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## **MODALES D5.2: Functional specifications**

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## Adapting driver behaviour for lower emissions

# MODALES D5.2: Functional specifications

<b>WORK PACKAGE</b>	WP5: Guidelines and tools for low emission training
<b>TASK</b>	T5.2: Functional specifications of tools
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<b>Authorised by (Quality Manager):</b>	Jean-Charles Pandazis	ERTICO	02/12/2020
<b>Submitted by (Project Coordinator):</b>	Andrew Winder	ERTICO	02/12/2020

## Revision and history chart

Version	Date	Main author	Summary of changes
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<b>0.3-0.5</b>	17/09/2020	Neamah Hasan Al Naffakh, Sébastien Faye	Successive updates of the document with regular consultation of project partners. Specific work on features, description of tools, data collection, technical specification and GUI elements.
<b>0.6</b>	20/10/2020	Dimitris Margaritis, Nikos Dimokas	Specification of the web dashboard.
<b>0.7</b>	20/10/2020	Ramiro Camino, Sébastien Faye	Added screens and mobile app use cases.
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## Legal disclaimer

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## List of abbreviations and acronyms

Abbreviation	Meaning
<b>AI</b>	Artificial Intelligence
<b>API</b>	Application Programming Interface
<b>CMT</b>	Core Management Team
<b>CSS3</b>	Cascading Style Sheets
<b>DALED</b>	Driving Assistance app for Low-Emission Driving
<b>DoA</b>	Description of Action
<b>EC</b>	European Commission
<b>EOBD</b>	European On-Board Diagnostics
<b>EU</b>	European Union
<b>FTP</b>	File Transfert Protocol
<b>GPS</b>	Global Positioning System
<b>HTML5</b>	HyperText Markup Language
<b>ICT</b>	Information and Communication Technologies
<b>INEA</b>	Innovation and Networks Executive Agency (agency of the European Commission)
<b>JSON</b>	JavaScript Object Notation
<b>KPI</b>	Key Performance Indicator
<b>ML</b>	Machine Learning
<b>NOx</b>	Nitrogen oxides
<b>NRMM</b>	Non-Road Mobile Machinery
<b>OBD</b>	On-board diagnostics
<b>OS</b>	Operating System
<b>PCA</b>	Principal Component Analysis
<b>RDBMS</b>	Relational Database Management System
<b>REST</b>	Representational State Transfer
<b>RPM</b>	Revolutions Per Minute
<b>t-SNE</b>	t-distributed Stochastic Neighbour Embedding
<b>URL</b>	Uniform Resource Locator
<b>WCAG</b>	Web Content Accessibility Guidelines
<b>WP</b>	Work Package
<b>XML</b>	Extensible Mark-up Language



## Executive Summary

This deliverable is part of Work Package 5 "Guidelines & tools for low emission training," one of the project's five technical work packages. Furthermore, this deliverable is the result of Task 5.2. "Functional specifications of tools," which aims at defining the specifications to develop MODALES' mobile app and web dashboard in Task 5.3. The aim of these tools is to collect and analyse the driving patterns of individuals to adjust a user's driving style, with a specific aim on emission reduction. To achieve that, relevant user information such as accelerometer, gyroscope, location and OBD data will be collected transparently and continuously for the sake of developing a Driving Assistance tool for Low-Emission Driving (current working name: DALED). Based on the collected information, the proposed system would aim to provide two types of recommendations. On one hand, active recommendations will offer straightforward recommendations while the driver is on the way, which would reduce high-emission driving styles by providing immediate corrective actions. On the other hand, passive recommendations will be about analysing and understanding a user's driving behaviour patterns and contextual information (e.g., on traffic jams, weather) to generate a post-driving report that could be used for encouraging users for safe driving practices and possibly offer rewards for good driving behaviour.

The present specification document includes use-cases, mock-ups of graphical interfaces, development timelines, architecture designs, analysis of required technologies, data definitions, and the connection with the various theoretical aspects defined in previous deliverables. It is broken down as follows:

- This document starts with an introduction, which recalls the project's objectives, states the deviations from the Declaration of Action, and delimits this deliverable's scope.
- The background section analyses and compares the most popular smartphone apps related to car monitoring or emissions reduction. It includes a study that employs clustering for grouping existing apps. It then offers recommendations for developing the project based on the predicted cluster for our future mobile app.
- Based on the knowledge acquired from the second section, and building on the project's objectives, the next section presents the functionalities that are to be developed, i.e., the actions a user can perform by interacting with each of our tools. These actions are described with clear use-cases, along with a diagram that connects them.
- The next section enumerates all the hardware and software requirements for the development of the tools. It proposes a high-level system architecture and states security and privacy concerns. Furthermore, it presents details about the experimentation, testing, and deployment processes.
- The data specification section describes the factors related to the environment, vehicles, and users that the mobile app will estimate and analyse to offer precise and coherent driving recommendations. Additionally, the section enumerates parameters, sources, and methodologies related to the data collection.
- The next section focuses on user recommendations, how to generate them, and how to incentivise users to follow them (e.g., by implementing gamification).
- The graphical user interface section describes the visual elements for both tools and presents the mobile app's first mock-ups.
- Finally, the conclusion section offers closing remarks.



As of November 2020, it should be noted that some of the parameters that could influence the tools' development are unknown. Most of them will be determined empirically with the start of the experimental campaigns in 2021. This deliverable therefore serves as an initial guide proposing an approach for developing the project tools, which will be adjusted throughout the project. The definitive parameters will be detailed in an appendix provided along with the mobile app at its final release (Month 24).

# 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 addressing all 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 several innovative and complementary solutions in four key areas (driver, retrofits, EOBD and inspection) in order to reduce vehicle emissions from three main sources: powertrain, brakes and tyres.

The scope of vehicles covered comprises 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 OBDS, 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 one-year long 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. Scope

This deliverable is part of Work Package 5 (WP5) on **Guidelines and Tools for Low-Emission Training**, which is one of the five technical WPs of MODALES (the two "non-technical" WPs include WP1 on Project Management and WP7 on Awareness, Communication and Dissemination). The other four "technical" WPs that are directly connected with WP5 are the following:

- **WP2: Defining low-emission factors**, which explores driving behaviour variability using existing available data. This WP delivers a first approach on driving behaviour patterns and powertrain, brake and tyre emissions. It also addresses the state-of-the-art in retrofits, inspection and maintenance (I/M) and legal issues regarding tampering in various EU Member States. [Link with WP5](#): inputs from T2.1, T2.2 to develop the guidelines (T5.1) and therefore the mobile app and the trainings (T5.5).
- **WP3: Impact of user behaviours**, which undertakes a series of measurement campaigns to establish the interconnection between driving behaviour and powertrain exhaust emissions, as well as fine particulates from brakes and mass-loss from tyres. Measurement campaigns are also

carried out to address the impact of poor maintenance and deliberate tampering of the emissions control system. Link with WP5: inputs from T3.5 to develop the guidelines and implement part of the profiling methods in T5.1-T5.3.

- **WP4: Effectiveness of inspections and depollution systems**, which uses the findings of WPs 2 and 3 as a basis to investigate and propose solutions that will contribute to emission monitoring via the EOBD protocol and systems that detect lack of maintenance and tampering. It also investigates the potential of enhancing existing retrofit systems. Link with WP5: inputs from T4.1 to T5.2-T5.3 to integrate all the necessary data into the mobile app.
- **WP6: User trials and evaluation**, develops an evaluation plan and to test and evaluate with real-world trials the functionality of the innovations developed in MODALES, their effects on driver acceptance and performance, and their potential wider impact (their predicted overall effects on vehicle emissions). Link with WP5: the mobile app will be used as the main tool for T6.1, T6.2, T6.3.

The figure below shows how this deliverable fit in the project and highlights related deliverables which will consider the content of this one.



