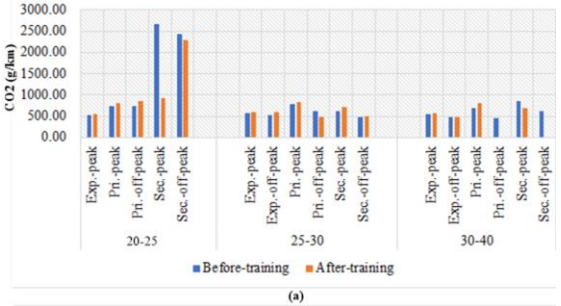


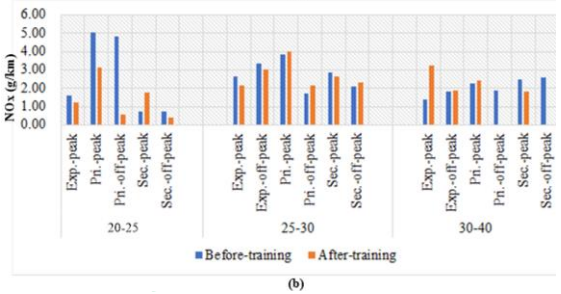
By Gender



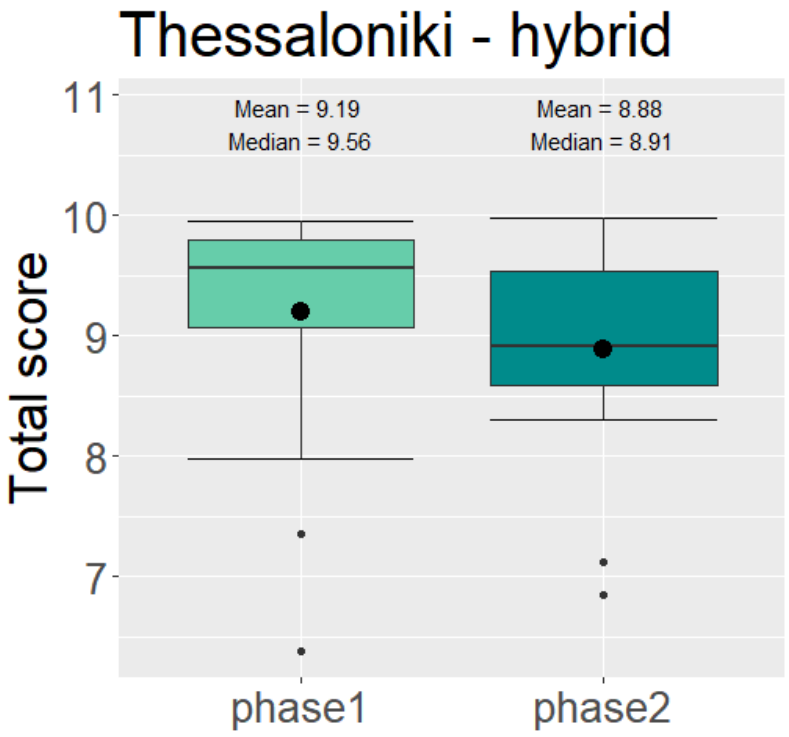


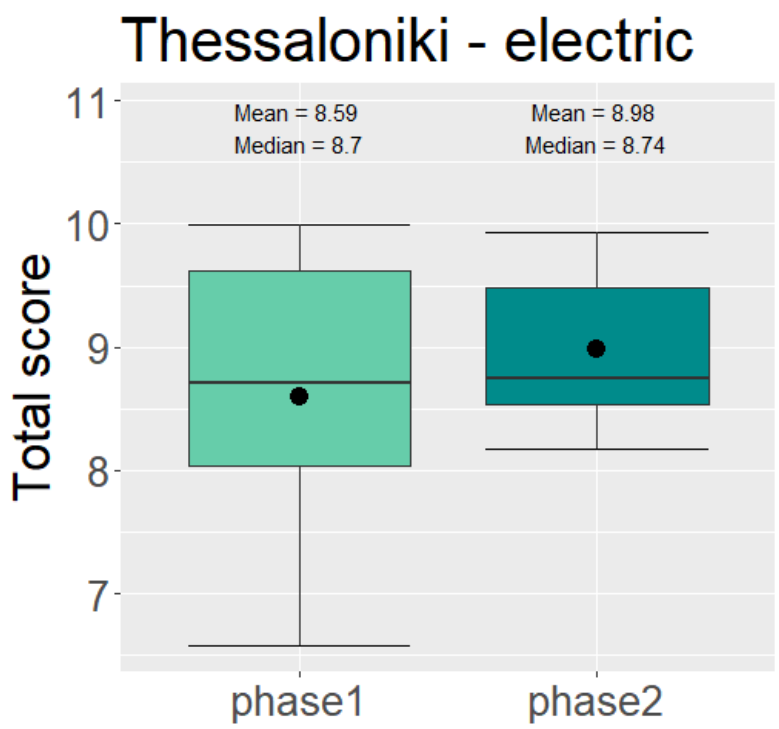
By Experience

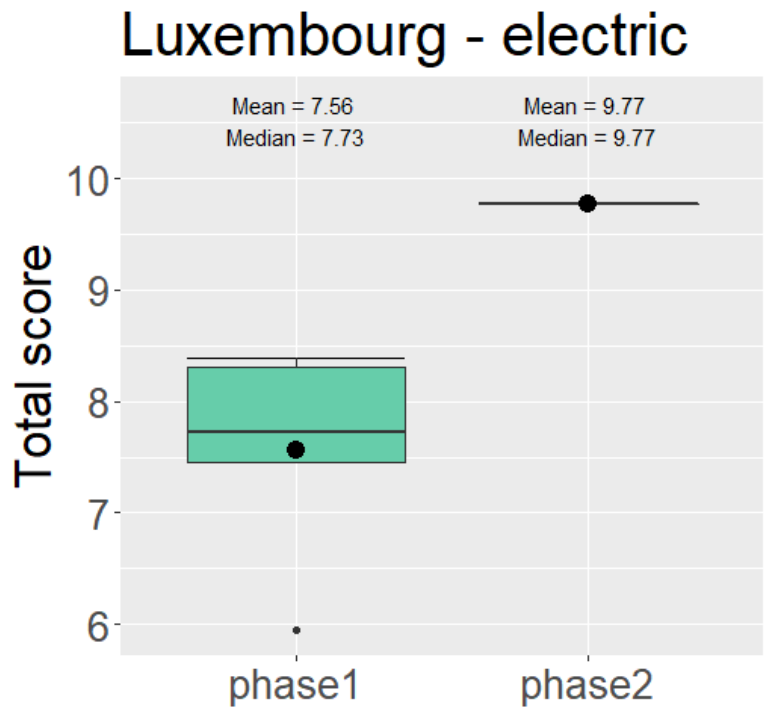




EV drivers versus others:







Conclusions – Key issues

- ***How much has MODALES changed people's driving behaviours?***
  - All the sites have improved journey scores ranging from <1% to 17%, which will lead to reduced combined emissions.
  - Most participants reduced both exhaust and non-exhaust emissions after training, as a result of gentler accelerations and smoother speed profiles.
  - **However**, there are considerable (if not contradicting) differences between users, road types, location and so on – *did we have adequate data to catch behavioural change which is representative of the wider population over a longer period, in terms of the number of users, number of journeys, distance, journey time etc.*?

- ***Was the observed change consistent with how drivers perceived their change?***
  - A final online user feedback survey is concluding and analysis ongoing

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Adapting driver behaviour for lower emissions

www.modales-project.eu

LinkedIn MODALES project

Thank you

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Adapting driver behaviour for lower emissions

Controlled trials: Portable Emissions Measurement System (PEMS) tests

Rasmus Pettinen– VTT Technical Research Centre of Finland

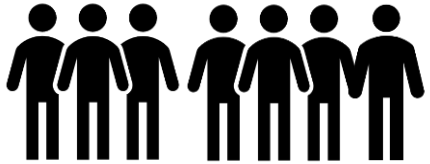
With contributions from:

Hannu Kuutti – VTT Technical Research Centre of Finland

MODALES Final Conference, Brussels, 12 May 2023

Real-world exhaust emission measurements from PEMS Overview

The motivation for the study was to perform a real world validation and demonstration of the potential gains obtained with MODALES application



7 Drivers from Helsinki trial site pool

1 SI

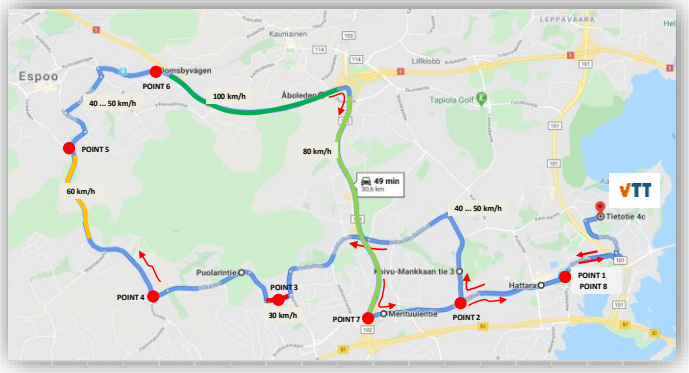
1 CI

2 Cars

Skoda Octavia passenger cars

→ Measured with PEMS

Urban – Rural Roads - Highway



1 Route

Route developed specifically for the MODALES-project (non RDE-compliant)

Test set-up for driving style experiments studying the real effect of MODALES application

Two test configurations:

1. Baseline PEMS tests (no driver aid applied)
   - Used as reference for each driver

→ MODALES training after baseline

2. PEMS tests with MODALES application activated (with recommendations)
   - Impact of scoring and possible gains with training studied

The benefits accounted for solely exhaust emissions alone = baseline results – tests with app activated (and training)

	MODALES trial site status	Vehicle	Test configuration	No. Test drivers	No. test repetitions	Total tests
Test setup 1 (baseline)	Phase 1	Petrol	No driver aid applied; user driving "as usual"	5	2	10
Test setup 2 (w. MODALES app.)	Phase 2	Petrol	MODALES application in use	5	2	10
Test setup 3 (baseline)	Phase 1	Diesel	No driver aid applied; user driving "as usual"	5	2	10
Test setup 4 (w. MODALES app.)	Phase 2	Diesel	MODALES application in use	5	2	10

Driver ID	Petrol	Diesel
Helsinki 1	x	x
Helsinki 2	-	x
Helsinki 3	x	-
Helsinki 6	-	x
Helsinki 16	x	-
Helsinki 26	x	x
Helsinki 27	x	x

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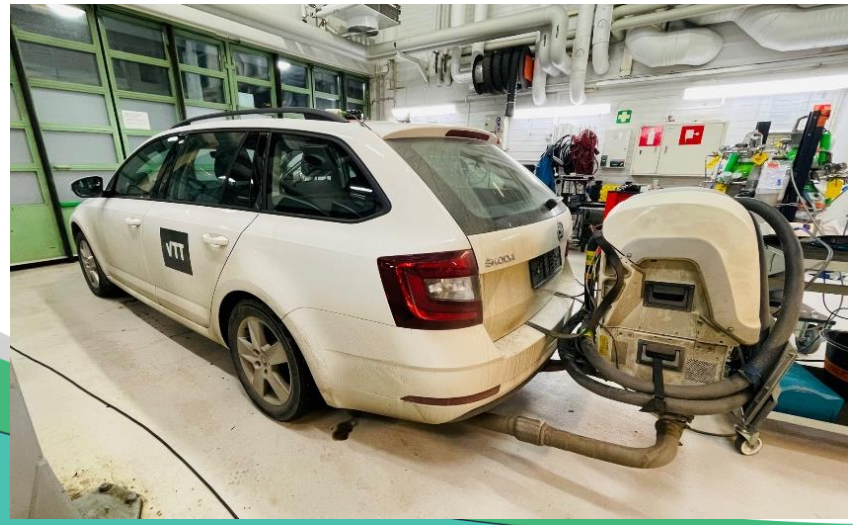
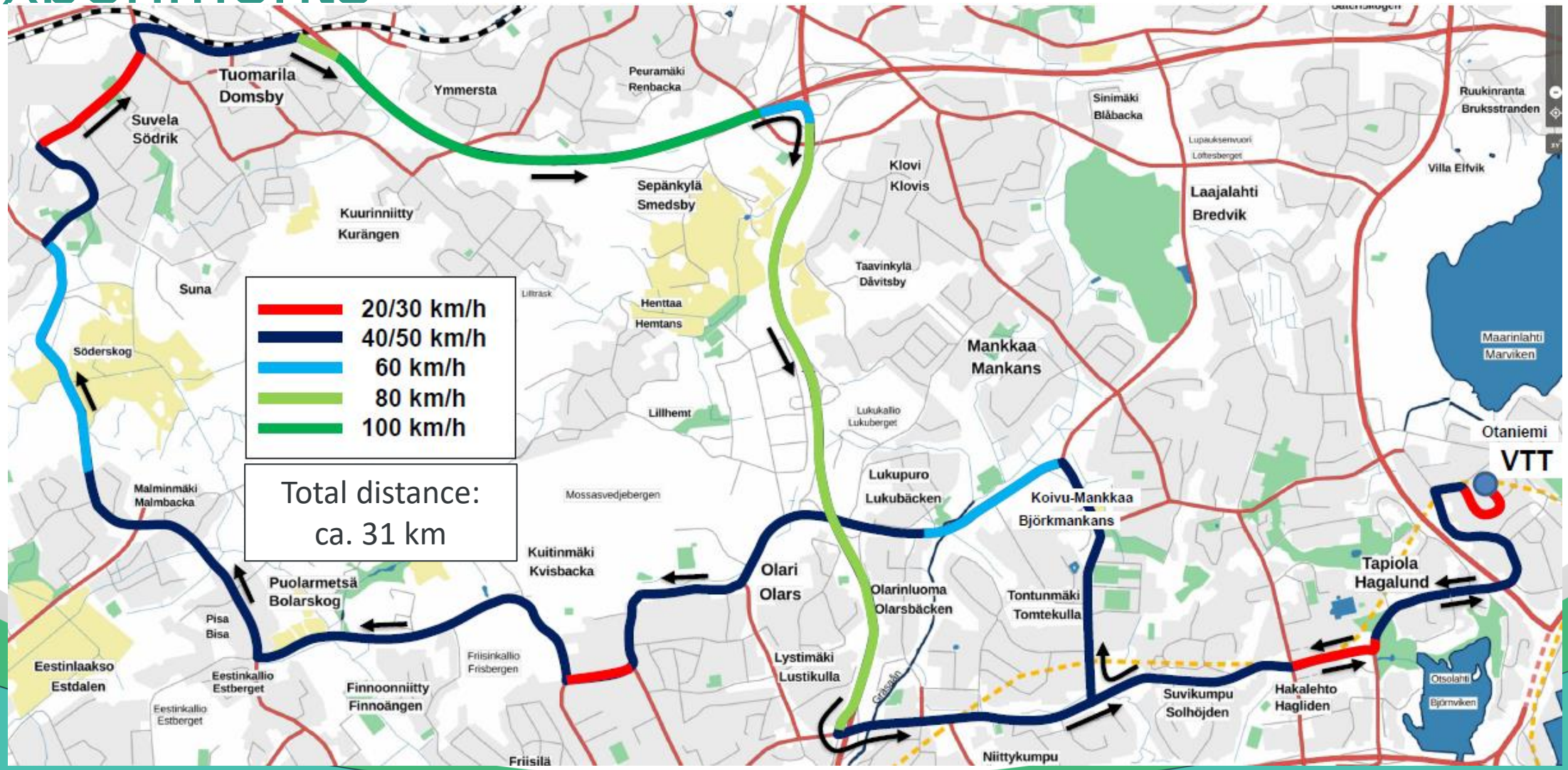
Test vehicles



