Adapting driver behaviour for lower emissions

"MODALES reveals: Mid-term results on the road to low emissions": webinar held on 28 May 2021

Summary report

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Legal disclaimer

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List of abbreviations and acronyms

MODALES partner abbreviations

Abbreviation	Meaning
ACASA/RACC	Automòbil Club Assistència SA (operating company of Royal Automobile Club of Catalonia / Reial Automòbil Club de Catalunya)
BREMBO	Freni Brembo SpA
BRIDG	Bridgestone Europe NV/SA
CEREMA	Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement
CERTH	Centre for Research and Technology Hellas / Ethniko Kentro Erevnas kai Technologikis Anaptyxis
DYNN	Dynnoteq Ltd
ERTICO	ERTICO – ITS Europe (MODALES project coordinator)
FIA	Fédération Internationale de l'Automobile
IRU	International Road Union
LEEDS	University of Leeds
LIST	Luxembourg Institute of Science and Technology
MICH	Manufacture Française des Pneumatiques Michelin
OKAN	İstanbul Okan Üniversitesi
PROV	Proventia Oy
SPARK	Spark Legal Network (EU) BVBA
VTT	Technical Research Centre of Finland Ltd / Teknologian Tutkimuskeskus VTT Oy

General abbreviations and acronyms

Abbreviation	Meaning
ACCT	Ammonia Creation and Conversion Technology
ASDS	Ammonia Storage and Delivery System
CAN bus	Controller Area Network
CO_2	Carbon Dioxide
DPF	Diesel Particulate Filter
EHC	Electrically Heated Catalyst
EPS	Environmental Protection System

Abbreviation	Meaning
EU	European Union
EV	Electric Vehicle
GDPR	General Data Protection Regulations
HMI	Human-Machine Interface
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LNT	Lean NO_X Trap
NO_X	Nitrogen Oxide
NRMM	Non-Road Mobile Machinery
OBD	On-Board Diagnostics
PEMS	Portable Emissions Measurement System
PM	Particle Matter
PN	Particle Number (ultrafine particles)
RDE	Real Driving Emissions
rpm	Revolutions per minute
SAE	Society of Automotive Engineers
SCR	Selective Catalytic Reduction
WLTP	Worldwide harmonised Light vehicle Test Procedure

1. Introduction

1.1. Project overview

The MODALES project works towards reducing air pollution from all types of on-road vehicles by encouraging adoption of low-emission driving behaviour and proper maintenance choice.

MODALES pursues a user-centric approach to address all of the challenges which on the one hand enhance low-emission practices and on the other hand suppress high-emission behaviour by researching, developing and testing a number of innovative and complementary solutions in four key areas (driver, retrofits, On-Board Diagnostics - OBD and inspection) in order to reduce vehicle emissions from three main sources: powertrain, brakes and tyres.

MODALES aims to modify user (driver) behaviour via dedicated training including a driver assistance app and awareness campaigns in order to support effective air quality improvement plans and enforcement strategies to be developed by local and national authorities.

To achieve this goal, MODALES is researching, developing and testing 13 innovation solutions, of which 11 are technical innovations, in order to substantially reduce vehicle emissions from the main sources given above, for passenger cars, light and heavy duty vehicles (buses and trucks) and Non-Road Mobile Machinery (NRMM).

The main activities of MODALES are:

- Measurement of real-world vehicle emissions and driving behaviour to produce accurate correlation between them using advanced mathematical and statistical techniques;
- Exploration of the most advanced technologies for retrofits designed to substantially reduce powertrain emissions from all types of vehicles and to validate their effectiveness under different real-world traffic and environment conditions, and by various drivers;
- Undertaking an in-depth analysis of OBD (On-Board Diagnostics), periodic inspection and legal issues on tampering in Europe to help regulatory authorities put in place effective anti-tampering legislation, and to help owners properly maintain their vehicles;
- Conducting low-emission user trials (with both driving and maintenance practices), supported by awareness campaigns, to enhance public engagement and help drivers better understand the impact of their driving and maintenance behaviours in all situations.

1.2. Mid-term webinar

A mid-term technical event was organised as one of the milestones of MODALES. Due to the COVID-19 situation, this event took place online as a half-day webinar.

The event was open to all interested stakeholders (registration required) and provided details of the project's achievements to date, with presentations from several members of the MODALES team.