	Year 1		Year 2		Year 3	
	2019	2020	2021	2022	2023	2024
 <b>This deliverable</b>						
 <b>Related deliverable</b>						
<b>Work Packages</b>						
WP1 - Project Management						
WP2 - Knowledge of low-emission factors						
<b>WP3 - Impact of user behaviours</b>						
D3.1 Emission measurements						
D3.2 Correlation of user behaviour variability with emissions						
<b>WP4 - Effectiveness of inspections and depollution systems</b>						
D4.1 Recommendations for a broader use of OBD						
D4.2 Recommendations for anti-tampering and an improved mandatory vehicle inspection						
D4.3 Retrofit solutions for road vehicles						
<b>WP5 - Guidelines &amp; tools for low emission training</b>						
D5.1 Guidelines for low-emission driving						
D5.2 Functional specifications						
D5.3 Mobile application (final version)						
D5.4 Experimental tests results and initial feedback on user acceptance						
D5.5 Training courses manual for low-emission driving						
WP6 - User trials and Evaluation						
WP7 - Awareness, communication and dissemination						

Figure 1: D5.2 Functional Specifications in the context of related MODALES deliverables

### 1.2.1. MODALES WP5 on Functional Specifications

The first mission of WP5 is to ensure the link between the theoretical aspects of the project and their validation and use for experimentation (WP6) and awareness campaigns (WP7). To do so, WP5 considers the results of all the WPs mentioned above, with the aim of (a) defining guidelines for low-emission driving and (b) defining tools to monitor and improve driving behaviours resulting in

emission reductions. In this context, a mobile app will be developed as a Driving Assistance tool for Low-Emission Driving (current working name: DALED). It will be complemented by a web dashboard addressed to public and local authorities, providing them with a statistical overview of the data collected in WP6. DALED will be developed and tested in this WP. Finally, the guidelines will be used as input for training courses, which will be designed to ensure a consistency with existing learning processes and serve as input for on-road trials and awareness campaigns.

WP5 is broken down into 5 tasks:

- **T5.1 Guidelines for low-emission driving.** Objective: create a reference list of good and bad practices for low-emission driving, their impact and the actions the user could take to improve them.
- **T5.2 Functional specification of tools.** Objective: specify the tools to be developed in T5.3, including: The mobile application and its modules, its operating logic, HMI aspects, the centralised web application.
- **T5.3 Low-emission driving assistance tools.** Objective: develop all the elements specified in T5.2 into advanced prototypes.
- **T5.4 Testing and technical verification of tools.** Objective: test, verify and deploy all the software developed and integrated during the WP. This Task will also calibrate and technically validate the application.
- **T5.5 Developing training for low-emission driving.** Objective: use the guidelines, tools and all the knowledge accumulated in WP5 as an input to design the training courses carried out in WP6. Tailor-made training courses will be derived from guidelines, for various road vehicle users (including junior drivers, taxi drivers, driving schools, etc.), types and configurations of vehicles.

### 1.2.2. Scope and intended audience of this deliverable

The content of this deliverable is confidential, i.e. reserved for the consortium and the European Commission. This is notably linked to the fact that this document provides information related to the exploitation strategy of the project. However, an extended summary is provided for other readers.

## 1.3. Deviations from the Description of Action

### 1.3.1. Alignment with the DoA and content deviations

This deliverable is aligned with the content of the DoA. However, as introduced above, it is worth noting that at the time of submitting this document, many parameters are not yet known, and some will need to be adjusted and validated empirically during data collection campaigns and with users in 2021. This includes in particular gamification, which is not the only possible incentivisation strategy.

According to the DoA, this task had to specifying the tools to be developed in T5.3., including:

- *“The mobile application, composed of data collection, interpretation and recommendation modules.”* → This aspect is addressed in a transversal way throughout the document. Data aspects are developed in Section 5, while the last two are developed in Section 6. Section 4 lists the requirements for all of these elements.

- *“The operating logic of the mobile application, where gamification-based techniques will be specified (the “game logic”). It is aimed at including competition opportunities between user groups and a virtual ecoresponsibility coin to reward users.”* → Gamification is described in Section 6.2. It is one of the aspects that will have to be validated in parallel with WP6 when the first data collections will start in 2021, since several strategies (and not only gamification) are possible and cannot be selected/validated at the time of writing this deliverable. End-users should be consulted first, and progress made on T6.2. The comparison study (Section 2) will also serve as a basis for adjusting these parameters.
- *“The appearance and possible interactions with the user, in order to combine the two previous points.”* → The features of the tools are listed in section 3, while the first mock-ups of the mobile app are presented in section 7.
- *“A web interface, which will be able to collect and show usage statistics and relevant indicators in order to serve as an input for WP6 and WP7.”* → This aspect is detailed transversally in the document, in the same way as the mobile app. Sub-sections dedicated to the web interface are set up.

### 1.3.2. Time deviations

This deliverable was submitted with two months delay (Month 15 rather than Month 13 of the project) since alignment was needed with D5.1 Guidelines on low-emission driving, also due in Month 15.

## 2. Background

This section presents an analysis of the “state of the art” for smartphone apps related to car monitoring or to emissions reduction. The apps were selected according to both partner experience and exploratory analysis of the app marketplaces using keywords such “ecodriving” or “car monitoring”. The selected apps (26) are not an exhaustive overview of all the available apps, but according to consortium expertise, they constitute a representative sample.

These 26 apps have been documented using 26 variables, and a statistical analysis has been performed to discover clusters of homogeneous apps, together with their main characteristics. The complete list of apps along with the list of websites used to gather the data are listed below.

**Table 1: List of the 26 apps analysed, together with the websites used to collect the data.**

App name	Information (Owner name and/or project name and/or website)
ecoDriver	ecoDriver H2020 project <a href="http://www.ecodriver-project.eu/">http://www.ecodriver-project.eu/</a> <a href="https://www.sciencedirect.com/science/article/pii/S0968090X15001679">https://www.sciencedirect.com/science/article/pii/S0968090X15001679</a>
Geco air	IFP Energies nouvelles <a href="https://play.google.com/store/apps/details?id=com.ifpen.gecoair&amp;hl=fr&amp;gl=US">https://play.google.com/store/apps/details?id=com.ifpen.gecoair&amp;hl=fr&amp;gl=US</a> <a href="https://www.gecoair.fr/home_en/">https://www.gecoair.fr/home_en/</a>
Pace	PACE Telematics GmbH <a href="https://www.pace.car/en">https://www.pace.car/en</a>
OBD Fusion TouchScan	OCTech, LLC <a href="https://www.obdsoftware.net/software/obdfusion">https://www.obdsoftware.net/software/obdfusion</a> <a href="https://play.google.com/store/apps/details?id=OCTech.Mobile.Applications.TouchScan">https://play.google.com/store/apps/details?id=OCTech.Mobile.Applications.TouchScan</a>
Torque	Ian Hawkins <a href="https://torque-bhp.com/">https://torque-bhp.com/</a> <a href="https://play.google.com/store/apps/details?id=org.prowl.torque">https://play.google.com/store/apps/details?id=org.prowl.torque</a>
Dash Command	Palmer Performance Engineering <a href="https://www.palmerperformance.com/products/dashcommand/">https://www.palmerperformance.com/products/dashcommand/</a> <a href="https://play.google.com/store/apps/details?id=com.palmerperformance.DashCommand&amp;hl=fr&amp;gl=US">https://play.google.com/store/apps/details?id=com.palmerperformance.DashCommand&amp;hl=fr&amp;gl=US</a> <a href="https://apps.apple.com/app/id321293183">https://apps.apple.com/app/id321293183</a>
Carista ODB2	Carista <a href="https://play.google.com/store/apps/details?id=com.prizmos.carista&amp;hl=en">https://play.google.com/store/apps/details?id=com.prizmos.carista&amp;hl=en</a> <a href="https://apps.apple.com/app/id954363569">https://apps.apple.com/app/id954363569</a> (based on <a href="https://caristaapp.com/">https://caristaapp.com/</a> )
Changers CO2 Fit	<a href="https://play.google.com/store/apps/details?id=com.blacksquared.changers&amp;hl=fr">https://play.google.com/store/apps/details?id=com.blacksquared.changers&amp;hl=fr</a>
Conduire par MAIF	MAIF (French insurance company) <a href="https://play.google.com/store/apps/details?id=com.drivequant.testsofa&amp;hl=fr">https://play.google.com/store/apps/details?id=com.drivequant.testsofa&amp;hl=fr</a>
ecoconduite	TomTom Webfleet optidrive360 <a href="https://play.google.com/store/apps/details?id=com.kelnomad.ecoconduite&amp;hl=fr">https://play.google.com/store/apps/details?id=com.kelnomad.ecoconduite&amp;hl=fr</a> <a href="https://www.webfleet.com/en_gb/webfleet/products/webfleet/features/optidrive360/">https://www.webfleet.com/en_gb/webfleet/products/webfleet/features/optidrive360/</a>
ecoDrive	<a href="https://play.google.com/store/apps/details?id=be.ats.ecodrive&amp;hl=fr">https://play.google.com/store/apps/details?id=be.ats.ecodrive&amp;hl=fr</a> Actia telematics systems Only accessible for Telefleet Ecoconduite clients
Lowbrasys	Lowbrasis european project a LOW environmental impact BRAke SYStem
RideMyRoute Cogistics	CERTH/HIT <a href="https://apps.apple.com/us/app/ridemyroute/id1210706592?ls=1">https://apps.apple.com/us/app/ridemyroute/id1210706592?ls=1</a>
Optitruck	CERTH/HIT
AUTOPILOT	CERTH/HIT: iOS: <a href="https://apps.apple.com/us/app/autopilotvru/id1413711648">https://apps.apple.com/us/app/autopilotvru/id1413711648</a> CERTH/HIT:

App name	Information (Owner name and/or project name and/or website)
	Android: <a href="https://play.google.com/store/apps/details?id=autopilot.certh.gr.pedestrian">https://play.google.com/store/apps/details?id=autopilot.certh.gr.pedestrian</a>
ConfortDelGro Eye	Greatherthan <a href="https://greaterthan.eu/projekt/">https://greaterthan.eu/projekt/</a> <a href="https://play.google.com/store/apps/details?id=org.leanportal.delgro&amp;hl=fr">https://play.google.com/store/apps/details?id=org.leanportal.delgro&amp;hl=fr</a>
greenMeter	<a href="http://hunter.pairsite.com/greenmeter/">http://hunter.pairsite.com/greenmeter/</a>
ECO-Driving Speedometer	<a href="https://play.google.com/store/apps/details?id=com.eastcoders.speedometer&amp;hl=en_US&amp;gl=US">https://play.google.com/store/apps/details?id=com.eastcoders.speedometer&amp;hl=en_US&amp;gl=US</a> East Software Coders
ecoRoute (Garmin)	Garmin <a href="https://buy.garmin.com/fr-CA/CA/p/38354">https://buy.garmin.com/fr-CA/CA/p/38354</a>
Kiwi OBD	PLX Devices <a href="https://apps.apple.com/us/app/kiwi-obd/id1317045971">https://apps.apple.com/us/app/kiwi-obd/id1317045971</a> <a href="https://play.google.com/store/apps/details?id=com.plxdevices.galileo.kiwi_obd">https://play.google.com/store/apps/details?id=com.plxdevices.galileo.kiwi_obd</a>
Harrys Lap Timer	Harald Schlangmann <a href="https://www.gps-laptimer.de/">https://www.gps-laptimer.de/</a> <a href="https://apps.apple.com/app/harrys-laptimer-petrolhead/id338257907">https://apps.apple.com/app/harrys-laptimer-petrolhead/id338257907</a> <a href="https://play.google.com/store/apps/details?id=com.harrys.laptimerpro">https://play.google.com/store/apps/details?id=com.harrys.laptimerpro</a>
InCarDoc formerly OBD Car Doctor	PNN Soft <a href="https://play.google.com/store/apps/details?id=com.pnn.obdcardoctor_full">https://play.google.com/store/apps/details?id=com.pnn.obdcardoctor_full</a> (Pro) <a href="https://play.google.com/store/apps/details?id=com.pnn.obdcardoctor">https://play.google.com/store/apps/details?id=com.pnn.obdcardoctor</a> (free) <a href="https://apps.apple.com/us/app/obd-car-doctor/id652142348">https://apps.apple.com/us/app/obd-car-doctor/id652142348</a>
OBD Auto Doctor	Creosys Ltd (Riku Pelander) <a href="https://play.google.com/store/apps/details?id=com.obdautodoctor&amp;hl=fr&amp;gl=US">https://play.google.com/store/apps/details?id=com.obdautodoctor&amp;hl=fr&amp;gl=US</a> <a href="https://apps.apple.com/fr/app/obd-auto-doctor/id908897183">https://apps.apple.com/fr/app/obd-auto-doctor/id908897183</a>
Shift OBD	Hondata (ali feili) <a href="https://shift-obd2.firebaseio.com/android_main.html">https://shift-obd2.firebaseio.com/android_main.html</a> <a href="https://play.google.com/store/apps/details?id=com.sasanian.shiftobd&amp;hl=fr">https://play.google.com/store/apps/details?id=com.sasanian.shiftobd&amp;hl=fr</a> <a href="https://shift-obd2.firebaseio.com/ios_main.html">https://shift-obd2.firebaseio.com/ios_main.html</a> <a href="https://apps.apple.com/fr/app/shift-obd/id1516559383">https://apps.apple.com/fr/app/shift-obd/id1516559383</a>
aLOBD Smog PreCheck	<a href="https://play.google.com/store/apps/details?id=com.al.obd2.smog">https://play.google.com/store/apps/details?id=com.al.obd2.smog</a>

The 26 documented variables are described in the following table, together with the response observed in the dataset. Some variables have been transformed for the purpose of the statistical analysis, the variables entering the factor analysis being indicated in column 3 (Included in FA).

**Table 2: List of variables collected to describe the Apps, along with their description, and the variables used in factor analysis (FA)**

*The last column indicates the observed frequencies par category (for categorical variables) or the observed mean/median (for continuous/integer variables).*

Factor	Variable [unit]	Included in FA	Data type	Response means/frequencies
<b>Description</b>	App name		Character	
	Information (Owner name and/or project name and/or website)		Character	Text with webpage links
	Source of funding	✓	Categorical (nominal)	Private (18) Public (8)
	Category	Not included in FA because too	Categorical (nominal)	Prototype (7) Commercialised (19)



Factor	Variable [unit]	Included in FA	Data type	Response means/frequencies
		correlated with "Price"		
	Description & features		Character	Text describing the App
	Platform		Categorical (nominal)	iOS (1) Android (6) iOS & Android (18) Other (1)
	Targeted application	✓	Categorical (nominal)	Fleet management (4) Safe & Eco driving (9) promoting sustainable mobility (4) Basic monitoring (9)
	Targeted vehicles		Categorical (nominal)	Light-duty Vehicles (22) Heavy-duty vehicles (1) all (including bicycles, public transports) (3)
	Deployment area	✓	Categorical (nominal)	1: A local region (5) 2: A country (5) 3: Several countries (16)
<b>Business model</b>	Popularity (Nb of users or downloads)		Integer	Median=3000, Min=100, max=1000000
	Pop_cat	✓	Categorical (ordered)	1 :Less than 1000 users (14) 2 :between 1000 and 1000000 users (8) 3 :More than 1000000 users (4)
	User evaluation (score against 5)		Continuous	3.41 ±0.86
	Price	✓	Categorical (nominal)	Free (11) Not free (13) Not commercialised (3)
	Last update (year)		Integer	2020 min=2009 max=2020
	In app products (€)		Integer	Min=0.99, max=49.99
<b>Technical</b>	Sensing capabilities	✓	Categorical (ordered)	1 :Phone sensors (10) 2 :Phone sensors + OBD dongle (14) 3 :Phone sensors + OBD dongle + Collaborative sensing (2)
	Connexion protocol		Categorical (nominal)	None (9) OBD (15) CAN Bus (2) J1939 (0)
	Processing	✓	Categorical (nominal)	Embedded (19) Cloud (7)
	External data resources		Categorical (nominal)	None (15) open source API (2) external API (2) proprietary models & data (7)
<b>User experience</b>	User feedback (None, website only, on demand, post trip, event based, continuous)		Character	Text describing user feedback types (used only to derive user feedback level variable)
	User feedback level (extracted from previous variable and linked to the different feedback types used)	✓	Categorical (ordered)	0 :external feedback (website) (12) 1 :on demand or post-trip (11) 2 :continuous (including event based pop-ups) (3)
	HMI types (map, colours, numbers, curves, advanced graphics, events, sounds, vibrations, tips)		Character	Text describing HMI types (used only to derive HMI complexity level variable)

Factor	Variable [unit]	Included in FA	Data type	Response means/frequencies
	HMI complexity level (extracted from previous variable and linked to number of different HMI types)	✓	Categorical (ordered)	1 :One type (5) 2 :Two types (4) 3 :at least 3 different feedback types (17)
	Gamification (none, experience level, ranking, challenges, badges for achievements, rewards, social networks)		Character	Text describing Gamification types (used only to derive Gamification level variable)
	Gamification level (extracted from previous variable)	✓	Categorical (ordered)	0 : none (16) 1 : minimalist (6) 2 : good (4)
	Features (including emissions related features + additional ones)		Character	Text describing features provided by the app (used only to derive service level variable)
	Service level (extracted from previous variable and linked to number of different features)	✓		0 : simple service linked with emissions reduction (8) 1 : some additional services (6) 2 : several high quality services (12)

Most of the studied apps are from private companies (18), but a large part (8) is publicly funded. Most of the apps are operating under both OS (Android and iOS), but only one iOS specific app has been studied due to access difficulties on the app store for non-apple users. Applications targeted by the selected apps are distributed between four categories: Fleet management apps (4 apps, dedicated to paid services for fleet management), safe & eco driving (9 apps, dedicated to emissions reductions through improvement of driving style), sustainable mobility promotion (4 apps, dedicated not only to light duty cars, but also improving mobility efficiency through increasing bicycle and public transportation usage), and basic monitoring (9 apps, dedicated to technical car monitoring through internal sensors visualisation). Only one app is dedicated to heavy-duty vehicles, the rest being dedicated to light duty vehicles (i.e., private cars), sometimes including also bicycles and public transportation.