Test vehicle #	1	2
Make	Skoda	Skoda
Model	Octavia	Octavia
Model year	2017	2019
Fuel type	Petrol	Diesel
Engine size [dm3]	1.498	1.598
Induction	Turbo	Turbo
Power [kW]	110	85
Transmission type	Manual 6-speed	Automatic DSG 7-speed
Mass [kg]	1470	1556
Emission class	Euro 6C	Euro 6d_temp
EATS	TWC	EGR + DOC + SCR + DPF

Route for emissions and driving style experiments



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Recorded driving parameters

Main parameters collected during driving:

- From ECU/OBD: Driving speed (km/h), Engine speed (rpm), Engine power (kW), Engine torque (Nm)
- From PEMS: Exhaust emissions: CO_2, CO, NO, NO_2, PN_{23}
  - GPS position, distance travelled
- MODALES application

VTT AVL PEMS M.O.V.E. assembly

- AVL 492 Gas PEMS iS
  - NDIR: CO + CO2
  - NDUV: NO/NO2
- AVL 496 PN PEMS iS
  - Advanced diffuser charger
- AVL EFM 2”

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Results: overview of average driving parameters

Very little impact on average trip duration throughout the tests

Trip Duration	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	5 %		1 %		-3 %	5 %	-7 %	0 %
Diesel	4 %	-4 %		-4 %		3 %	3 %	1 %
Avg	4 %	-4 %	1 %	-4 %	-3 %	4 %	-2 %	0 %

Trip Distance	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	0 %		0 %		0 %	-1 %	0 %	0 %
Diesel	0 %	0 %		0 %		0 %	0 %	0 %
Avg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %

Avg. Speed	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	-5 %		-1 %		3 %	-6 %	7 %	0 %
Diesel	-3 %	4 %		4 %		-3 %	-3 %	-1 %
Avg	-4 %	4 %	-1 %	4 %	3 %	-5 %	2 %	0 %

Avg. Engine speed	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	-13 %		-1 %		3 %	-6 %	7 %	-6 %
Diesel	-3 %	n/a		1 %		-1 %	2 %	0 %
Avg	-8 %	n/a	-1 %	1 %	3 %	-3 %	5 %	-3 %

Avg. Engine Power	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	-14 %		-5 %		-1 %	-8 %	8 %	-4 %
Diesel	-4 %	n/a		3 %		0 %	-1 %	-1 %
Avg	-9 %	n/a	-5 %	3 %	-1 %	-4 %	4 %	-2 %

Avg. Engine Torque	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	-1 %		-4 %		-1 %	-4 %	8 %	0 %
Diesel	0 %	n/a		3 %		0 %	5 %	2 %
Avg	0 %	n/a	-4 %	3 %	-1 %	-2 %	6 %	1 %

Trip Work	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	-11 %		-5 %		-3 %	0 %	0 %	-4 %
Diesel	0 %	n/a		0 %		3 %	2 %	2 %
Avg	-6 %	n/a	-5 %	0 %	-3 %	2 %	1 %	-1 %

Va_pos	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG
Petrol	-17 %		-2 %		-3 %	-7 %	-7 %	-7 %
Diesel	-14 %	-5 %		-15 %		-8 %	-24 %	-14 %
Avg	-15 %	-5 %	-2 %	-15 %	-3 %	-7 %	-15 %	-10 %

The effect of recommendations were found greater for certain drivers

Impact most evident for engine power and engine speed with manual-transmission cars

Common parameter for both vehicles: v*a positive decreased in all cases

o — Driver did not drvie this car

n/a — Result not available due to malfunctions

Result for the driver, one trip with regeneration event omitted

Results: overview of average emissions

CO_2 [%]	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	AVG %
	TEST DRIVERS							
Petrol	-5 %		-2 %		2 %	2 %	-8 %	-2 %
Diesel	-10 %	-9 %		-8 %		-3 %	-6 %	-7 %
Avg	-8 %	-9 %	-2 %	-8 %	2 %	-1 %	-7 %	-5 %

CO [%]	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	
Petrol	31 %		206 %		-68 %	41 %	-33 %	-25 %
Diesel	-100 %	-100 %		109 %		-100 %	-100 %	-99 %
Avg	-34 %	-100 %	206 %	109 %	-68 %	-29 %	-66 %	-62 %

NOx [%]	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	
Petrol	17 %		-18 %		10 %	15 %	-15 %	1 %
Diesel	-58 %	11 %		-31 %		-51 %	-70 %	-47 %
Avg	-20 %	11 %	-18 %	-31 %	10 %	-18 %	-43 %	-23 %

PN [%]	Helsinki 1	Helsinki 2	Helsinki 3	Helsinki 6	Helsinki 16	Helsinki 26	Helsinki 27	
Petrol	-18 %		-36 %		-46 %	-35 %	-54 %	-41 %
Diesel	-3 %	0 %		-9 %		2 %	3 %	-2 %
Avg	-10 %	0 %	-36 %	-9 %	-46 %	-17 %	-26 %	-22 %

Minor improvements for CO_2 and fuel consumption was found for both test cars

CO decreased on average for both vehicles

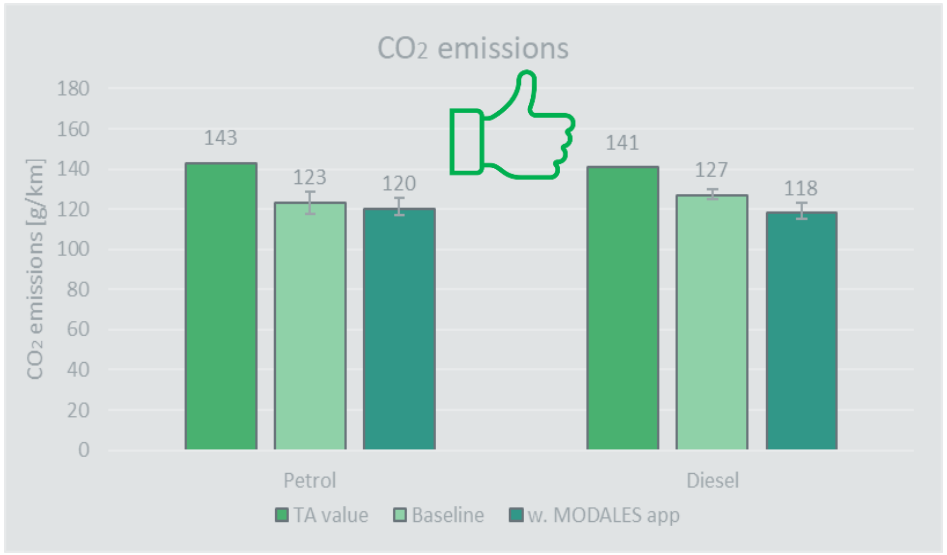
Most evident gains in NOx obtained for the diesel vehicle

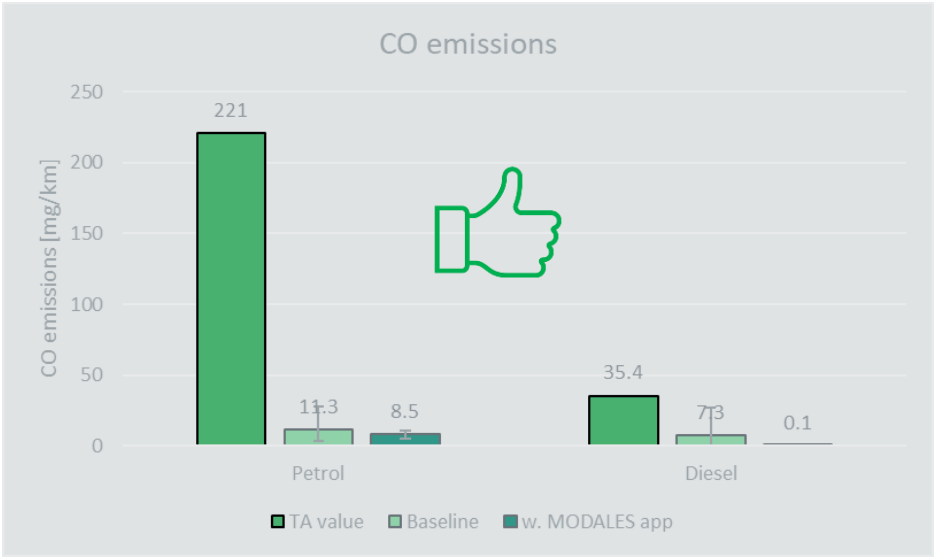
Meanwhile PN decreased on average for the petrol vehicle

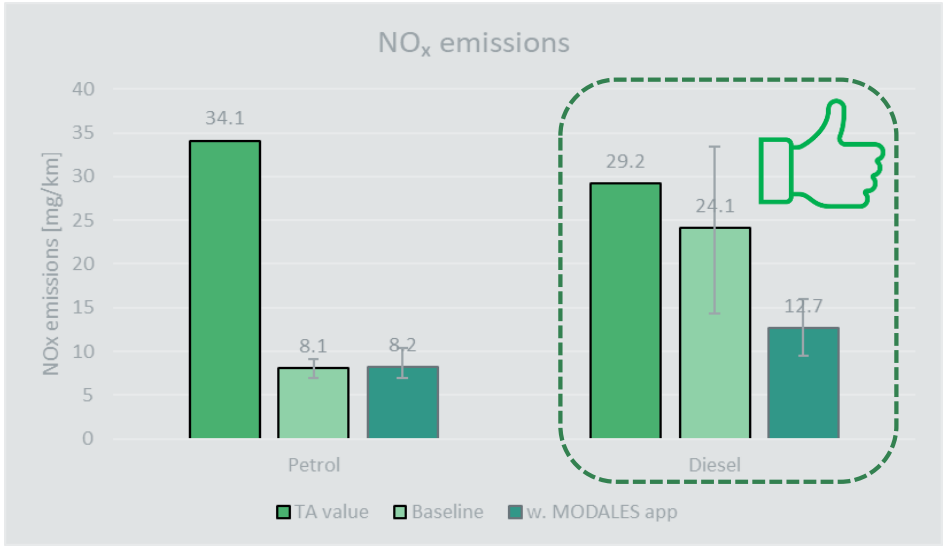
High increase in relative change, but absolute values remain low