It was promoted on the project website (news item and link to registration page here: https://modales-project.eu/registrations-are-open-for-modales-mid-term-results-on-the-road-to-low-emissions) as well as on partner media such as https://erticonetwork.com and on social media of partners (LinkedIn and Twitter). The project's Client – CINEA (Climate, Infrastructure and Environment Executive Agency of the European Commission) – also promoted the event on its social media.

2. Participation and Agenda

2.1. Registrations

A total of 58 people registered for the event, of which 45 were external to the MODALES consortium.

Most registrations (31) were from the education, science and research sector. Eleven were from industry or business, nine were from associations. Four were from public administrations and three were consultants.

Participants came from 16 countries, including 38 participants from EU Member States (Belgium, Croatia, Czech Republic, Finland, France, Germany, Italy, Lithuania, Luxembourg, Netherlands and Sweden) and 20 from other countries (China, Pakistan, Switzerland, UK and USA).

Parallel projects within the same European call were also represented:

- CARES – "City Air Remote Emission Sensing", https://cares-project.eu – represented by IVL, the Swedish Environment Institute
- DIAS – "Diagnostic Anti-tampering Systems", https://dias-project.com – represented by Aristotle University of Thessaloniki in Greece
- uCARe – "You Can Always Reduce Emissions because you care", www.project-ucare.eu – represented by TNO in the Netherlands.

Other projects and initiatives represented (or in which participants are/were involved) include:

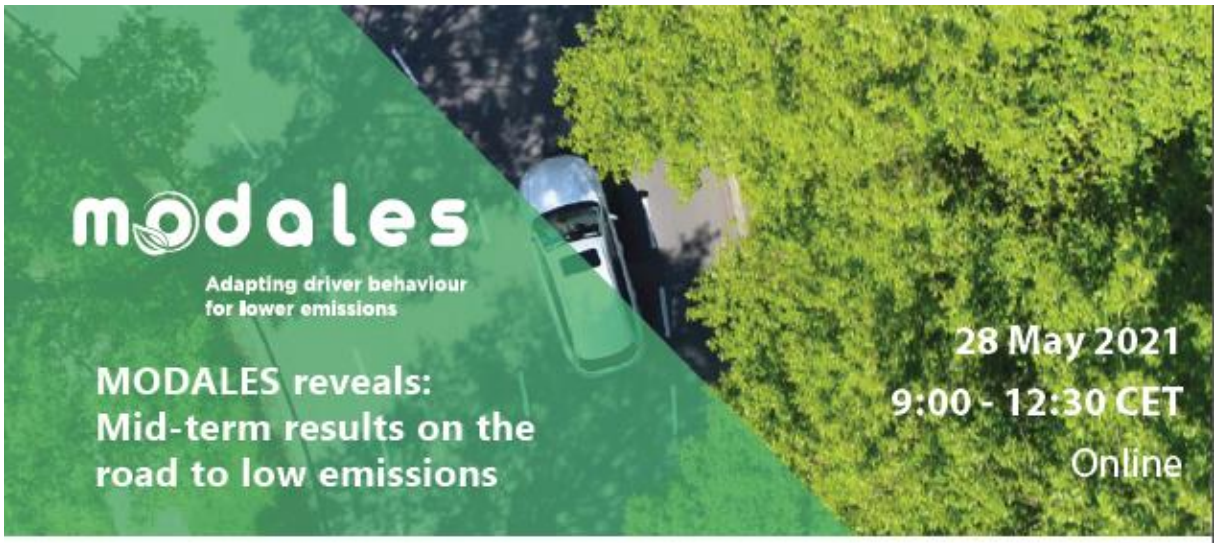
- 5G-Drive, https://5g-drive.eu
- 5G ROUTES – "5th Generation connected and automated mobility cross-border EU trials", www.5g-routes.eu
- eBussed – "Building capacities for European-wide e-bus deployment" (Interreg Europe), www.interregeurope.eu/ebussed
- Green NCAP, www.greenncap.com
- GVI – "Green Vehicle Index", www.gvi-project.eu
- IRU RoadMasters, www.iru.org/what-we-do/certification-standards/iru-roadmasters
- LuxTurrim5G, www.luxturrim5g.com
- PAsCAL – "Enhance driver behaviour and Public Acceptance of Connected and Autonomous vehicLes", www.pascal-project.eu

2.2. Participation

During the event, a total of 46 people attended (including speakers) and the average attendance at any one time was 40 people.