There is a large variability between economic models of the studied apps, some being distributed locally and targeting less than 100 users (14 apps), and some being internationally used with more than millions of users (4 apps). Half of the apps are paying, the rest being free, or prototypes used for studies. Free apps are not always designed to be used as a standalone service, some of them requiring an additional OBDII dongle sell separately. This OBD dongle being sometimes sell together with the app itself (as a bundle). 17 apps are designed to operate jointly with an OBD or CAN Bus dongle, while 9 are relying to internal sensors of the smartphone. Quite few apps are relying to external data sources (open source or private API, 4 apps), the rest relying mostly on proprietary models or data (7), or no additional resource at all (15). User feedback are diverse, with 12 apps without any on demand or continuous feedback, only relying on external websites. Surprisingly, very few apps are providing continuous feedback while driving, probably for road safety reasons. We observed few gamification strategies (16 apps without gamification), despite 17 apps are relying to various and complex HMI types.

## 2.1. Procedure

Target apps have first been identified during the MODALES project construction, and several additional apps have then entered the documentation phase. This set of 26 apps is not exhaustive but can be considered as a good picture of the European market for smartphone-based solutions to reduce emissions. Some apps were excluded from the final analysis (therefore not counted in the 26) for missing data reasons.

The apps were manually described through the help of a coding scheme with predefined categories (a maximum of four categories per variable). Some of these variables have been constructed using collected information in text form, extracted from websites describing the app. The apps have not been bought and tested in real conditions.

The performed analysis is a multi-factorial correspondence analysis considering 11 categorical variables. This approach allows us to visualise the apps according to the main 2 dimensions representing the largest observed variability. Then a hierarchical clustering method based on apps coordinates on the principal plan is producing a classification, the number of groups being automatically deduced using statistical optimisation based on Ward criterion minimisation.

MCA plot of variables using R package FactoMineR

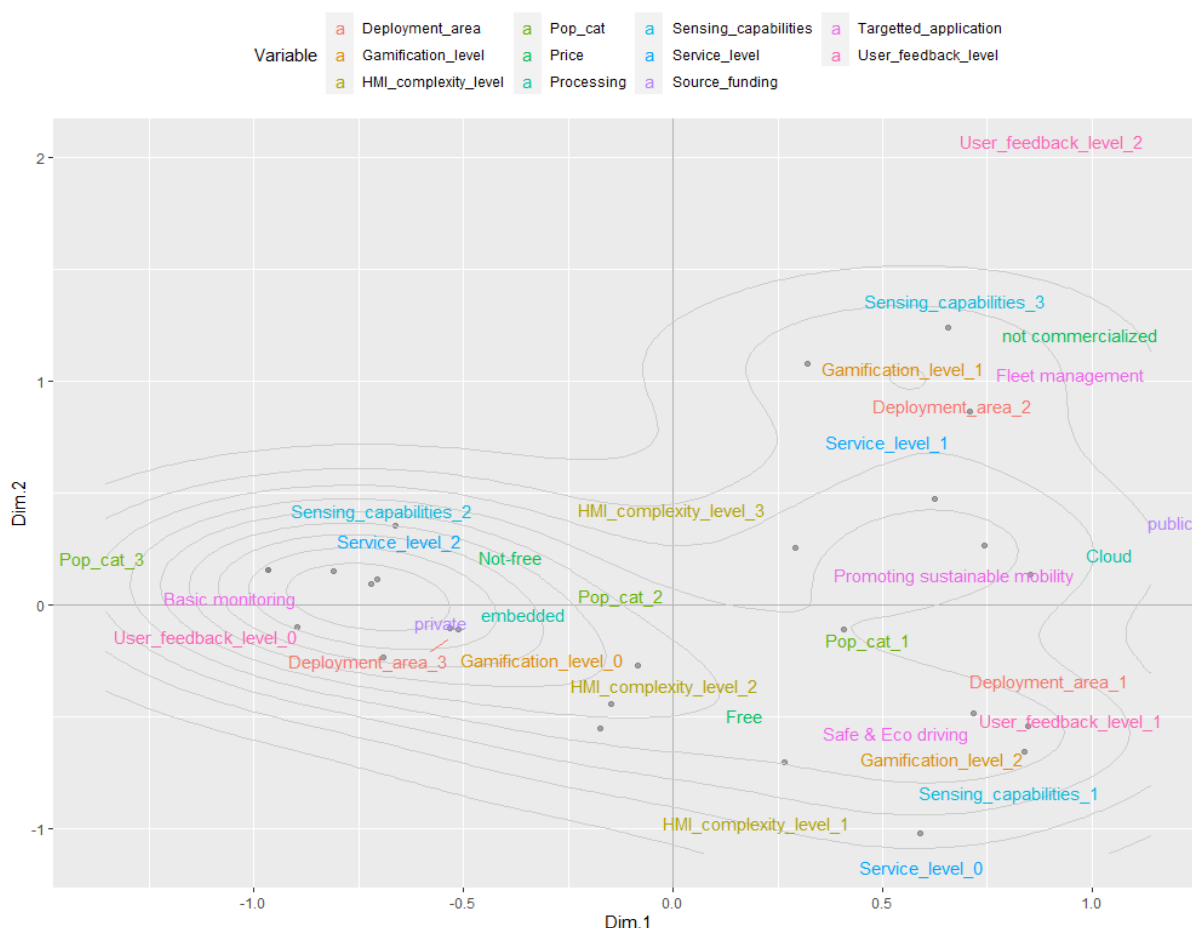


Figure 2: Categorical variables factor map projects the class of variables in the principal plane

## 2.2. Results

Figure 2 presents the plan with the greatest variability, according to the first two dimensions, together with the position of the categorical variable's modalities:

- The first dimension (X) is strongly linked to the following variables: User\_feedback\_level, Source\_funding, Targetted\_application, Processing, Deployment\_area, Sensing\_capabilities, Pop\_cat, Service\_level, Gamification\_level. It represents the opposition between private (left) and public (right) funding, but also between a low level of feedback (left) and a moderate one (right), and between low sensing capabilities (left) and intermediate ones (right).
- The second dimension (Y) is linked with the following variables: Service\_level, User\_feedback\_level, Sensing\_capabilities, Gamification\_level, HMI\_complexity\_level, Price. This second axis represent the opposition between a low service level (bottom), and an intermediate one (up). This axis is also useful to discriminate between intermediate (bottom) and good sensing capabilities and user feedback. It also highlights the difference between commercialised but free apps, and not commercialised apps, which are more confidential and sometimes linked with research projects.

Based on this visual representation, it is possible to cluster the different apps using an automatic hierarchical clustering procedure. This approach leads to four clusters being the best number of clusters allowing for the best representation of the global inertia of the data, while minimising the Intra-cluster inertia. The results of this clustering procedure are displayed in Figure 3 and 4.