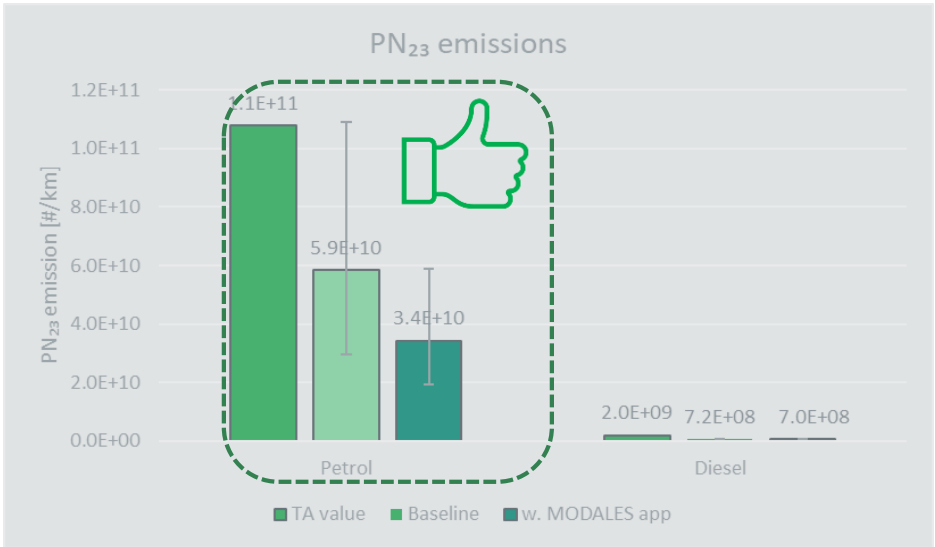
modales

Results – Summary of average results







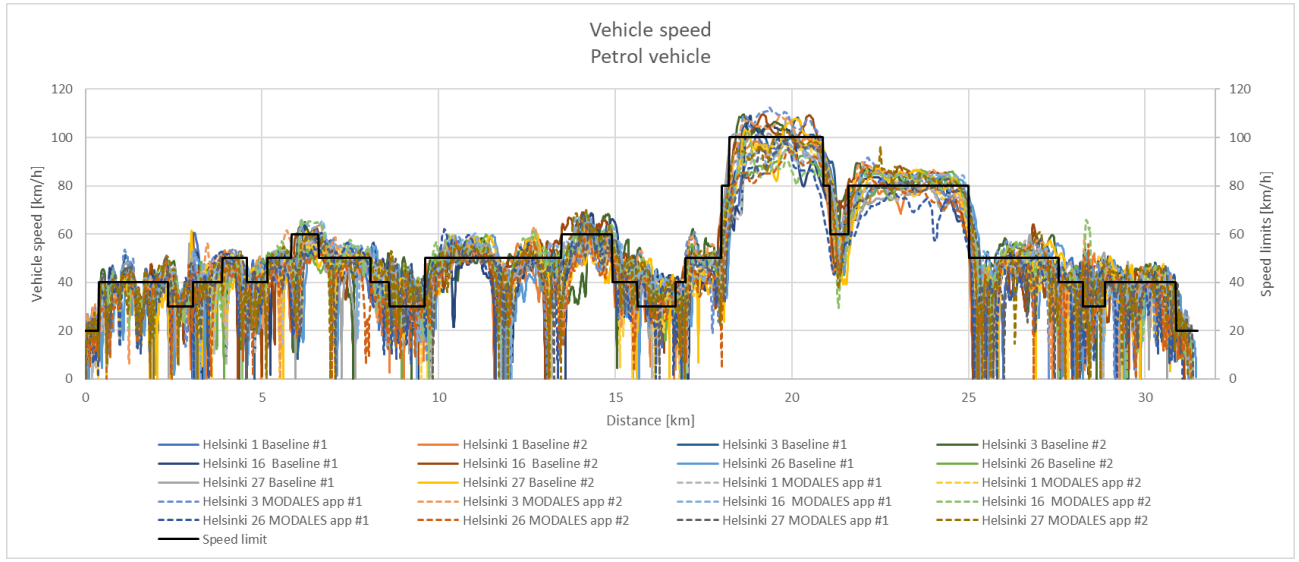


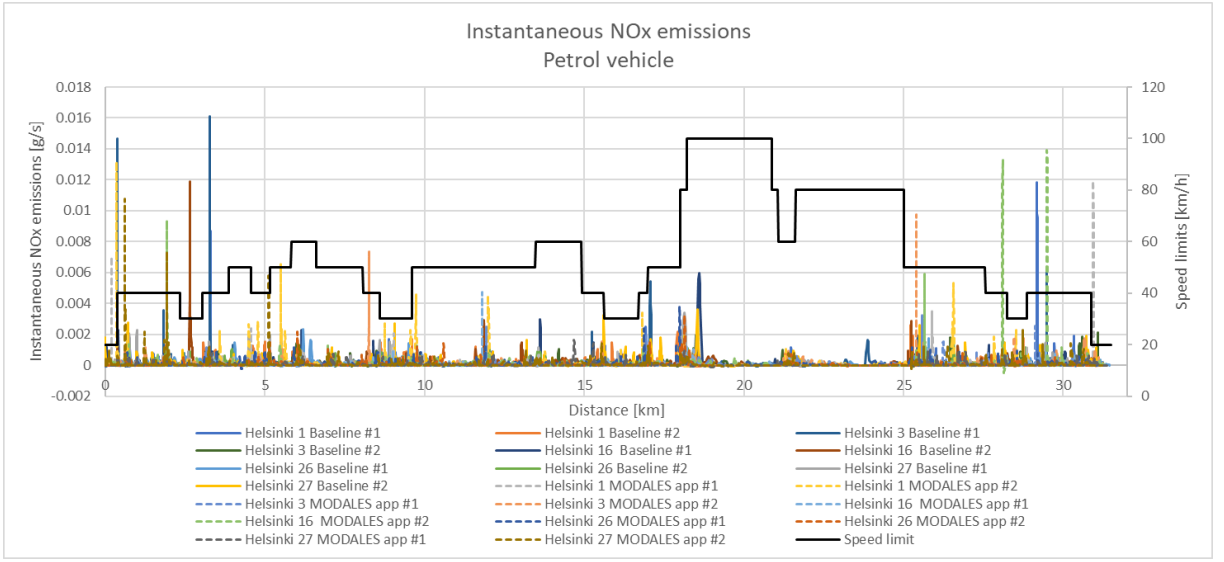
*TA = Type-approval values declared by the vehicle manufactureer, note that values are determined in WLTP including cold start

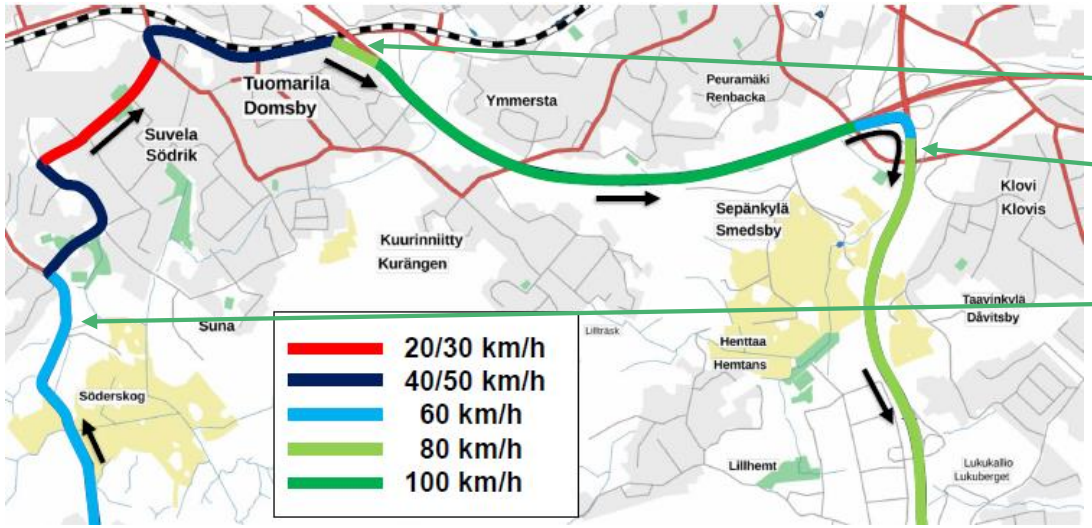
**The error bars express the deviation between driver to driver

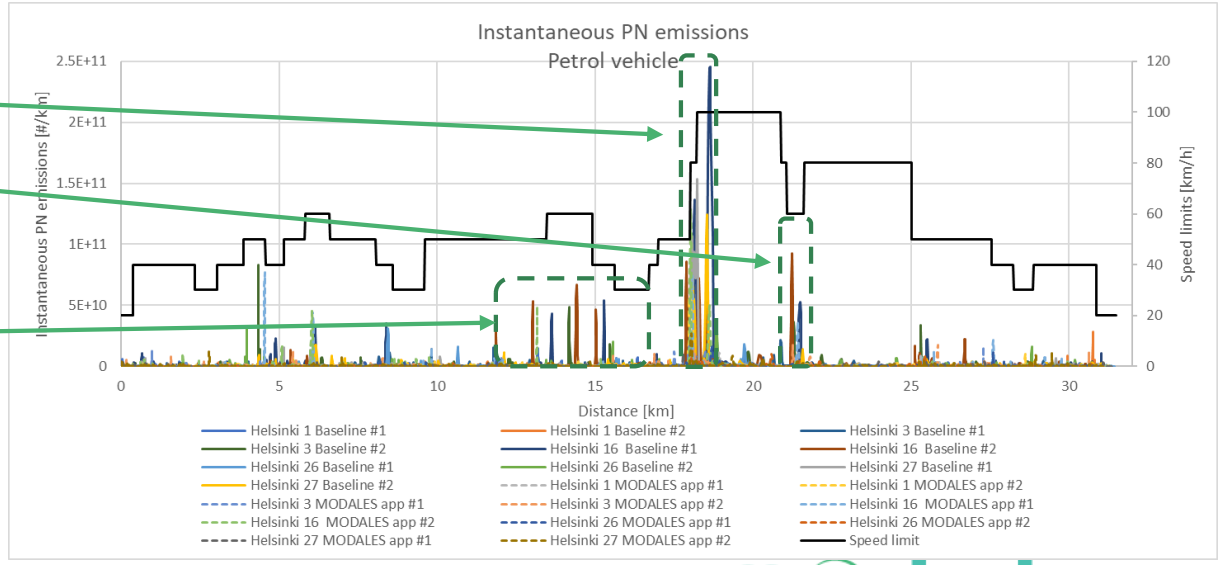
Results: Examples of real time data, Petrol vehicle