2.3. Agenda

The agenda is shown in the figure on the next page.



AGENDA

Session 1 | 9:00-10:35
Introduction and driving behaviour aspects: Chaired by Andrew Winder (ERTICO) MODALES Project Coordinator

9:00-9:20	Introduction to the project - Andrew Winder (ERTICO)
9:20-9:40	Impact of user behaviour - Juhani Laurikko (VTT, Technical Research Centre of Finland)
9:40 - 9:55	Low emission driving guidance and training - Ted Zotos (IRU, International Road Transport Union)
9:55-10:20	Low-emission driving app and demonstration - Sébastien Faye and Ramiro Camino (LIST – Luxembourg Institute of Science and Technology)
10:20-10:35	On-road trials with real users - Joan Domingo (RACC Mobility Club/ACASA)
10:35-10:50	BREAK

Session 2 | 10:50-11:50
OBD, Retrofits, Tampering and Inspection: Chaired by Dimitris Margaritis (CERTH)

10:50-11:00	Data access from On-Board Diagnostics (OBD) - Dimitris Margaritis (Hellenic Institute of Transport – CERTH/HIT)
11:00-11:15	Simulation of retrofits - Haibo Chen (Institute for Transport Studies, University of Leeds)
11:15-11:25	Real-world tests of retrofits - Arno Amberla (Proventia)
11:25-11:50	Tampering and inspection - Dimitris Margaritis (Hellenic Institute of Transport – CERTH/HIT) and Esther Tenge (Spark Legal Network)

Session 3 | 11:50-12:30
Discussion: Chaired by Jean-Charles Pandazis (ERTICO)

11:50-12:20	Questions and discussion - Moderator: Jean-Charles Pandazis (ERTICO)
12:20-12:30	Wrap up - Andrew Winder (ERTICO)

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www.modales-project.eu
#MODALESproject

Figure 1: Final Agenda

3. Event report

Please note that the slides are available separately in two pdf documents: one for Session 1 and another for Sessions 2 and 3.

3.1. Session 1: Introduction and Driving Behaviour aspects

3.1.1. Introduction to the project

Andrew Winder (ERTICO), the MODALES Project Coordinator, opened the event and presented the project's vision to reduce air pollution from all types of on-road vehicles (but especially older vehicles) by encouraging adoption of low-emission driving behaviour and proper maintenance choice.

He outlined the difference between eco-driving (the topic of previous research projects and also several commercially available applications or training services) and low-emission driving. Eco-driving targets a reduction in CO_2 emissions and fuel consumption by encouraging green driving behaviour. MODALES focuses on other air pollutants much more loosely correlated with CO_2, e.g.: NOx – Nitrogen oxides, O3 – Ground-level ozone, PM – Particle matter and PN – Ultrafine particles, as well as particle emission from brake and tyre wear (especially for heavier vehicles, including EVs and other newer models).

He presented the 12 main innovation areas of MODALES, as shown in Figure 2 below.