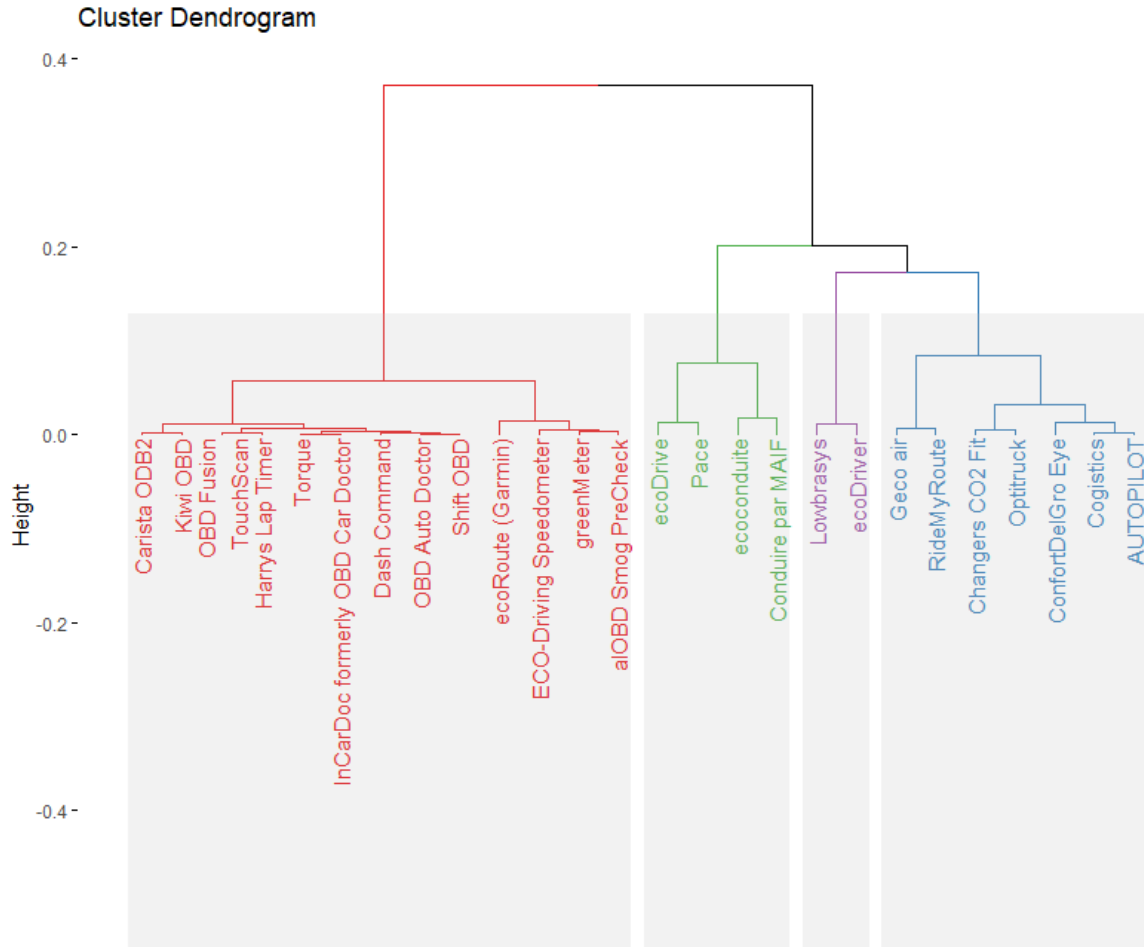


Figure 3: Hierarchical clustering of the 26 apps, organised among 4 clusters (optimal number of groups according to the inertia gain criteria and the Ward criterion minimisation)



Figure 4: Visualisation according to the two main dimensions of factor analysis, of the four groups found by the hierarchical clustering of the apps

The four identified groups are described in Table 3. Each group is characterised by the values of the qualitative variables indicated by a “+” (for which this value is statistically over represented) and by a “-” (for which this value is statistically less present).

Table 3: Synthesis of the characteristics of the four groups according to the values of the qualitative variables

A “+” indicates that this value is significantly over represented in this group, while a “-” indicates a significantly lower representation.

Qualitative variable included in FA	Description	Modalities of the variable	Group 1 (red)	Group 2 (green)	Group 3 (blue)	Group 4 (purple)
Source of funding		Private	+		-	
		Public	-		+	
Targeted application		Fleet management	-	+		
		Safe & Eco driving promoting sustainable mobility	-			
		Basic monitoring	+		-	
Deployment area	Level of geographical deployment	1 : A local region	-			+
		2 : A country				
		3 : Several countries	+			

Qualitative variable included in FA	Description	Modalities of the variable	Group 1 (red)	Group 2 (green)	Group 3 (blue)	Group 4 (purple)
Pop_cat	Number of users arranged by categories	1 :Less than 1000 users 2 :between 1000 and 1000000 users 3 :More than 1000000 users	-			
Price	How can the public obtain the app	Free Not free Not commercialised			+	+
Sensing capabilities	Level of sensing required by the app	1 :Phone sensors 2 :Phone sensors + OBD dongle 3 :Phone sensors + OBD dongle + Collaborative sensing	-		+	-
Processing	Type of processing	Embedded Cloud	+		-	+
User feedback level	Level of app user feedback	0 :external feedback (website) 1 :on demand or post-trip 2 :continuous (including event based pop-ups)	+		-	+
HMI complexity level	Level linked to the number of different HMI used for user feedback	1 :One type 2 :Two types 3 :at least 3 different feedback types				
Gamification level	Level linked to the number of different gamification strategies	0 : none (16) 1 : minimalist 2 : good	+			+
Service level	Level of services provided by the app	0 : simple service linked with emissions reduction 1 : some additional services 2 : several high quality services			+	-

We can formerly describe the four groups below.

- **Group 1** (OBd Fusion TouchScan, Torque, Dash Command, Carista OBD2, greenMeter, ECO-Driving Speedometer, ecoRoute (Garmin), Kiwi OBD, Harrys Lap Timer, InCarDoc formerly OBD Car Doctor, OBD Auto Doctor, Shift OBD, aLOBd Smog PreCheck).
  - This is the biggest group of the dataset, which is grouping the commercialised apps. They are, for most of them, designed for a basic monitoring of the car parameters

without any gamification strategies. These apps are not primarily designed for emissions reductions, but often incorporate basic services related to fuel savings, usually through an external media only (website). These apps rely mostly on an OBD device to collect the car information, this device being sold with the app (the app is not free) or needed to be bought separately (the app is sometimes free). Interestingly, this category of apps is widely used across regions or countries, with sometimes millions of users. **We can call this group “simple and efficient car monitoring”.**

- **Group 2** (Pace, ecoconduite, ecoDrive).
  - This cluster regroups fleet management designed apps (or their eco driving dedicated tool). This specificity allows for improved sensing strategies, considering the community of drivers, and using their information to produce high-level feedback, usually in a continuous way. **We can call this group “efficient community driving”.**
- **Group 3** (Geco ai, Changers CO2 Fit, Conduire par MAIF, RideMyRoute, Cogistics, Optitruck, AUTOPILOT, ConfortDelGro Eye).
  - This cluster regroups public founded apps, free of charge, and providing simple services which goal are to promote sustainable mobility through the emissions reductions. They are usually based on a simple sensing strategy (only smartphone sensors), with post-trip user feedback to avoid safety issues while driving. **We can call this group “public incitation for emissions reduction”.**
- **Group 4** (ecoDriver, Lowbrasys).
  - This last group is very specific to non-distributed apps, which comes from research projects and have been used for demonstration purposes. They are usually very different from a basic monitoring strategy, being focused on a specific question: ecodriving for ecoDriver, and brake emissions for Lowbrasys. **This could be the group called “expert’s apps”.**

### 2.3. Recommendations for MODALES App

This analysis allowed for a classification of apps in 4 different groups. The future envisioned MODALES app will most probably be a member of one of these groups. It is relevant to extrapolate the future position of the MODALES app in the galaxy of existing apps, considering the already known constraints.

The MODALES app will be designed to support the driver in reducing emissions from three main sources (powertrain, brakes and tyres) for all types of vehicles. None of the studied apps are sharing these abilities. Heavy-duty vehicles are targeted only by a single app (Optitruck), despite some apps allow for transportation mode recognition and therefore deal also with bicycle rides and public transportation modes. The more different vehicle types are considered by the app, the less specialised should be the sensing tool. It is not relevant for a user to buy an app with an OBD dongle if a large part of the travels is done by bicycle.

We observe that specialised apps (Group 1, car monitoring related apps) are designed for a specific need, associated with suitable sensing tools. These apps are to be paid but are also widely



distributed and used. The willingness to pay for a service can be important if the service is precise and useful (technical monitoring of the car, helping passing emissions tests, ...). Considering MODALES, emissions controls are mandatory in Europe, but only for global CO2 emissions. It is likely that brakes and tyres emissions will not be considered in a near future. It seems difficult to envision a strong support of MODALES app in everyday life, with a strong perceived utility and an important willingness to pay. The MODALES app should be free for several reasons: it is funded by public funds and it is not linked with mandatory restrictions.

Under the assumption of a free MODALES app, it will most likely be part of the right side of the graph (Figure 4). The bottom right part of the graph represents the cluster of free apps with poor sensing capabilities (Group 3). The upper right part of the graph is for apps with good sensing capabilities, usually adding collaborative sensing the usual OBD dongle. It is likely that MODALES app will rely at least on an OBD dongle to collect continuous information from car sensors, mandatory to extrapolate (using MODALES theoretical models) brake and tyre emissions.