Baseline
w. MODALES application

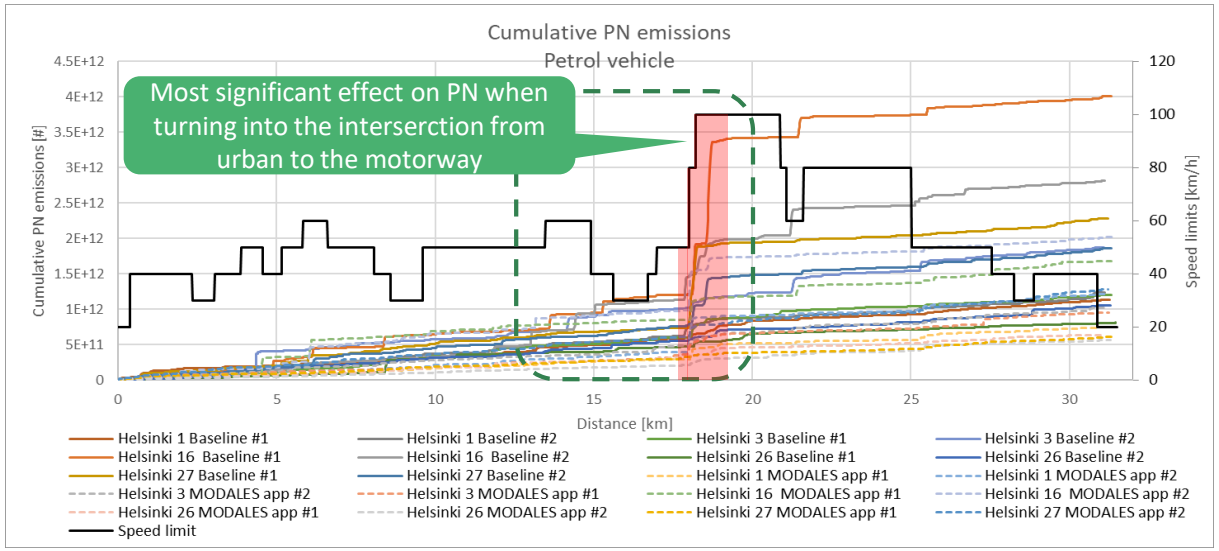


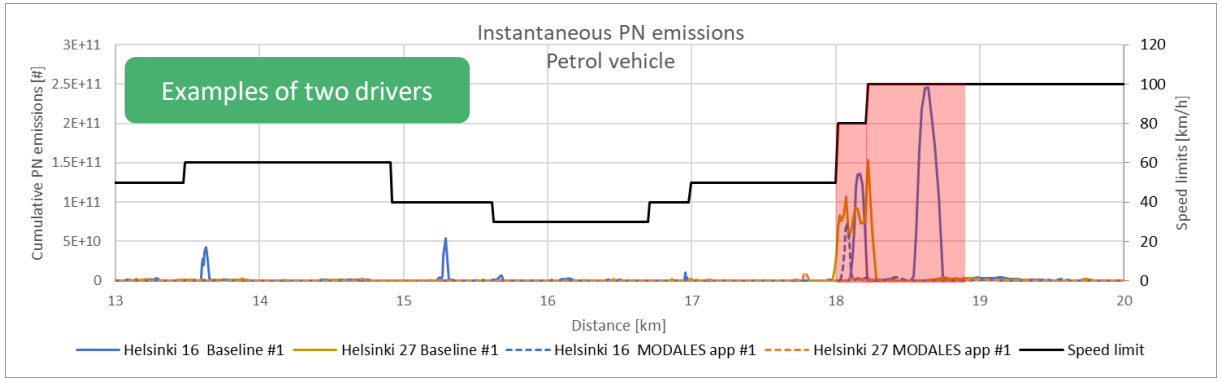


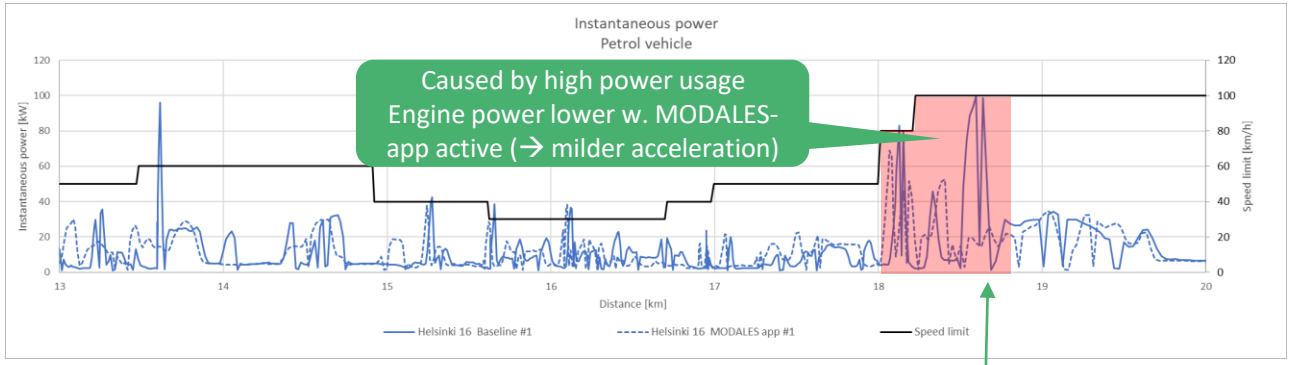


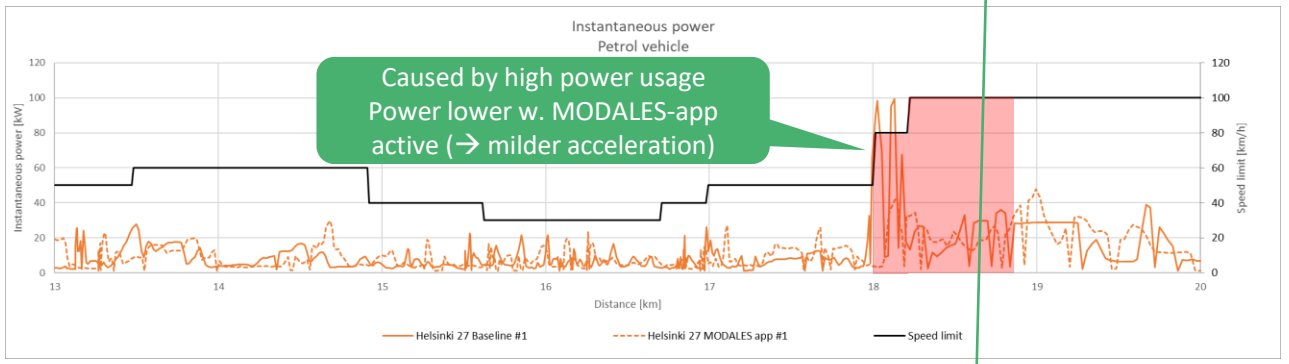


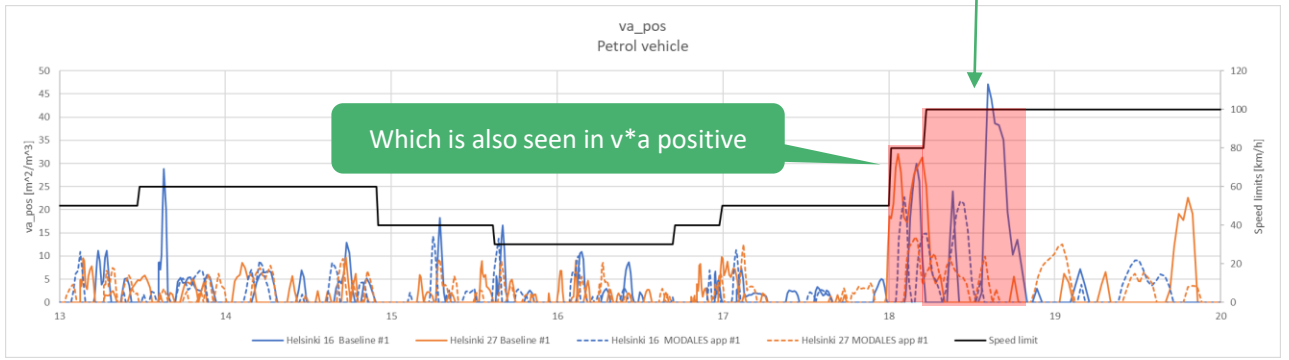
Results: Examples of real time data



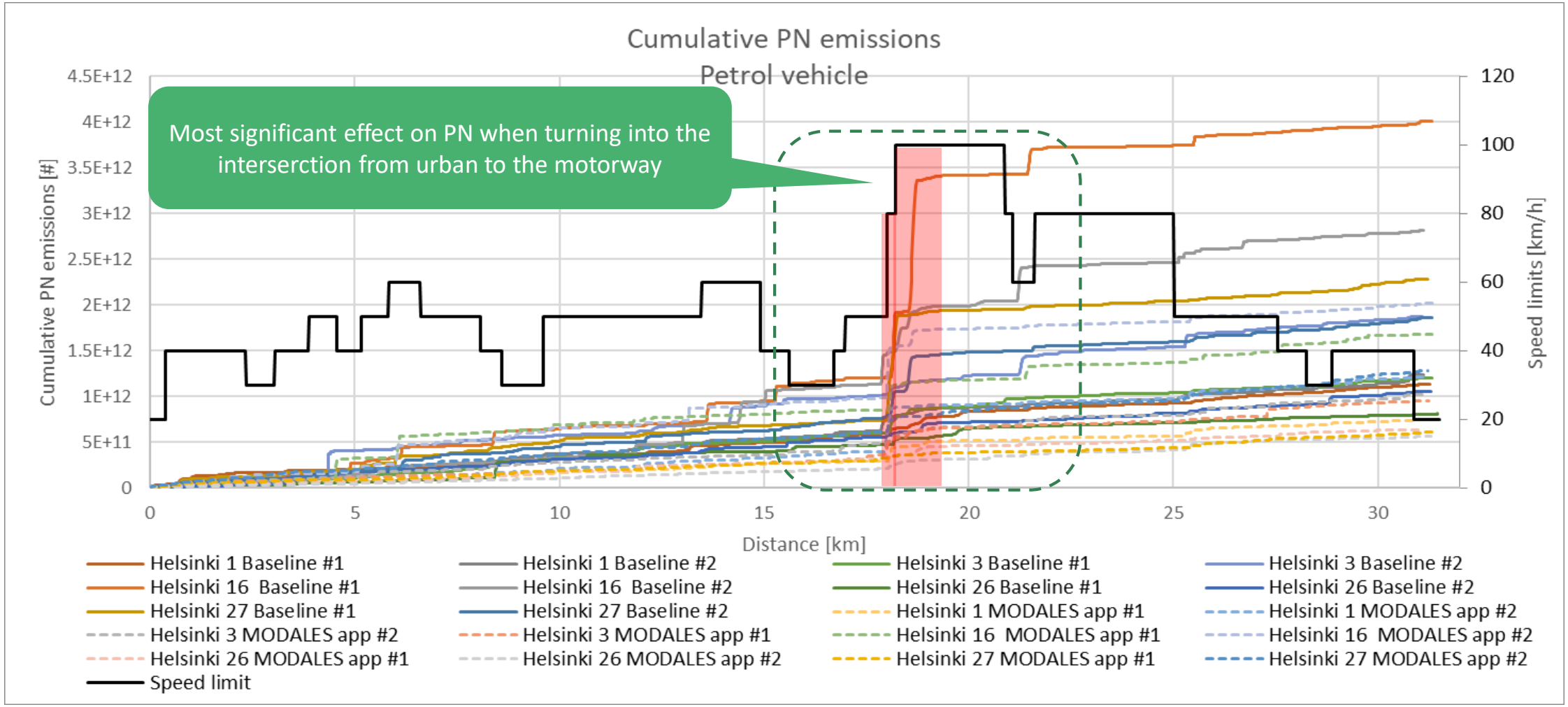




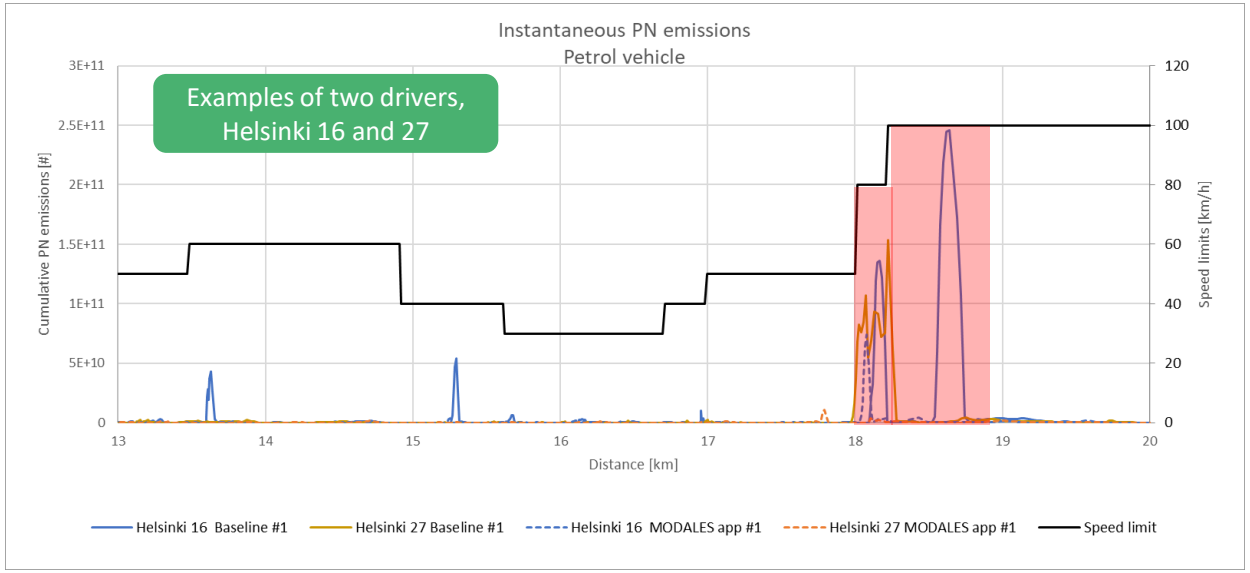


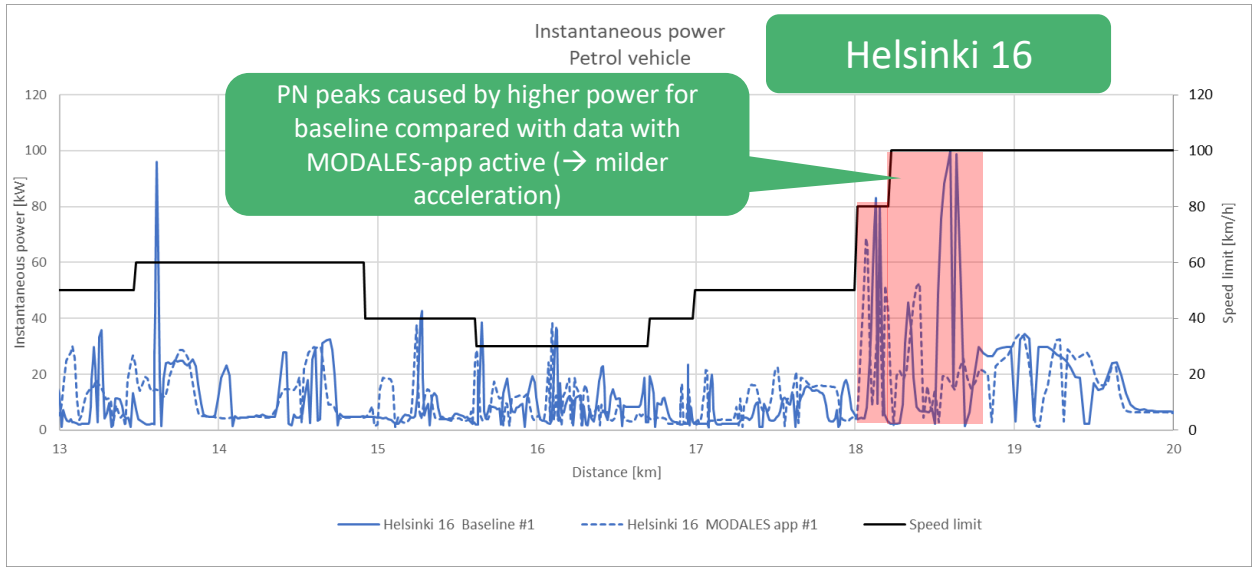