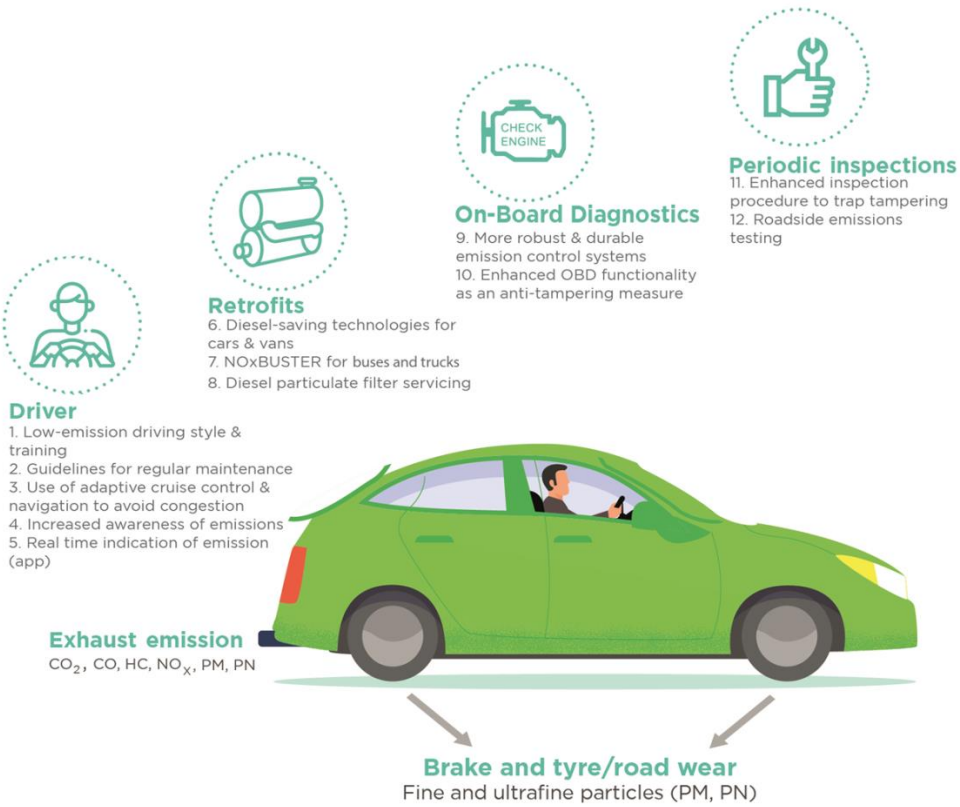

Figure 2: MODALES project innovation areas

3.1.2. Impact of user behaviour

Juhani Laurikko (VTT), MODALES' Technical Coordinator, presented the impact of user behaviours on exhaust emissions, brake and tyre wear. Partners Brembo and Bridgestone also contributed to this presentation, for brake and tyre aspects respectively.

Driving style experiments were undertaken by VTT to measure powertrain exhaust emissions from 15 drivers, each driving six different cars on a fixed route of 31 km to the west of Helsinki, featuring a mixture of urban, semi-rural and motorway sections. The cars were equipped with a Portable Emissions Measurement System (PEMS). Parameters collected included GPS position, distance travelled (km), road gradient (%), driving speed, engine power, engine speed (rpm), throttle position and exhaust emissions (CO, CO_2, NO, NO_2, NO_X, PN). Some significant differences in these outputs were found among different drivers, even when driving the same car (see accompanying presentation for details). There were also different consistencies between the first and second drive for each driver in a given car. Cumulative CO_2 and NO_X emissions were measured over the whole route, to identify sections of the route where for all drivers/cars the emissions are particularly high or low (effects of road features such as intersections, speed bumps and uphill sections). This data will be used to assess the dependency between driving parameters and tailpipe emissions.

Partner Brembo carried out brake emissions experiments using a brake dynamometer, with tests being done on a Ford Focus reference vehicle in Italy using the standard WLTP driving cycle (Worldwide Harmonised Light Vehicle Test Procedure) and a "mild" driving cycle based on the MODALES driving recommendations. During the mild cycle the brakes dissipate 20% less energy than in the case of the reference WLTP-brake cycle. The modified braking cycle based on MODALES guidelines resulted in a 50% reduction in brake emissions using the dynamometer equipment.

For tyres, partners Bridgestone and Michelin collected telemetry data (e.g. longitudinal acceleration, lateral acceleration and average speed), tyre rubber volume loss every 3 months/15 000 km, and odometer values at every measurement, using 75 vehicles comprising two different Toyota models (Prius and Auris) in Italy and Greece. This was done for the left-hand tyres (front and rear). Collected data was used to calibrate existing models and provide perceptions of key performance indicators on tyre wear.

Results of the above will be available in a public deliverable (D3.1 – Emission measurement) which will be available during summer 2021.

3.1.3. Low emission driving guidance and training

Ted Zotos (IRU) presented the MODALES approach to low-emission driving training. This builds on previous efforts (project and applications) on eco-driving, for which several applications now exist and which have been shown to achieve fuel savings of between 1% and 16.9%. Many drivers, especially professional drivers, are familiar with the concept of eco-driving. While eco-driving may also result in lower pollutant emissions, the main objective of it is to save fuel and reduce CO_2 emissions, whereas the focus of MODALES is on pollutant emissions from the exhaust, brakes and tyres. MODALES produced over 30 low-emission driving guidelines[1] from previous activities in the

[1] MODALES Deliverable 5.1: Guidelines for low-emission driving, December 2020. Available at https://modales-project.eu/deliverables

project[2], which were categorised as guidelines on pre-trip preparation and route choice, on driving, on maintenance, and additional tips.