The final suggestion, after analysing the market, would be to implement two versions of the app:

- A simple one, easy to use, with friendly HMI, with feedback coming from model-based extrapolations of emissions. The apps from group 3 (Autopilot for example) could be considered as good examples of what can be done.
- A more complex one, relying on data collected through an OBD dongle, allowing for more precise exhaust emissions estimation, eventually with collaborative sensing or gamification possibilities (comparisons with other drivers).

The two versions of the app could be different, and for different usage. The one with an OBD dongle being used for drivers taking part of MODALES experiments. The simple one being freely available on the market, with an option for users to transmit their data and/or feedback to the MODALES project.

The left part of the graph, denoting commercial apps devoted to car monitoring does not seem a good target for MODALES.

## 3. Functionalities

Based on what we know from the related work (WP2) and the comparison study from the previous section, this section describes the two tools developed in WP5 together with the tasks a user can perform by interacting with them.

### 3.1. Mobile app

This mobile app for low-emission driving (DALED, provisional name) will take the role of personal assistant to the project's end-users. This app will profile a user's driving style and recommend attitudes to adopt or to avoid. It will allow many users to be reached easily, thus enabling experimentation and awareness campaigns to be conducted on a wide range of configurations (e.g., car types, engines, geographical areas). DALED will aim to assist users throughout their journeys, providing recommendations as they travel, and in ways that won't interfere with their driving (e.g., when stationary at a traffic light, or in the form of sound notifications). The app will also cover maintenance issues and not only on driving style analysis.

Technically speaking, the app will adopt a modular approach, which allows several small components to be developed independently and then interact with each other to provide a unique driver experience. This approach makes it possible to technically feed the other elements of the project that require specific tools; it also facilitates collaborative development and validation. The app will be developed natively for Android and iOS. In order to prevent breaches of privacy, the processes developed will, as far as possible, be entirely local, and will not use services external to the application (i.e., not using an Internet connectivity).

The following diagram depicts the basic use cases for the mobile app "DALED". Each use case is described with more details afterwards (Tables 4 to 17).



Figure 5: Use cases for the mobile app

Table 4: Use Case - Start Session

Title		Start Session
<b>Actors</b>	Driver	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The Driver opens the System for the first time.</li> <li>2. The System shows alternatives to start the session.</li> <li>3. The Driver selects an alternative.</li> <li>4. After starting the session, the System shows the main section.</li> </ol>	
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Alternative path for step 1: This use case starts if the session is lost.</li> <li>• Alternative paths for step 2:               <ol style="list-style-type: none"> <li><b>2.a. Sign In</b></li> <li><b>2.b. Sign In with Social Network</b></li> <li><b>2.c. Sign Up</b></li> </ol> </li> <li>• After starting the session, the Driver can <b>Sign Out</b>.</li> </ul>	

Table 5: Use Case - Sign Up

Title		Sign Up
<b>Actors</b>	Driver (primary actor), Mail Server, MODALES Server	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System shows a registration form.</li> <li>2. The Driver completes the information:               <ol style="list-style-type: none"> <li>2.a. Email.</li> <li>2.b. Password (twice).</li> <li>2.c. Accept the Terms and Conditions.</li> </ol> </li> <li>3. The Driver submits the form.</li> <li>4. The System sends the data to the MODALES Server.</li> <li>5. The MODALES Server sends an email to the Email Server asking confirmation.</li> <li>6. The Driver opens the email and confirms the registration to MODALES Server.</li> <li>7. The System awaits (or asks) confirmation from the MODALES Server.</li> <li>8. The System starts the session for the Driver.</li> <li>9. Continue with <b>View or Update Profile</b> (mandatory for the first time).</li> </ol>	
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Alternative paths without filling the form:               <ol style="list-style-type: none"> <li>2.d.1. <b>Sign In</b>.</li> </ol> </li> <li>• Alternative path filling the form:               <ol style="list-style-type: none"> <li>2.e.1. The Driver inputs invalid information:                   <ol style="list-style-type: none"> <li>2.e.1.a. Malformed email.</li> <li>2.e.1.b. Email already in use.</li> <li>2.e.1.c. Mismatching passwords.</li> <li>2.e.1.d. Password not strong enough.</li> <li>2.e.1.e. Terms and conditions not accepted.</li> </ol> </li> <li>2.e.2. The Driver submits the form.</li> <li>2.e.3. The System shows an error message.</li> <li>2.e.4. Go back to step 2.</li> </ol> </li> <li>• The Driver can read the terms and conditions before step 3.</li> <li>• If something goes wrong from steps 4 to 7:               <ol style="list-style-type: none"> <li>8.a.1. The System shows an error message.</li> <li>8.a.2. Go back to step 1.</li> </ol> </li> </ul>	

Table 6: Use Case - Sign In

Title		Sign In
<b>Actors</b>		Driver (primary actor), MODALES Server
<b>Basic Flow</b>		<ol style="list-style-type: none"> <li>1. The System shows a login form.</li> <li>2. The Driver completes the information:               <ol style="list-style-type: none"> <li>2.a. Email.</li> <li>2.b. Password.</li> </ol> </li> <li>3. The Driver submits the form.</li> <li>4. The System sends the data to the MODALES Server.</li> <li>5. The System awaits confirmation from the MODALES Server.</li> <li>6. The System starts the session for the Driver.</li> </ol>
<b>Extensions</b>		<ul style="list-style-type: none"> <li>• Alternative paths without filling the form:               <ol style="list-style-type: none"> <li><b>2.c. Reset Password</b></li> <li><b>2.d. Sign In with Social Network</b></li> <li><b>2.e. Sign Up</b></li> </ol> </li> <li>• Alternative path filling the form:               <ol style="list-style-type: none"> <li>2.f.1. The Driver inputs wrong credentials.</li> <li>2.f.2. The Driver submits the form.</li> <li>2.f.3. The System shows an error message.</li> <li>2.f.4. Go back to step 2.</li> </ol> </li> <li>• If something goes wrong from steps 4 to 5:               <ol style="list-style-type: none"> <li>6.a.1. The System shows an error message.</li> <li>6.a.2. Go back to step 1.</li> </ol> </li> </ul>

Table 7: Use Case - Reset Password

Title		Reset Password
<b>Actors</b>		Driver (primary actor), Mail Server, MODALES Server
<b>Basic Flow</b>		<ol style="list-style-type: none"> <li>1. The System sends an email to the Email Server.</li> <li>2. The Driver opens the email with a new generated password.</li> <li>3. The Driver can continue with the <b>Sign In</b> use case.</li> <li>4. Afterwards the Driver should follow the <b>Change Password</b> use case.</li> </ol>

Table 8: Use Case - Sign In with Social Network

Title		Sign In with Social Network
<b>Actors</b>		Driver (primary actor), MODALES Server
<b>Basic Flow</b>		<ol style="list-style-type: none"> <li>1. The Systems opens an interface from the corresponding Social Network.</li> <li>2. The Driver follows the Sign In steps in the Social Network interface.</li> <li>3. The Social Network Server sends a session token to the System.</li> <li>4. The System sends the session token to the MODALES Server.</li> <li>5. The System awaits confirmation from the MODALES Server.</li> <li>6. The System starts the session for the Driver.</li> <li>7. Continue with <b>View or Update Profile</b> (mandatory for the first time).</li> </ol>
<b>Extensions</b>		If any step fails, go to <b>Start Session</b> use case.

Table 9: Use Case - Sign Out

Title		Sign Out
<b>Actors</b>	Driver	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System removes all local data and ends the current session.</li> <li>2. Go to <b>Start Session</b> use case.</li> </ol>	

Table 10: Use Case - View or Update Profile

Title		View or Update Profile
<b>Actors</b>	Driver (primary actor), MODALES Server	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System shows a profile form.</li> <li>2. The Driver completes or updates the information:               <ol style="list-style-type: none"> <li>2.a. Gender</li> <li>2.b. Age</li> <li>2.c. Driving experience (years)</li> </ol> </li> <li>3. The Driver submits the form.</li> <li>4. The System sends the data to the MODALES Server.</li> </ol>	
<b>Extensions</b>	If communication with MODALES Server cannot be achieved in step 4, the System stores the information and synchronises with MODALES Server when possible.	