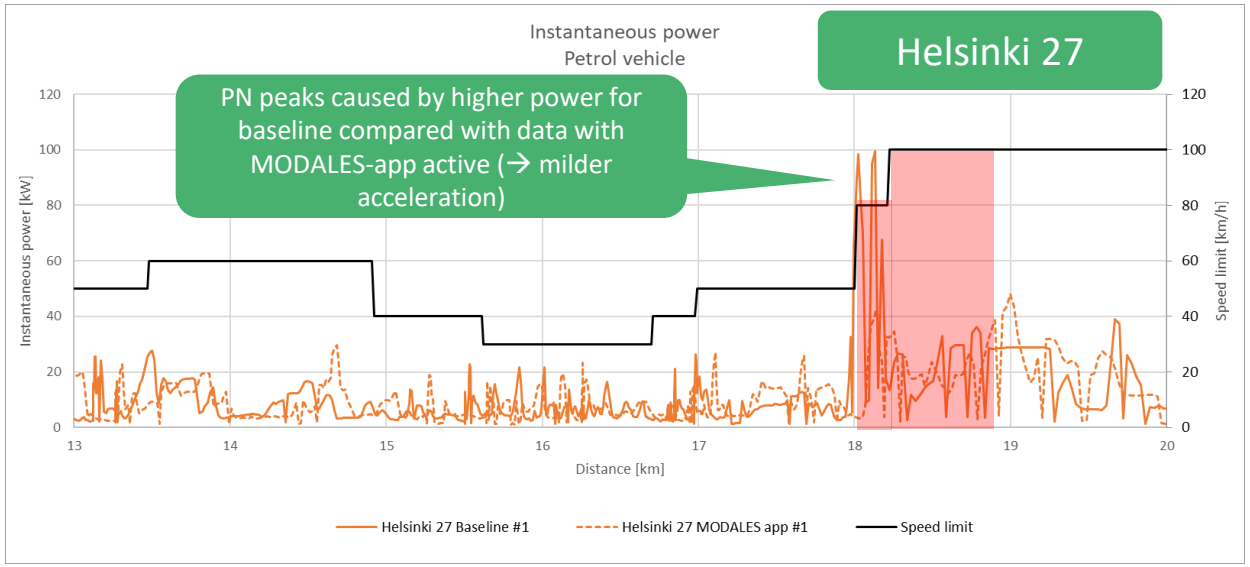
Results: Examples of real time data

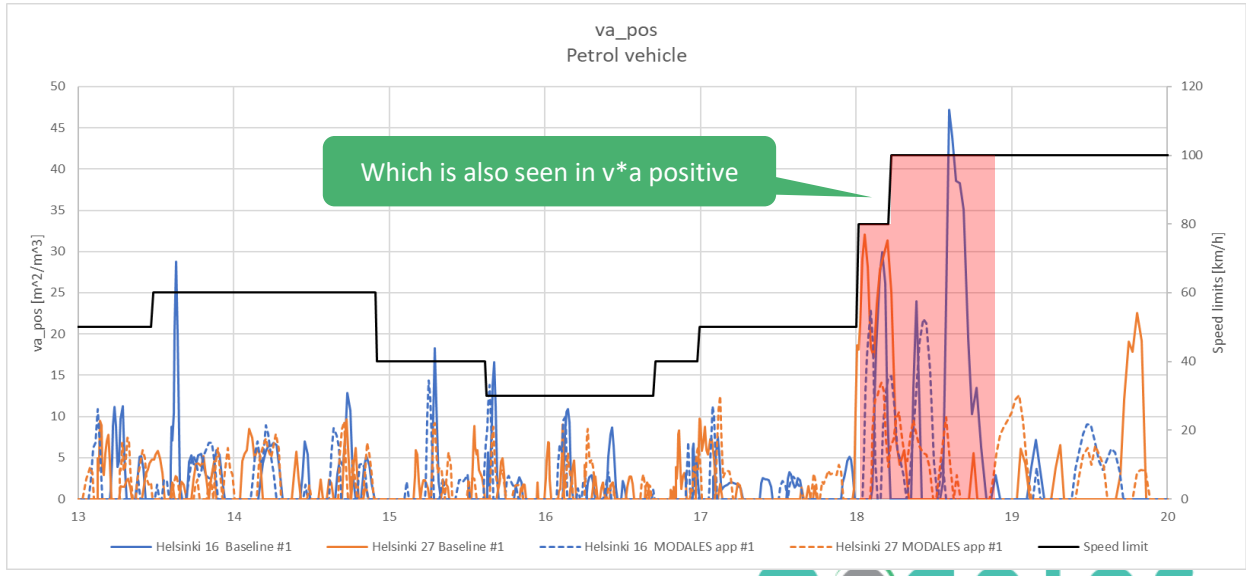


Results: Examples of real time data, petrol vehic



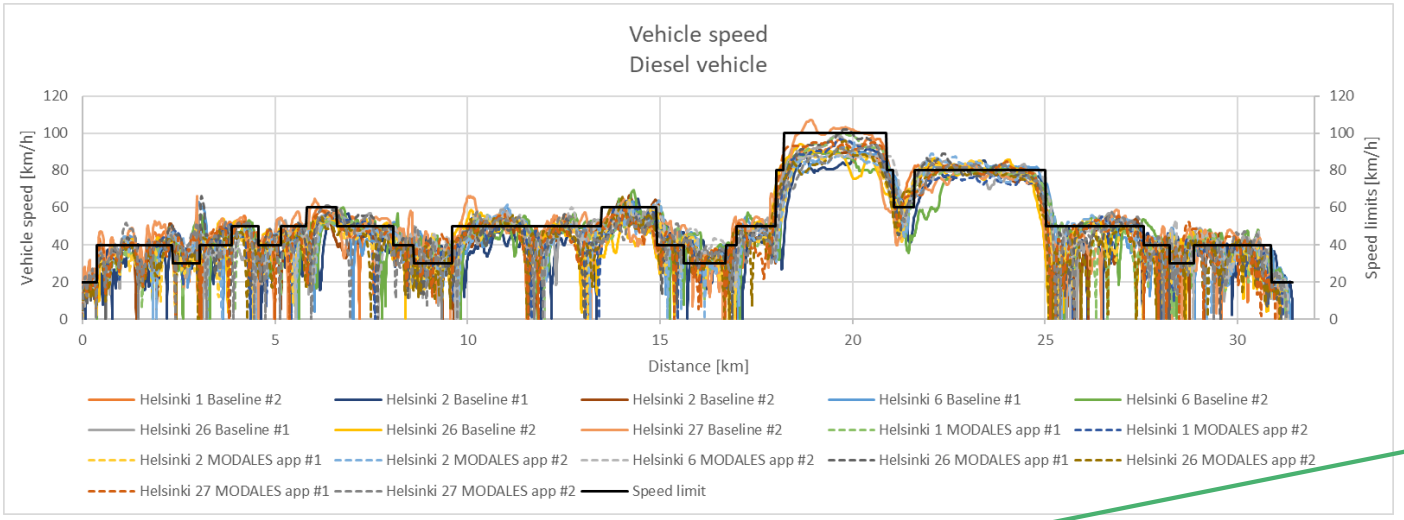


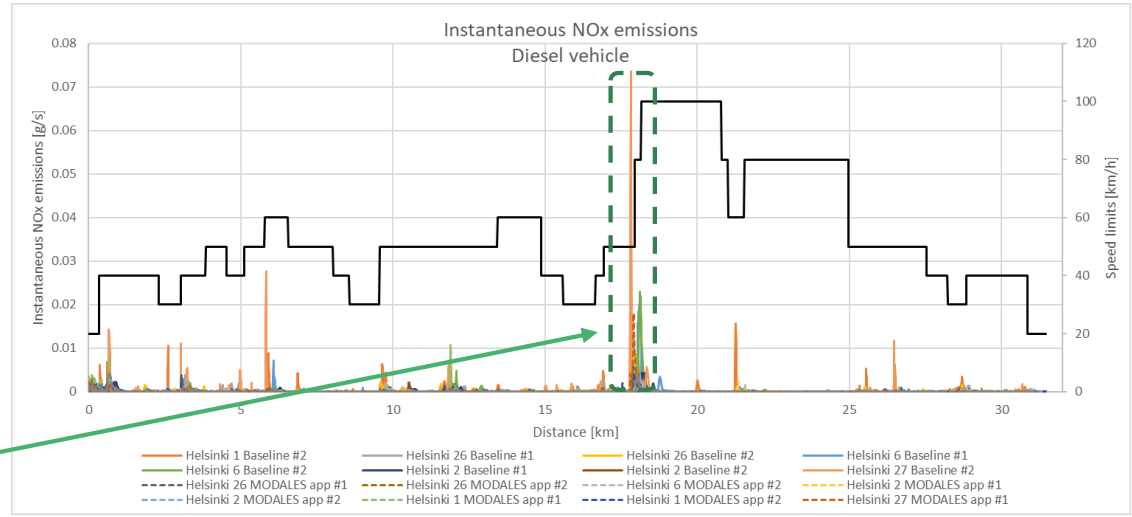


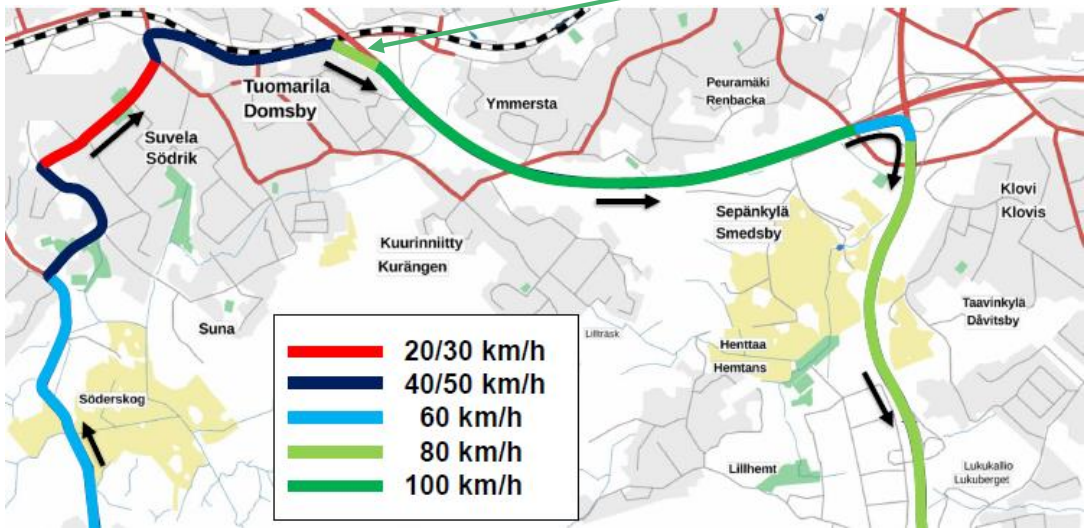


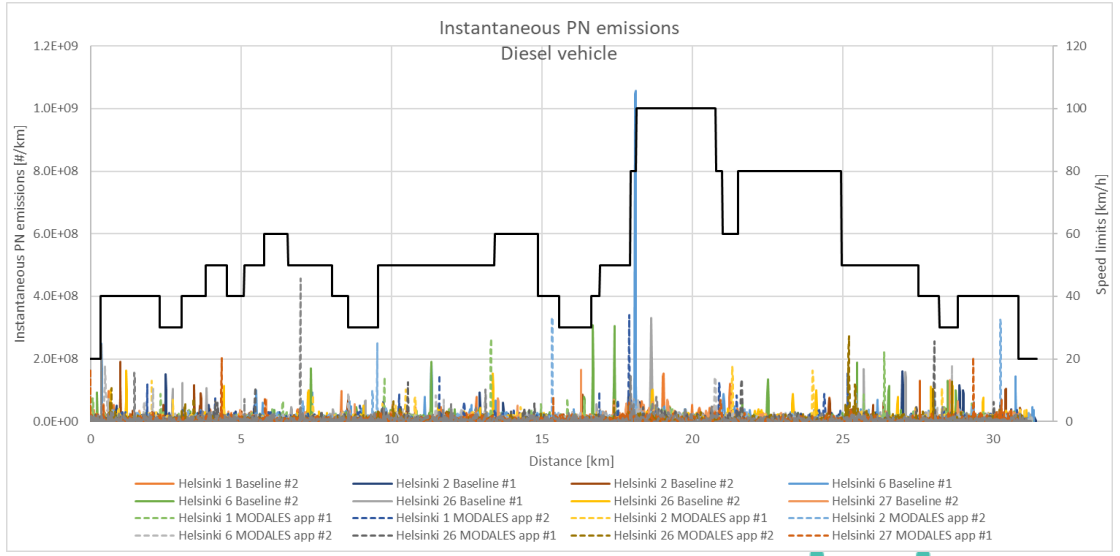
Results: Examples of real time, Diesel vehicle