Training in MODALES will cover the proposed trial sites and be directed at private car drivers, with an adapted version for professional drivers, taking into account that many of them have already received some sort of eco-driving training and also because certain pre-trip planning guidelines, such as route choice or driving at less congested times, are often not possible for professional drivers. It will cover driving behaviour, vehicle maintenance aspects (considering that for professional drivers, maintenance activities are normally the responsibility of the driver's employer, except for one-person businesses), and use of the low-emission driving app (described in the next presentation). Awareness campaigns will also seek to disseminate the easier-to-follow guidelines in a simple and engaging way to a wider audience.

Current work is focusing on a training courses manual (internal document to guide trainers and to provide a concept for online training material, such as videos). Short videos for virtual trainings will be developed over summer 2021 and a certification for pilot participants by MODALES is planned. Pre- and post-training evaluation on low-emission background and progress will be undertaken later in 2021 and an exploitation plan the training beyond MODALES will be done at the end of the project in 2022.

3.1.4. Low-emission driving app and demonstration

Sébastien Faye and Ramiro Camino (LIST) presented their work to date on a mobile (smartphone) assistant for low-emission driving. This started with the relevant data sources for different vehicle types, such as CAN bus, OBD and SAE J1939 (vehicle bus used in the commercial vehicle area for connection and communications), as well as the relevant data to be accessed (gear, accelerator and brake pedals, speed, rpm, acceleration, etc.). The project identified minimum OBD requirements and developed an app based on three modules: in-vehicle data collection, data interpretation, and recommendations to the driver. The app is currently in a beta testing phase and the full version with recommendations is expected in September 2021, available for Android and iOS.

The recommendations will include active ones (simplified, so as to minimise driver distraction) and passive ones (post-trip). An analysis was done on 26 existing trip planning, car monitoring and (eco-) driving applications – both prototypes from publicly-funded research projects and commercially available products – in order to position MODALES according to the project objectives (for example MODALES does not directly deal with eco-routing/navigation).

3.1.5. On-road trials with real users

Joan Domingo (ACASA/RACC Mobility Club) explained the upcoming on-road trials in MODALES. Limited ramp-up trials with 19 internal staff of project partners in Barcelona and Luxembourg have recently been completed and the experiences are being used to establish larger scale trials in seven European city-regions, with around 30-40 drivers per site. These will cover different age groups and genders, levels of driving experience and different types of car and also, in some sites, commercial vehicles or taxis.

[2] In particular, MODALES Deliverable 2.1: Variability of driving behaviours and Low-emission driving requirements, March 2020; and MODALES Deliverable 2.2: Real effectiveness of OBD inspection and maintenance, and retrofits, August 2020. Available at https://modales-project.eu/deliverables

The purpose of the trials will be to test the MODALES app and associated training with real drivers – to analyse the impact (including by user group and geographical location) to enable a final impact assessment, as well as to test the user reaction and acceptance. They will feature a baseline period (1 to 2 months, depending on distance driven) in which the app and an OBD dongle will be used to collect "normal" driving behaviour (not providing any guidance to the driver), followed by a treatment period after which the driver has received the training and updates the app so that it provides on-trip and post-trip advice. Drivers would drive according to their normal everyday needs and wishes; there are no specific routes to follow or other exercises.

Data will be anonymised so that only the local partner knows the driver's identity (for contact purposes) and not the team doing the data analysis. Care is taken to ensure personal data protection and privacy for drivers, in accordance with EU GDPR rules. Drivers will answer a small number of online questionnaires about their driving habits and reactions to the training and app.

Commercial vehicle operators (logistics, deliveries, buses, taxis) are invited to participate in the trials, which would allow their drivers to benefit from the training session, to give them feedback on driving behaviour and to be included in project promotion activities. Interested companies can contact Joan Domingo, the Coordinator Andrew Winder, or their local partner in the project.

3.2. Session 2: OBD, Retrofits, Tampering and Inspection

3.2.1. Data access from On-Board Diagnostics (OBD)

Dimitris Margaritis (CERTH) chaired this overall session. He outlined the availability and selection criteria of dongles for OBD data access, as well as their vulnerability to tampering. For the tampering aspect, MODALES is guided by output from the EU project DIAS.