Table 11: Use Case - Change Password

Title		Change Password
<b>Actors</b>	Driver (primary actor), MODALES Server	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System shows a password form.</li> <li>2. The Driver completes the information:               <ol style="list-style-type: none"> <li>2.a. Current password</li> <li>2.b. New password (twice)</li> </ol> </li> <li>3. The Driver submits the form.</li> <li>4. The System sends the data to the MODALES Server.</li> </ol>	
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Alternative path filling the form:               <ol style="list-style-type: none"> <li>2.c.1. The Driver inputs incorrect information:</li> <li>2.c.2. The Driver submits the form.</li> <li>2.c.3. The System shows an error message.</li> <li>2.c.4. Go back to step 2.</li> </ol> </li> <li>• If something goes wrong from step 4 (e.g. no connection):               <ol style="list-style-type: none"> <li>4.a.1. The System shows an error message.</li> <li>4.a.2. Go back to step 1.</li> </ol> </li> </ul>	

Table 12: Use Case - Clear Stored Data

Title		Clear Stored Data
<b>Actors</b>	Driver (primary actor), MODALES Server	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System asks for confirmation.</li> <li>2. The Driver confirms.</li> <li>3. The MODALES Server clears all data related to the Driver.</li> <li>4. Continue with <b>Sign Out</b> use case.</li> </ol>	
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Alternative path for step 2:               <ol style="list-style-type: none"> <li>2.a.1. The Driver does not confirm.</li> <li>2.a.2. Stop the use case flow (no data is cleared).</li> </ol> </li> <li>• Alternative path for step 3:               <ol style="list-style-type: none"> <li>3.a.1. The MODALES Server cannot clear the data.</li> <li>3.a.2. The System shows an error message.</li> <li>3.a.3. Stop the use case flow (no data is cleared).</li> </ol> </li> </ul>	

Table 13: Use Case - Pair OBD Dongle

Title		Pair OBD Dongle
<b>Actors</b>	Driver (primary actor), MODALES Server	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System shows the Bluetooth pairing interface.</li> <li>2. The Driver selects the OBD dongle.</li> <li>3. The System confirms the pairing.</li> <li>4. The System reads the vehicle VIN.</li> <li>5. The System selects the corresponding vehicle from the garage.</li> </ol>	
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Alternative path for step 1:               <ol style="list-style-type: none"> <li>1.a.1. The System cannot show the interface.</li> <li>1.a.2. The System shows an error message.</li> <li>1.a.3. Stop the use case.</li> </ol> </li> <li>• Alternative path for step 2:               <ol style="list-style-type: none"> <li>4.a.1. The Driver does not select an OBD dongle.</li> <li>4.a.2. Stop the use case.</li> </ol> </li> <li>• Alternative path for step 3:               <ol style="list-style-type: none"> <li>3.a.1. The System cannot pair the OBD dongle.</li> <li>3.a.2. The System shows an error message.</li> <li>3.a.3. Stop the use case.</li> </ol> </li> <li>• If the System cannot read the VIN on step 4, or if the System cannot find the car on step 5, the Driver manually solves the conflict:               <ol style="list-style-type: none"> <li>4/5.a. The Driver selects a car from the garage.</li> <li>4/5.b. The Driver adds a new car to the garage.</li> <li>4/5.c. The Driver cancels (stop the use case).</li> </ol> </li> <li>• If a previously paired OBD dongle is connected, automatically go to step 3.</li> </ul>	

Table 14: Use Case - Report an Issue

Title		Report an Issue
<b>Actors</b>	Driver (primary actor), MODALES Server	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The System shows a contact form.</li> <li>2. The Driver completes the information:               <ol style="list-style-type: none"> <li>2.a. Name</li> <li>2.b. Email</li> <li>2.c. Message</li> </ol> </li> <li>3. The Driver submits the form.</li> <li>4. The System sends the data to the MODALES Server.</li> </ol>	
<b>Extensions</b>	If communication with MODALES Server cannot be achieved in step 4, the System stores the information and synchronises with MODALES Server when possible.	

Table 15: Use Case - Manage Vehicles

Title		Manage Vehicles
<b>Comments</b>	This definition was simplified and might need further development in the future. See use cases "Pair OBD Dongle" for more information about vehicle selection.	
<b>Actors</b>	Driver (primary actor), MODALES Server	
<b>Preconditions</b>	A valid session must exist.	
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>a. The System lists the current vehicles in the garage.</li> <li>b. The Driver can update a vehicle or add a new one:               <ol style="list-style-type: none"> <li>b.1. The System shows a vehicle form.</li> <li>b.2. The Driver completes or updates the information:                   <ol style="list-style-type: none"> <li>b.2.a. Vehicle Model</li> <li>b.2.b. Vehicle Type</li> <li>b.2.c. Engine Type</li> <li>b.2.d. Fuel Consumption Label</li> <li>b.2.e. Emission Label</li> <li>b.2.f. Vehicle Weight</li> <li>b.2.g. Use of Vehicle</li> </ol> </li> <li>b.3. The Driver submits the form.</li> <li>b.4. The System sends the data to the MODALES Server.</li> </ol> </li> <li>c. The Driver can delete a vehicle:               <ol style="list-style-type: none"> <li>c.1. The System asks for confirmation.</li> <li>c.2. The Driver confirms.</li> <li>c.3. The MODALES Server clears all data related to the vehicle.</li> <li>c.4. The System clear all local data related to the vehicle.</li> </ol> </li> <li>d. The Driver can select the current vehicle.</li> </ol>	
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• If connection is not available in step a, local information is used.</li> <li>• If communication with MODALES Server cannot be achieved in step b.4, the delete request is stored locally and synchronised when possible.</li> <li>• If the Driver does not confirm in step c.2 then stop the use step c.</li> </ul>	



Table 16: Use Case - Open Dashboard

Title	Open Dashboard
<b>Comments</b>	This definition was simplified and might need further development in the future.
<b>Actors</b>	Driver (primary actor), MODALES Server
<b>Preconditions</b>	A valid session must exist.
<b>Basic Flow</b>	<p>The System shows simple aggregated statistics and indicators:</p> <ul style="list-style-type: none"> <li>• Current score</li> <li>• Number of trips</li> <li>• Distance travelled</li> <li>• Score history with different aggregation levels: <ul style="list-style-type: none"> <li>○ Last week</li> <li>○ Last month</li> <li>○ Last year</li> </ul> </li> <li>• Number of recommendations: <ul style="list-style-type: none"> <li>○ The Driver can navigate through the recommendations</li> </ul> </li> </ul>

Table 17: Use Case - Start a Trip

Title	Start a Trip
<b>Comments</b>	This definition was simplified and might need further development in the future. The collected data will be associated to the current vehicle. See “Pair OBD Dongle” and “Manage Vehicle” for more information on selecting a vehicle.
<b>Actors</b>	Driver (primary actor), MODALES Server
<b>Preconditions</b>	A valid session must exist.
<b>Basic Flow</b>	<ol style="list-style-type: none"> <li>1. The Driver indicates the start of the trip.</li> <li>2. The System shows a real time score.</li> <li>3. The System alerts the Driver of score changes (e.g., with sound or colours).</li> <li>4. The Driver indicates the end of the trip.</li> </ol>
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Alternative path for step 1: <ol style="list-style-type: none"> <li>1.a.1. The System detects that a trip started.</li> <li>1.a.2. The System pops up and asks for confirmation to start a trip.</li> <li>1.a.3. The Driver confirms.</li> <li>1.a.4. Go to step 2.</li> </ol> </li> <li>• Alternative at any moment: The Driver can pause the trip.</li> <li>• Alternative path for step 4: <ol style="list-style-type: none"> <li>4.a.1. The System detects that a trip ended.</li> <li>4.a.2. The System pops up and asks for confirmation to stop the trip.</li> <li>4.a.3. The Driver confirms or the System stops the trip after some time.</li> </ol> </li> <li>• Alternative path after step 1: if the application losses the focus, it keeps running in the background and keeps collecting information. In this mode recommendations could pop up as notifications or they could be silenced.</li> </ul>

### 3.2. Web dashboard

For each app user, anonymous indicators will be transmitted to a **web dashboard** hosted by CERTH to collect usage statistics and performance metrics. The latter will allow the authorities and the public to understand the benefits of the mobile app, and view statistics by region or type of user. The web dashboard will aggregate the data and present them in various graphical representations in order to assist the decision making.

The Web dashboard application will be based on the data received and stored and more precisely in some significant and indicative indicators. The indicators are:

1. Vehicle emissions (e.g., NOx)
2. Fuel Consumption
3. Driver aggressiveness based on the information received by the smartphone's accelerometer and vehicle speed sensors.

The three indicators will be time based. Thus, the application can present also the performance evaluation based on time.