Baseline
w. MODALES application



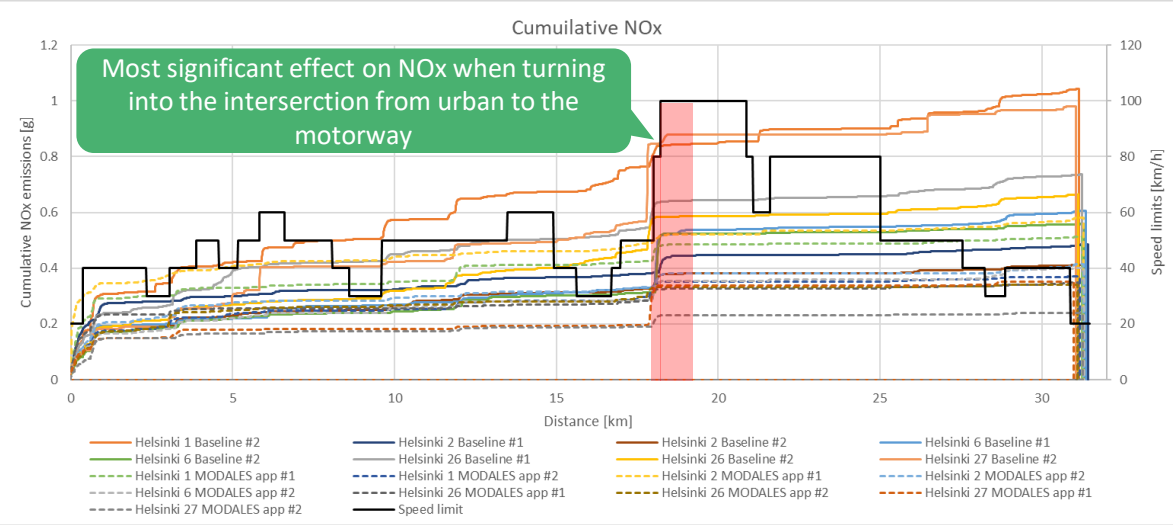


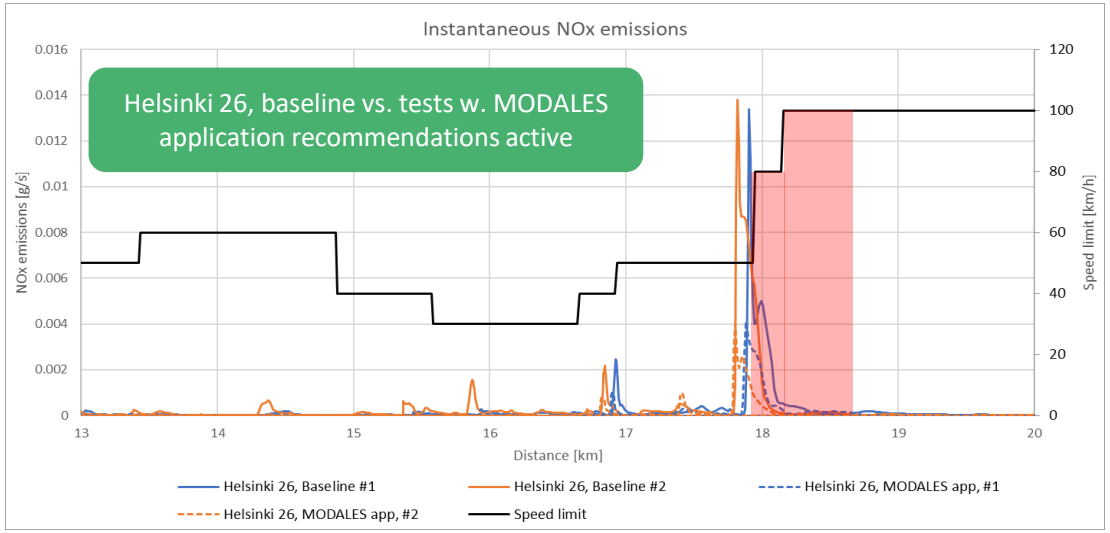


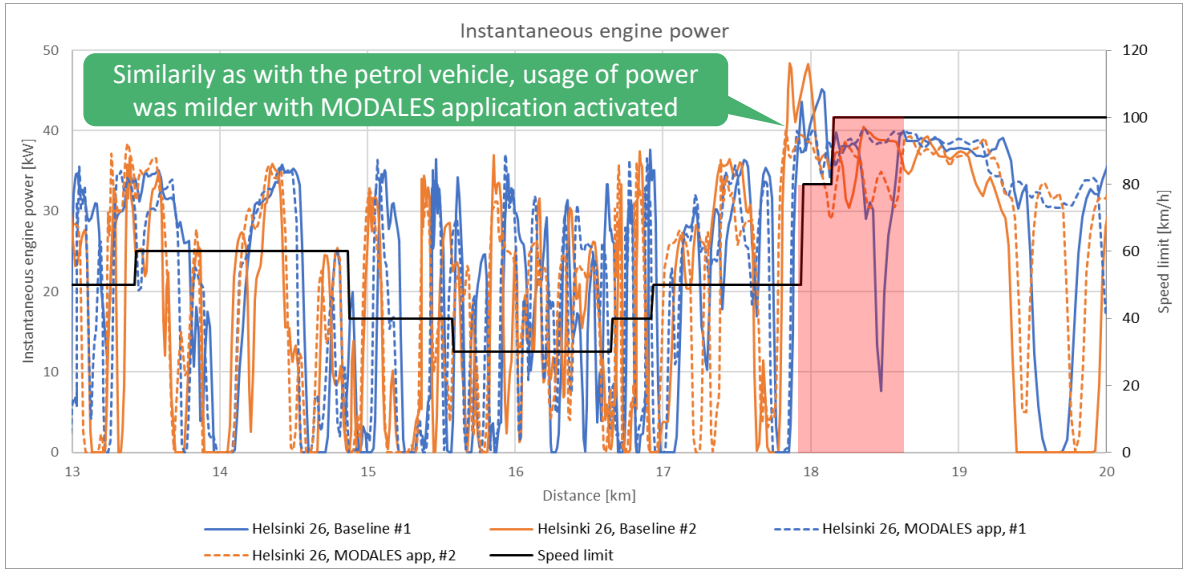


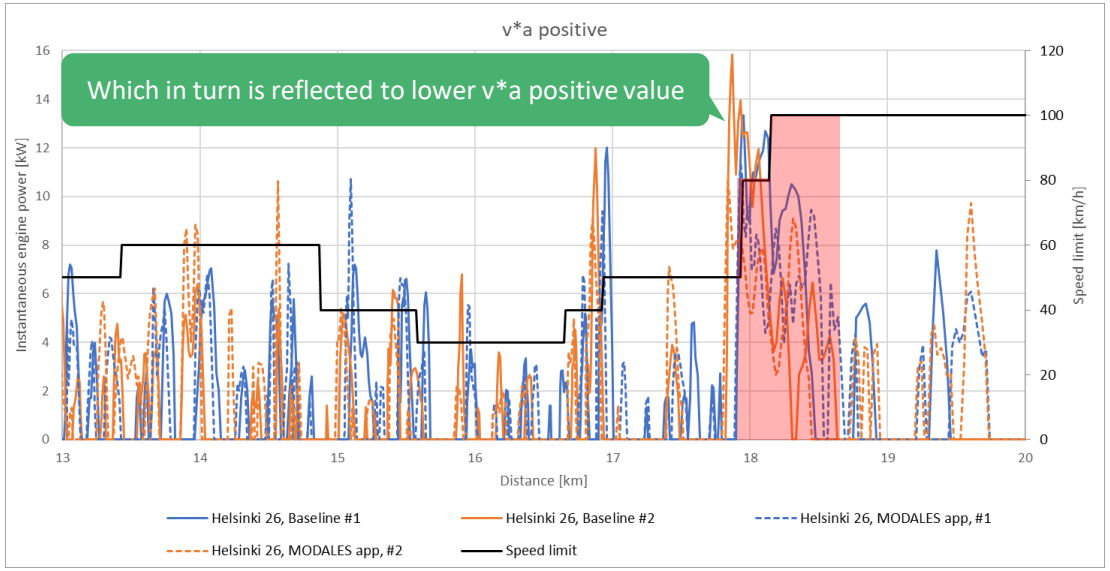
Results: Examples of real time, Diesel vehicle

Baseline
w. MODALES application









Conclusions

- **Clear and evident benefits in terms of exhaust emissions** (and thus fuel economy) were found by using the recommendations provided by MODALES application
  - Relatively high driver to driver variation was seen, in particular those with less smooth or most emitting driving style improved most and vice versa
  - Net effect on emissions was seen varying case by case, but overall throughout the fleet, clear improvements with the usage of MODALES application was seen
  - Generally, the application guides for a smoother driving style with less aggressive accelerations
    - This was seen in terms of lower peak power usage during accelerations and in terms of milder milder average v*a positive values
- Net effect varies between fuel type and powertrain type:
  - An average PN_{23} reduction up ca 45 % was achieved for the petrol vehicle (without GPF)..
  - ..and for the diesel vehicle, a reduction for NOx of ca 47 % was obtained
  - Simultaneously as benefits in fuel consumption (CO_2) and CO was reduced with both vehicles
- This demonstration is solely one example conducted with a limited quantity of population and using a route with many different driving conditions. The magnitude of effect most likely differs case by case
- However, this demonstration proves that using the MODALES app, driving behaviour typically improves from an environmental perspective

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Adapting driver behaviour for lower emissions

www.modales-project.eu

LinkedIn MODALES project

Thank you

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Adapting driver behaviour
for lower emissions

WP6 Impact assessment

Guillaume SAINT PIERRE – Cerema

With contributions from:

Pascal SALMANE, **Abdou SOW**, **Guillaume COSTESEQUE, Lucas RIVOIRARD, Jean-Paul GARRIGOS** – Cerema

+ **all Modales partners : Results & advices & expertise & feedback**

MODALES Final Conference, Brussels, 12 May 2023

Impact assessment methodology

copert

Computer Program to Calculate Emissions from Road Transport Version 5.6.1

Use the COPERT Software & methodology to estimate emissions from road transport at the national level

1. Estimate the baseline emissions, i.e. without MODALES, for year 2025
2. Use the MODALES results to estimate the emissions with MODALES solutions
3. Obtain the emission savings for the following pollutants: CO^2, CO, NOx, PM




Countries with MODALES trials


Countries with large vehicle fleet

modales

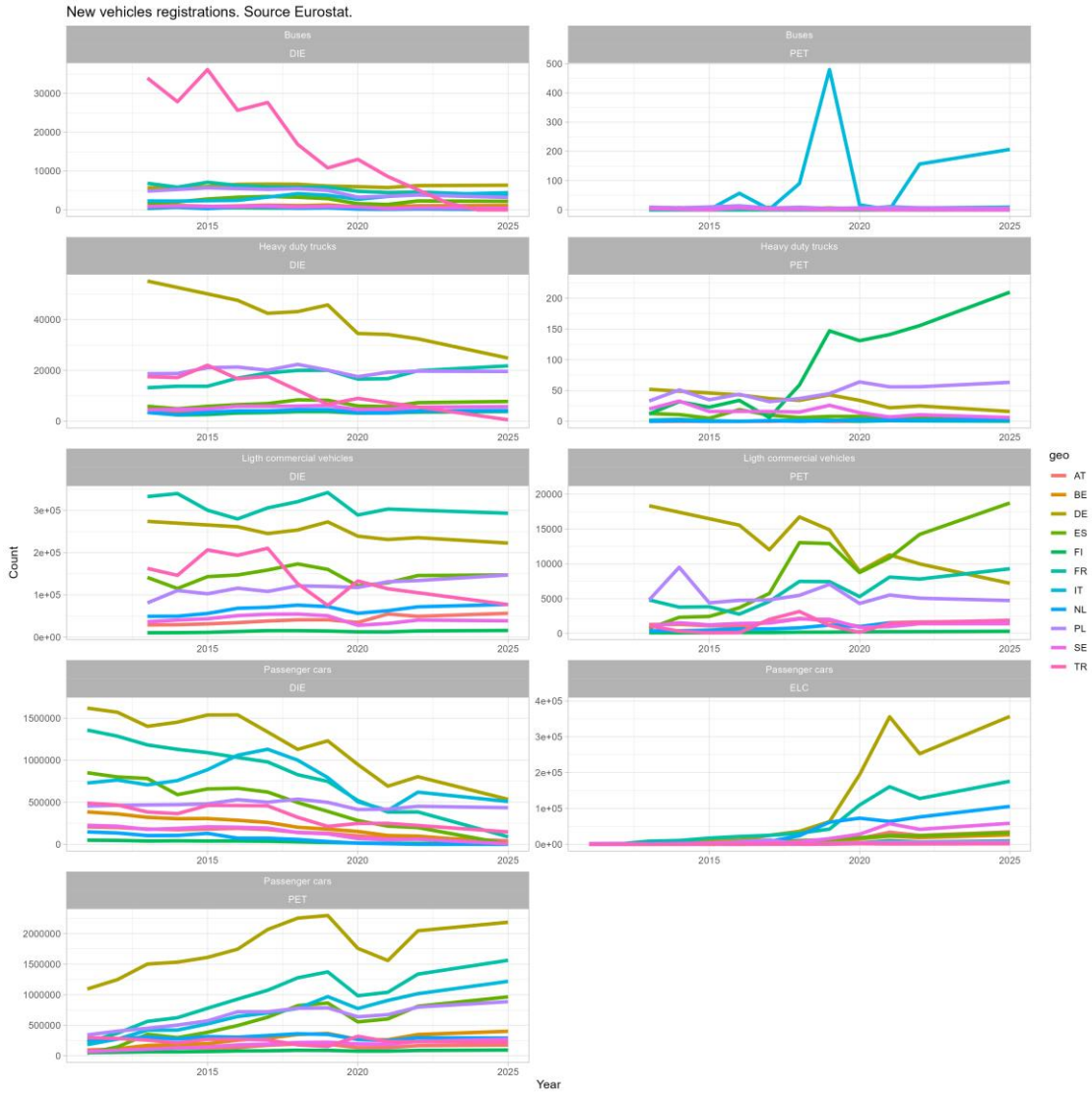
Using Copert

- **Data needs:**
  - Fleet composition, stock & activity data, circulation data, environmental data
- **Level of precision:**
  - Category of vehicles (Passenger cars, Heavy duty trucks, Light commercial vehicles, Buses)
  - Fuel type (PET, DIE, ELC)
  - EU Standards (Euro 4, Euro 5, Euro 6 a-b-c, Euro 6 d temp, Euro 6 d)
- **Biggest issue:**
  - Reconstruction & prediction of the national vehicle fleets using Eurostat data

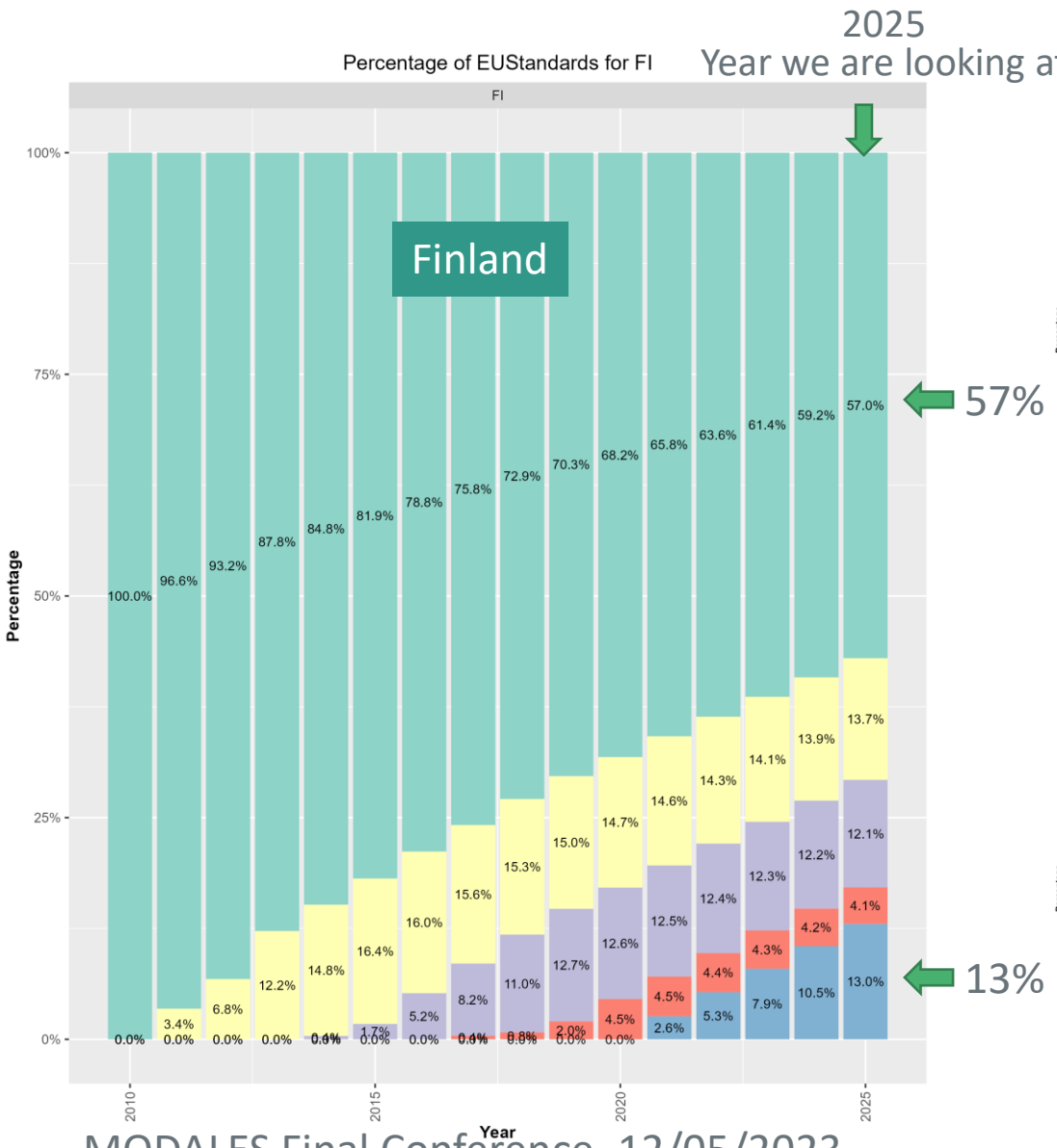
Stock reconstruction & prediction methodology