3.2.2. Simulation of retrofits

Haibo Chen (LEEDS) showed different NO_X control technologies and presented a vehicle model including after-treatments, in which its emission sources are based on emission maps, with the signals of engine speed and torque from powertrain model as inputs. Performance comparisons between SCR and ACCT technologies were given. In summary, the pipe-out NO_X emission is not significantly affected by driving behaviour, but the engine-out emission is. Both SCR and ACCT are not efficient for low exhaust temperatures. More work is needed to understand how NO_X retrofits perform in real-time under different traffic and weather conditions, and on certain vehicles.

3.2.3. Real-world tests of retrofits

Arno Amberla (PROV) presented his company's analysis of NO_X emissions of retrofitted diesel-powered buses, fitted with emission monitoring telemetry. The technology is Proventia's NOxBUSTER® City DPF and SCR retrofit system, which was fitted to different makes of single-deck, double-deck and articulated buses in the UK and Germany. Retrofitting has been found to be an effective way to reduce emissions of heavy vehicles in cities. A rather direct correlation was found between ambient temperature and exhaust gas temperature (10°C difference versus 10°C difference). In this study, Euro 5 hybrids were operated at lowest speed routes. Electrification of buses moves these buses to faster lines and efficiency of retrofitted SCR systems improves.

3.2.4. Tampering and inspection

Dimitris Margaritis presented the technical aspects of tampering and inspection, including common inspection failures. Examples of mandatory periodic inspection data were given from two countries: Turkey and Finland. Four tampering techniques currently used for manipulating the environmental protection system (EPS) were outlined.

He described a test carried out by VTT in Finland on cars before and after servicing (oil filter, air filter and spark plugs).

Esther Tenge (SPARK) outlined the work done on legal issues relating to tampering. This comprised desk research on 14 European countries and a stakeholder survey. A wide discrepancy between countries exists both in terms of legal requirement on vehicle tampering and the severity of penalties/sanctions in case of violation of legal requirements.

There is no official data or research identified at national level on awareness of rules on tampering, although media coverage (such as "Dieselgate") could have increased awareness regarding rules on tampering. At national level, studies generally identify national systems as proportionate and globally efficient but some gaps in legislation were identified. Regarding the effectiveness of the enforcement of rules on tampering, issues mostly relate to the lack of severity of the sanctions and therefore a poor dissuasive effect in some countries.

3.3. Session 3: Discussion

3.3.1. Questions and discussion

Jean-Charles Pandazis (ERTICO) opened the discussion session, summarising that the presentations shown in this webinar illustrate the purpose and challenges we are facing with the MODALES project, as well as the different competences of our partnership to address this topic.

He invited written questions from the audience to the presenters, noting that in the second part of the morning (OBD, Retrofits, Tampering and Inspection) was more technical than the first session.

The main points of discussion were as follows.

General question:

1. How does MODALES take into account the results from previous and on-going projects and how does it distinguish itself from previous eco-driving initiatives?

- *Response:* There are quite some overlaps between eco- and low-emission driving. MODALES will use tips and results from previous eco-driving projects. Two MODALES reports: Deliverable 2.1 "Variability of driving behaviours and Low-emission driving requirements" and Deliverable 5.1 "Guidelines for low-emission driving"[3] show how we took into account previous knowledge. Furthermore, low-emission driving is not necessarily opposed to eco-driving, but rather something that can be added on top of eco-driving, enhancing it by taking into account additional factors. One of the challenges however is to learn what the differences are (and how much difference there is) between behaviour needed to reduce fuel use and CO_2 emissions (eco-driving) and that needed to reduce pollutant emissions such as NO_X. Sometimes

[3] MODALES D2.1 and D5.1 are both available at https://modales-project.eu/deliverables, under WP2 and WP5 respectively

there might be a contradiction between an eco-driving recommendation and a low-emission driving one. One of the future roles of the project is to increase knowledge about such differences and propose appropriate compromise solutions, which may differ by vehicle type and propulsion system.

Questions on impact of user behaviour:

2. In the powertrain emissions experiments (presentation by Juhani Laurriko) , were the drivers instructed to drive in a certain style (e.g. “mild”, “average”, “aggressive”), or were they told to drive as they always do?

- *Response:* They were told to drive in their normal way, as they always do. No specific instructions were given.