- Vehicles registration data are predicted for 2022-2025
- Starting from 2011 to 2025, year by year, the stock is rebuilt and new registred vehicles are attributed to an EUStandard according to the year
- Stock(n)=stock(n-1)+registration(n)-out_of_stock(n)

- Not possible to take Euro 3 into account (no data)

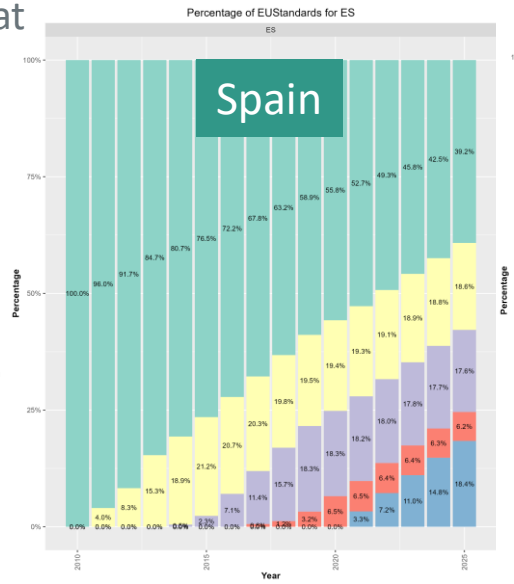


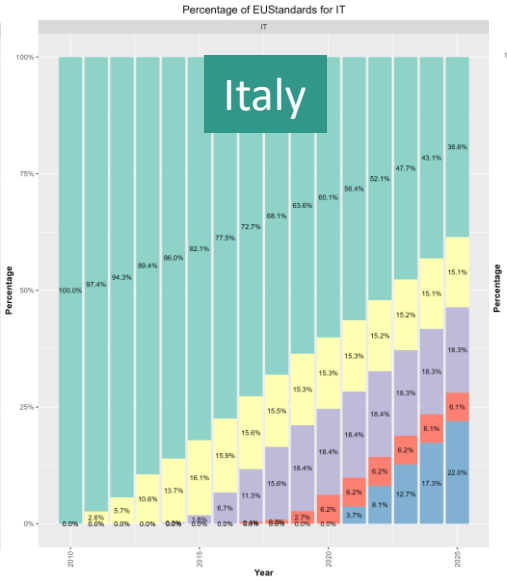
Estimated stock for relevant countries

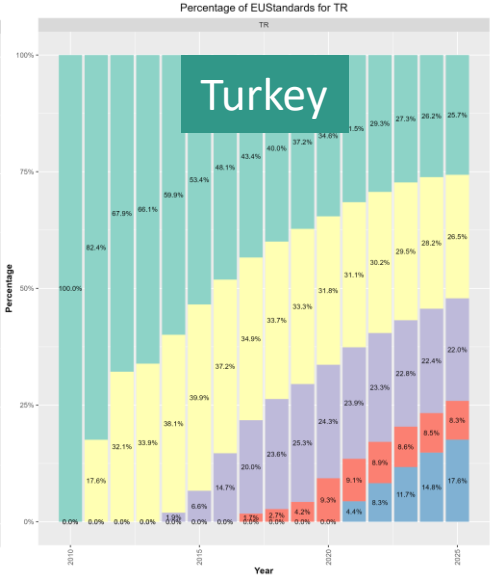


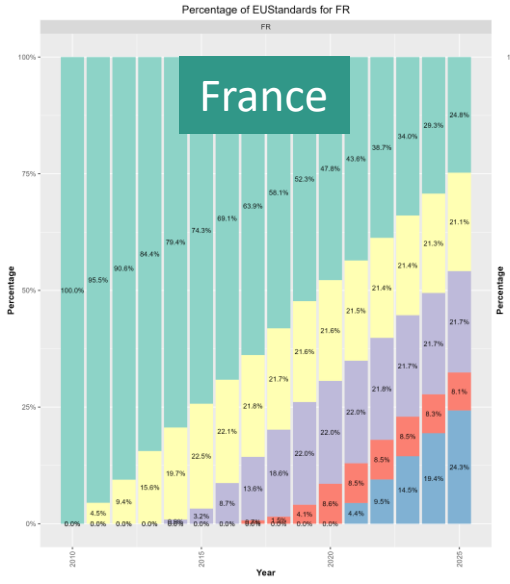
57%

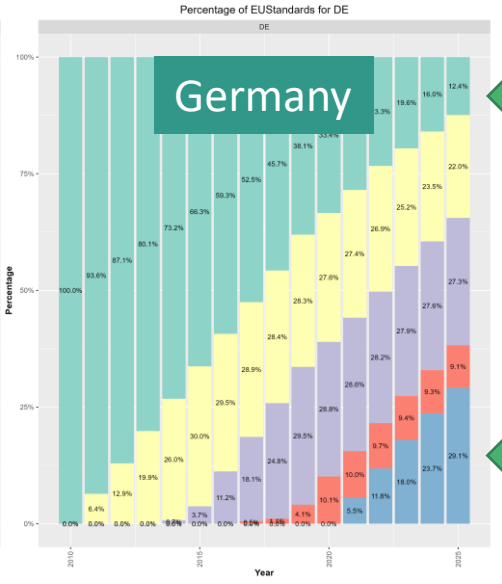
13%





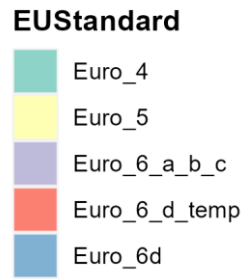






12,4%

29%



MODALES expected impacts & solutions

Impact areas	Hypotheses	Research questions	MODALES solution
AREA 1 Contribute to **reduction of emissions** from the existing combustion-engined car fleet	Expected average of 20-35% reduction in pollutant emissions for tampered/poorly maintained vehicles.	How much can MODALES help to increase the detection rate of tampered/poorly maintained vehicles?	Implement a poor maintenance and tampering detection measure
	For retrofitted vehicles, those reaching Euro VI standards will have a reduction of >60% in PMs and NO_X.	How well does the system perform in real use cases?	Apply diesel SCR + DPF retrofit systems on Euro IV & V heavy duty vehicles
	MODALES targets to a 20-30% reduction of non-engine PMs	What is the potential reduction of brake and tyre emissions due to MODALES?	App & training
AREA 2 Contribute to **reduction of unnecessary driver-induced emissions** though a better awareness by the public of their role in controlling polluting emissions	5-10% reduction of emissions by applying the MODALES low emission driving/riding guidelines	To what extent can vehicle emissions be reduced by using the MODALES app and training?	

MODALES solution 1: Regulation policy

Implement a poor maintenance and tampering detection measure :

- *Mandatory tampering detection using OBD data during the periodic inspections*
- *Penalties to vehicle owners when a manipulation of the vehicle data by an aftermarket software is detected*

Parameters used for Copert simulations:

- Targeted vehicles:
  - Light and heavy duty diesel vehicles
  - 10% of them being tampered (source icct-2022)
  - For every additional 1% of tampered vehicles, we have an increase of 2-3% of PM and NOx emissions for the whole fleet (source icct-2022)
- Detection rate:
  - 25% (lower scenario) or 50% (upper scenario)
  - From MODALES experiments (CERTH)

MODALES solution 2: Retrofits

Apply diesel SCR + DPF retrofit systems on Euro IV & V heavy duty vehicles

Parameters used for Copert simulations:

- Targeted vehicles:
  - Light, heavy duty & buses diesel vehicles
- Proportion of vehicles with SCR possible:
  - Light commercial vehicles Euro 4 & 5: 0,5% (lower scenario) or 1% (upper scenario)
  - Heavy duty trucks Euro IV: 5% (lower) or 10% (upper)
  - Heavy duty trucks Euro V: 25% (lower) or 50% (upper)
- Observed reduction with SCR:
  - CO: 50%
  - Nox: 70%
  - VOC: 50%
  - PM: 90%
  - From Modales experiments (Brembo)

MODALES solution 3: App & training

Widespread adoption of the MODALES App + online training

Parameters used for Copert simulations:

- Targeted vehicles:
  - Passenger cars only
  - No data yet available for light, heavy & buses
  - Petrol & diesel
- Observed & modelled emissions reduction:

What if European drivers are as efficient as Finnish ones?

	lower scenario	upper scenario	target	
CO	4.6%	18.6%	petrol	← Okan Univ. model
CO2	2.85%	11.4%	Petrol & diesel	← Okan Univ. model
NOx	11.75%	47%	diesel	← VTT experiments
PM 10 & 2.5	10.45%	41.8%	Petrol & diesel	← Okan Univ. model

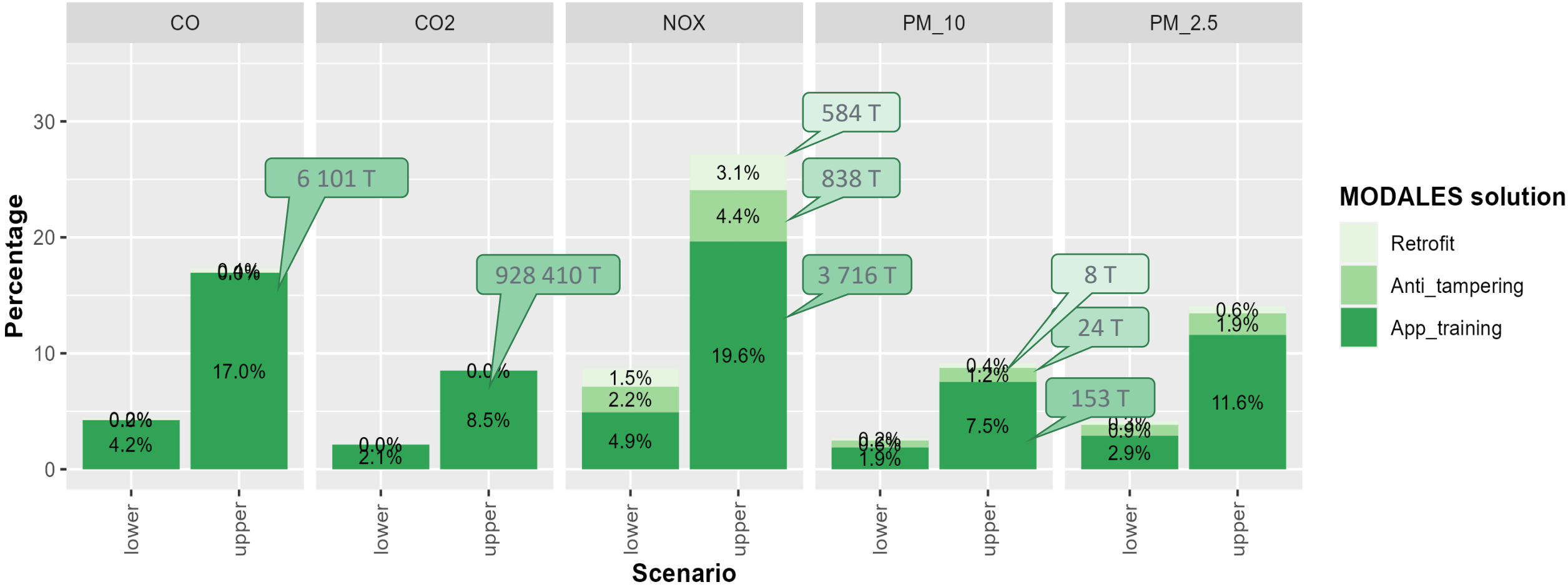
What if performances decrease on the long term?

- Upper scenario values were obtained using the “score vs emissions” model from Okan Univ. trained on VTT data and applied to Istanbul drivers
- Lower scenario designed to take into account the long term effect (well known in eco-driving): Effect divided by 4 after 6 months (literature study)

Results: Finland example

Estimated emissions percentage of reduction due to Modales solutions for the road transport system

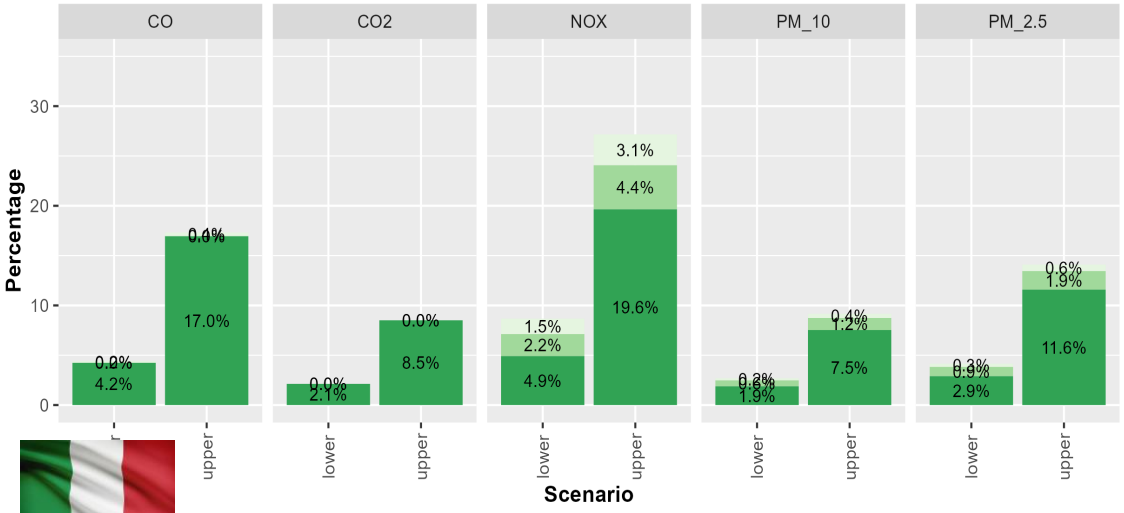
Per pollutant, Finland 2025.