3. It was mentioned in Juhani Laurriko’s presentation that the routes and driving times were chosen in that way that the driving behaviour will not be affected too much by the traffic. This will result in higher differences in driving behaviour than for dense traffic or heavy traffic load. How does MODALES ensure that generalised conclusions can be drawn from the results?

- *Response:* There were not many possibilities to understand the effects of different traffic situations on the driver. However, one part of the test was to analyse the extent to which drivers replicated their behaviour on their first and second circuits in immediate succession: often when there was a difference this was due to a traffic feature (e.g. red traffic lights, queue, etc.).

4. Has the project investigated how the average emissions from the real-world measurements correspond with official statistics or type approval values?

- *Response:* Type approval values are included in the presentations of Juhani Laurikko (for PEMS tests) and Dimitris Margaritis (for maintenance).

5. Can you indicate the level of repeatability/reproducibility of RDE (real driving emissions) testing? In particular with respect to changing traffic and weather conditions?

- *Response:* For the tests near Helsinki, VTT tried to use hours when traffic is light, to minimise changes to conditions. Having different drivers drive each of the cars on the same route twice in succession helped illustrate which differences were due to the driver, which ones due to the vehicle and which were due to circumstances during the drive (resulting in a significant difference in emissions between the first and second run for the same driver in the same car).

6. For the brake emissions, how were exactly the particles collected and separated from the particles in ambient air (background particle emissions)? Same question for tyre particles.

- *Response:* The brake emission measurement was in laboratory conditions, with filtered ambient air. For tyres, particle emissions were not measured directly but rather tyre-wear (mass loss).

Questions on the driving app:

7. Is driver distraction prevented while driving with the app?

- *Response:* The app can be configured to give minimal information/advice during driving and more feedback post-trip. Distraction should be no more than other in-car systems like navigation, however this is aspect is not within the scope of MODALES: it has already been covered in other projects such as ecoDriver (EU FP5 project which ended in 2016, in which some MODALES partners were involved). This project dealt with HMI issues such as ergonomics and driver distraction of different interfaces (integrated into the vehicle and smartphone/tablet based), so MODALES is not repeating this work but taking into account its results. In the user trials, feedback questionnaires will ask the users about distraction issues in order to assess this issue and propose post-project recommendations.

8. How do you deal with privacy issues, e.g. domicile of the user?

- *Response:* In the full trials we will not use GPS tracking so we will not know e.g. where the user goes back to every evening. Users will be pseudonymised so the team collecting data (LIST in Luxembourg) only knows the city where the user is and their gender and age group, not their identity. While GPS may be enabled, this is just to enable the app to provide guidance based on the context of the driver's situation (road type and geometry, urban or rural, etc.) and indicators of this kind are stored, but not geographical positioning information. The MODALES app is not a navigation application. For retrofit data collected from bus operations by Proventia, the drivers are company drivers and the data collected relates to the vehicle, not the driver.

Questions on retrofits:

9. Based on the real-world NO_X emission data collected from the retrofitted buses in London, what are the most influencing factors that affect the efficiency of the after-treatment system?

- *Response:* Temperature is the main factor on emissions. Sometimes temperature and driving speed have a correlation. In a traffic jam with very slow speeds then the grams per km emissions will be high but they will not be high in terms of grams per hour.

Questions on maintenances:

10. Studies show that vehicle maintenance is very important for emission control. Does the data analysed in MODALES support such a claim? If not, why?

- *Response:* There were slight differences in the test results (just a few vehicles) e.g. before and after cleaning or renewing the particulate filter (DPF), so there is some effect but not huge. However if you look into larger scale monitoring for maintenance, it is a matter also of safety so the overall effects of good maintenance practice could be a lot greater. Future project work will extrapolate data from test results to assess the effects. Also, the project was not able to find and test vehicles that have been very badly treated and not properly maintained, so in these bad cases then the effects of maintenance will be much more important.

3.3.2. Wrap up

Andrew Winder concluded the webinar by highlighting next events where MODALES will be presented (ITS Spanish Congress in Madrid, July 2021, and ITS World Congress in Hamburg, October 2021). Other online events such as webinars focusing on more specific technical results will be organised where appropriate.

Participants are encouraged to follow the project website, www.modales-project.eu and also social media: in particular all are welcome to join the MODALES project LinkedIn group and initiate discussions there or highlight aspects related to the themes of this project.

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