Results: Finland, Spain, Italy, Turkey

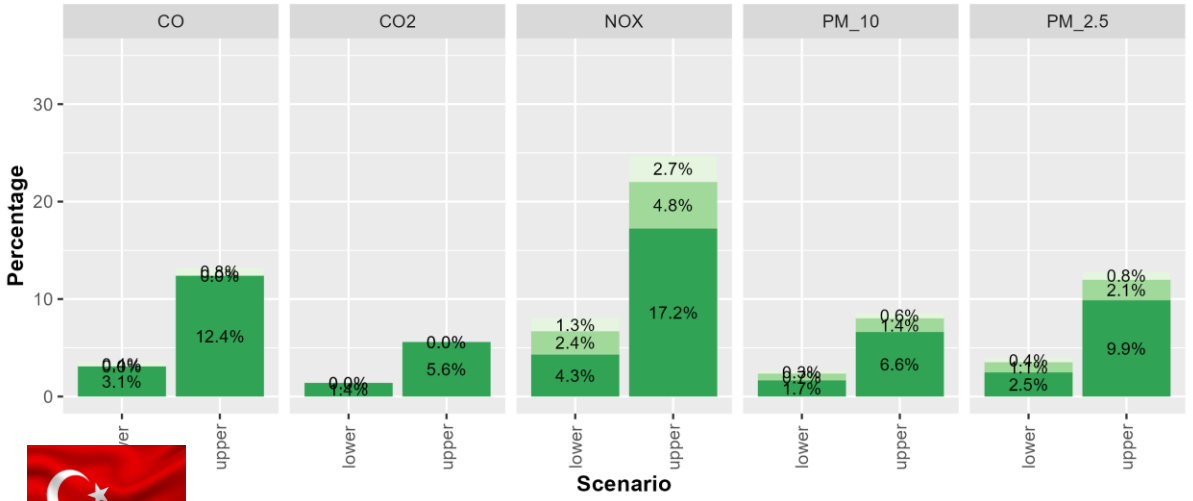
Estimated emissions percentage of reduction due to Modales solutions for the road transport system

Per pollutant, Finland 2025.



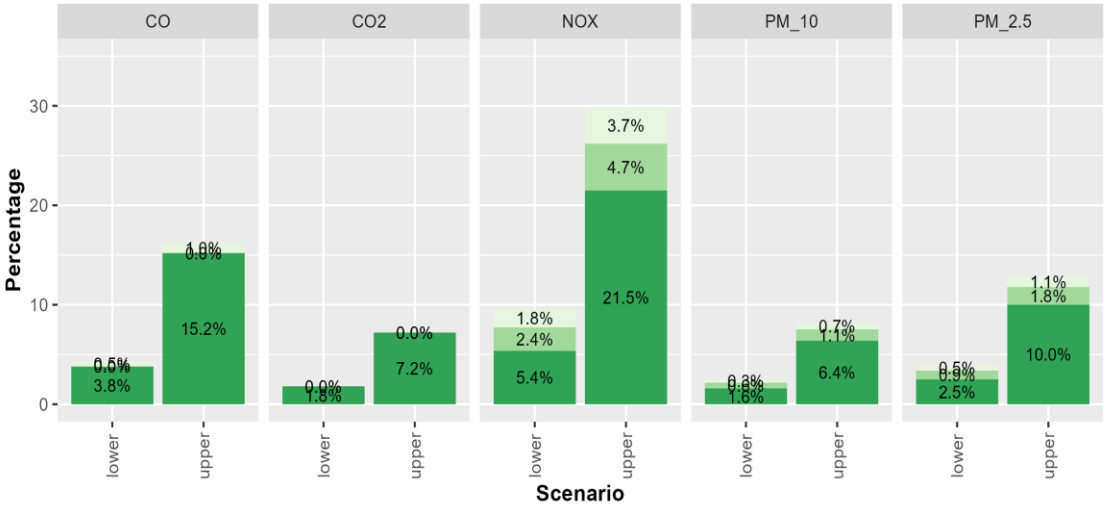
Estimated emissions percentage of reduction due to Modales solutions for the road transport system

Per pollutant, Spain 2025.



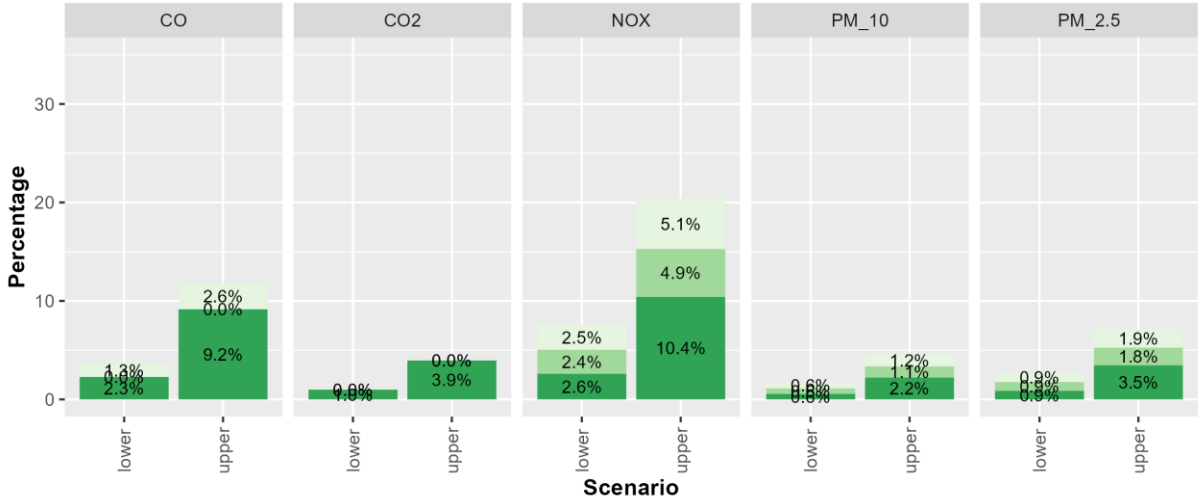
Estimated emissions percentage of reduction due to Modales solutions for the road transport system

Per pollutant, Italy 2025.

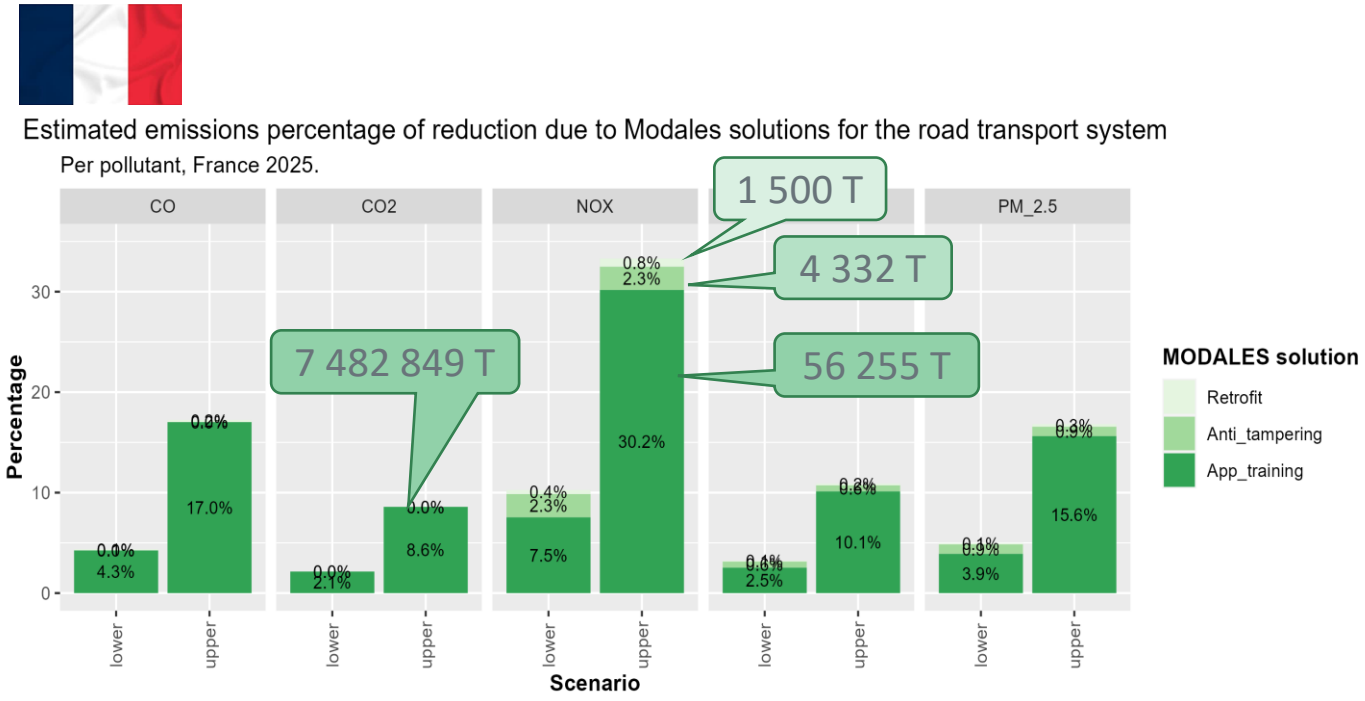


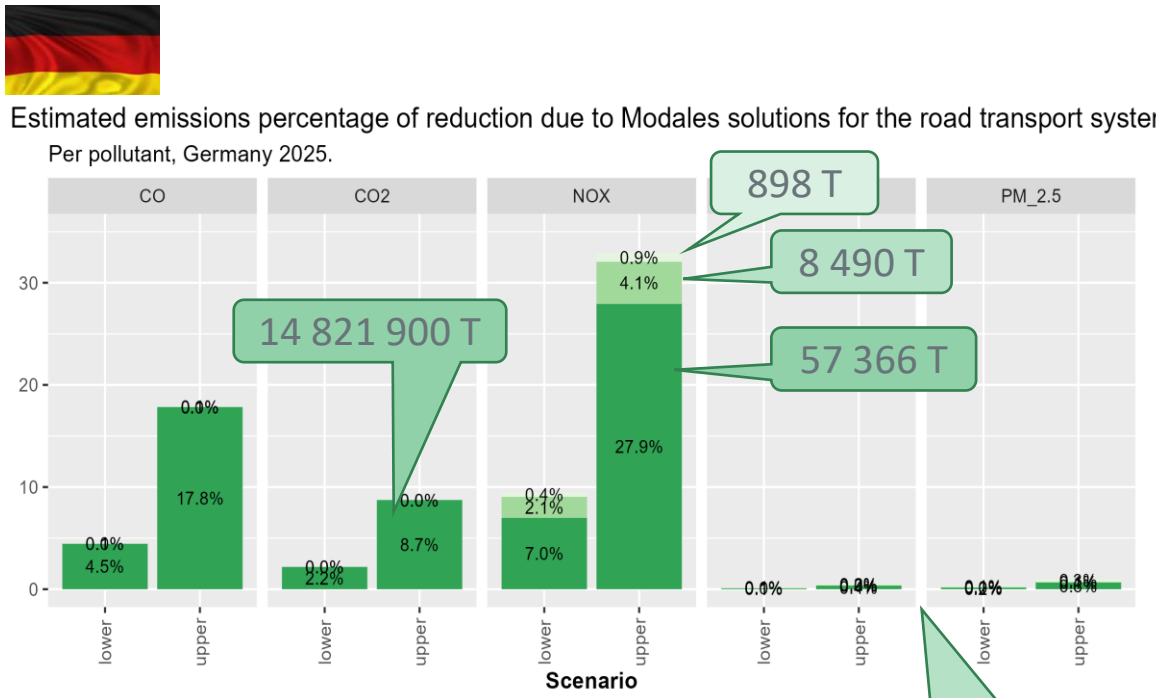
Estimated emissions percentage of reduction due to Modales solutions for the road transport system

Per pollutant, Turkey 2025.



Results: France, Germany





No passenger cars below Euro 5 -> no impact on PM's from Copert

These are early results:

- Only data from Istanbul & Helsinki for the app & training
- Final results in the deliverable available by the end of May 2023

- Results are country dependant
- Potential impact depends on the stock constitution

MODALES expected vs observed

Minimum across countries for the lower scenario

Maximum across countries for the upper scenario

Impact areas	Hypotheses	MODALES solution	Observed reduction
AREA 1 Contribute to **reduction of emissions** from the existing combustion-engined car fleet	Expected average of 20-35% reduction in pollutant emissions for tampered/poorly maintained vehicles.	Implement a poor maintenance and tampering detection measure	Individual tampered vehicle: reduction > 80% for NOx & PM **At the fleet scale :** **NOx [2.1% ; 4.8%]** **PM [0.6% ; 2.1%]**
	For retrofitted vehicles, those reaching Euro VI standards will have a reduction of >60% in PMs and NO_x.	Apply diesel SCR + DPF retrofit systems on Euro IV & V heavy duty vehicles	Individual retrofitted vehicle: Reduction > 70% for NOx, > 90% for PM **At the fleet scale:** **NOx [1.3% ; 5.1%]** **PM [0.3% ; 1.9%]**
	MODALES targets to a 20-30% reduction of non-engine PMs	App & training	Individuals: high variability across drivers **At the fleet scale:** **CO [2.3% ; 17%]** **CO2 [1% ; 8.7%]** **NOx [7% ; 30.2%]** **PM [0.6% ; 15.6%]**
AREA 2 Contribute to **reduction of unnecessary driver-induced emissions** though a better awareness by the public of their role in controlling polluting emissions	5-10% reduction of emissions by applying the MODALES low emission driving/riding guidelines		

Discussion

- Good potential of anti tampering measures
  - NOx reduction between 2.1% and 4.8%
  - PM reduction between 0.6% and 2.1%
- Greater potential of Retrofit for older light & heavy duty fleets
  - NOx reduction between 1.3% and 5.1% for countries with older stock
  - Limited or no impact for countries with newer stock (Germany)
- Very high potential for behaviour related changes through the App & training
  - Difficult to estimate the long term evolution with MODALES experiments
  - Lower scenario likely more reliable as a picture of long term benefits of such systems
  - The “upper” scenario most likely represents the best performances that could be obtained by an OEM embedded system

modales

Adapting driver behaviour for lower emissions

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LinkedIn MODALES project

Thank you

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