#### **Registration and login**

- **Sign up:** Each stakeholder or authority needs to create a profile by simply entering the appropriate information such as username, password, name (e.g., company name), address, email, VAT number, etc. After that, the stakeholder/authority can create several users (it will be defined a maximum number of users per stakeholder/authority) with different roles.
- **Sign in:** After the registration has been completed, the user can login using the credentials.

#### **Dashboard**

- **Descriptive information** about the number of trips, driving score, etc.
- **Descriptive information** about the most popular/bad habit
- **Aggregated indicators:**
  - For the general fleet population (for example average NOx emissions for a specific area or a few trips etc),
  - For each trial site; for all trial sites (Vehicle emissions, Fuel Consumption, Driver aggressiveness),
  - Vehicle emissions vs vehicle type (European emission standards - EUROX (e.g., EURO6), car, van, truck, etc)
  - Vehicle emissions vs road type (urban, highway, etc)
  - Vehicle emissions vs topography (slope)
  - Vehicle emissions vs user profile (e.g., age, gender)
- **Report of violations** per trial site for the local authorities
- **Share/Print** information

**User Management:** management of the users who can connect to this dashboard, which are different from those of the mobile app.

- **Categories/Roles:** Administrator can manage (add, edit, delete) user categories. Thus, each user belongs to a specific category and can access specific information.
- **Stakeholder/Authority account:** Administrator can create (also edit or delete) a new account about a stakeholder/authority.
- **User account:** Administrator can create (also edit or delete) a new user account and assign him/her to a specific category/role. The user can also edit his/her information.

***Storage. This feature/functionality will be transparent to the users. It can be called from mobile applications in order the data to be stored in the database.***

- **Store anonymised training data** from the mobile app (in case there is a need for AI/ML models)
- **Store aggregated data** (not real time data – synchronised from the mobile app opportunistically)

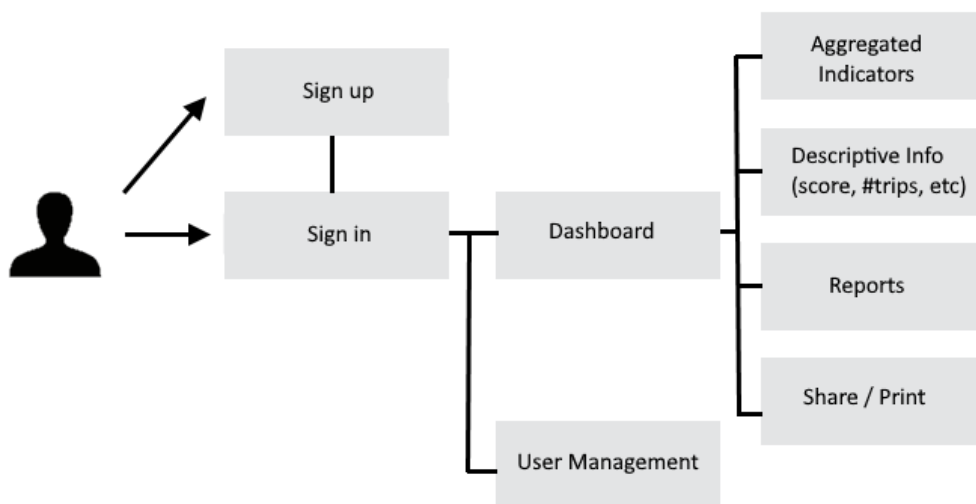


Figure 6: Available actions for the user inside web dashboard application

## 4. Technical requirements and initial parameters

This section considers the conclusions reached earlier in the document, as well as the functionalities to be developed, and outlines all the practical parameters that the development team will have to respect when creating the mobile app and the dashboard.

### 4.1. Requirements

The main requirements for the mobile app can be broken down as follows:

#### 4.1.1. Requirements for recommendations

The mobile app will generate two types of recommendations:

- **Active recommendations**, which will be presented to the user while driving.
  - The user's driving style will be analysed in real time and transcribed in a score. When the score is bad, the driver will be guided to act.
  - The following components would be considered for this score: velocity, frequency of acceleration/deceleration and magnitude of the acceleration/deceleration. These values will be aggregated, in line with the EU 2017/1151 regulation. They will be calculated with a sampling frequency of 1 Hz (when possible). Complementary data from simulation, testing and literature results will be used to train the system and calculate an instantaneous driving score. It will be implemented empirically in the first test phases in 2021, based on the descriptions and recommendations provided by D5.1.
  - The user interface and possible actions should be limited and not be displayed as complex text (or only one or two words), to preserve the user's safety. Other strategies may be used, such as a coloured screen, or a gamification logic (e.g., a glass of water spilling in case of misconduct). All these possibilities will need to be experimented and assessed with the end-users before being selected.
  - Active recommendations would require local data processing and storage. They would not require data from OBD.
- **Passive recommendations**, which will be given to the user after a trip:
  - A report will be generated, which would include textual recommendations in the form of a report, including statistical analyses and contextual elements, so that the driver can improve his/her emissions the next times, and learn from bad driving habits.
  - Active recommendations would mean that data processing and storage will be outsourced to an external server (e.g., the dashboard).
  - Active recommendations would ideally need OBD data so that all the necessary metrics are estimated and used by the recommender system.

#### 4.1.2. Requirements about the hardware to be used

MODALES proposes the use of multi sensors approach to classify a driver's pattern. This could include the utilisation of the built-in smartphone sensors (3 axes accelerometer, gyroscope, GPS, compass, barometer, and wireless interfaces) and OBD-II dongle information to compute a set of indicators (e.g., speed, position, acceleration, and RPM), to addresses the driving style.

The app will work by default in a standalone mode (only considering the phone sensors, and therefore with only limited recommendations), but it will be possible to add an OBD dongle to generate more complete reports, automate the registration of a vehicle, etc.

#### 4.1.3. Requirements about the OS

The rapid development of new smartphone operating systems improves the levels of performance as well as offer better understanding of the user’s need. The mobile app will be compatible with both iOS and Android devices. Cross-platform frameworks will be considered to avoid duplication of work. The two potential candidates, i.e., Flutter and Ionic, are described in the table below. Given that Apple and Android are releasing on new devices and OS versions on a regular basis, this project would target mobile devices of Android 6.0 and later, and iOS 11 or newer.

Table 18: Potential frameworks to develop and design the mobile app

Platform	Description	Advantage	Cost
<b>Flutter</b>	Flutter is Google's SDK for crafting beautiful, fast user experiences for mobile, web and desktop from a single codebase. Flutter works with existing code, is used by developers and organisations around the world	<ul style="list-style-type: none"> <li>- Flutter is fast and offers stateful hot reload, allowing you to make changes to your code and see the results instantly without restarting your app or losing its state.</li> <li>- Flutter works with any development tool (or none).</li> </ul>	Free & open source.
<b>Ionic</b>	Ionic Framework is an open-source mobile UI toolkit for building high quality, cross-platform native and web app experiences. Move faster with a single codebase, running everywhere	<ul style="list-style-type: none"> <li>- Reusable components</li> <li>- Ionic apps run with a mixture of native code and web code, providing full access to native functionality if necessary.</li> </ul>	Free & open source.

#### Requirements about the experimental settings:

Phones should if possible be fixed in the car, using a car holder, thus allowing the user to have a comfortable view on the phone's interface, as well as for the proper recording of accelerometric data, i.e., using a stable reference in space.

#### 4.2. Timeline and releases

The mobile app will be developed via three releases, which are described in the table below.

Table 19: Releases of the mobile app

#	MS	Description	Date
1	M5.1	<b>Alpha version of DALED released internally</b> (at least to LIST, ACASA). This version will focus on the data collection module, so that initial data can be collected during T6.2 / Ramp-up in Luxembourg and Barcelona. This module will focus on accelerometric and GPS data to build speed profiles and generate active recommendations. Where possible, OBD readers will be used, in parallel to the work done in D4.1, to collect OBD or J1939 data and validate the hypotheses made in this deliverable. In parallel, surveys will be carried out to study the best parameters for the development of the mobile app.	M16
2	M5.2	<b>Beta version of DALED released to a limited group of users</b> (at least to WP5 members).	M20



A detailed description of the verification plan for these tools is provided in Deliverable 6.1. The verification plan contains several steps, which will be explored in T5.4. These steps include:

- Requirements verification
- Design verification
- Code verification
- Stability
- Functional testing
- Usability testing
- Interaction testing
- Compatibility testing
- Performance testing
- Security testing

#### 4.4. Deployment and testing

The mobile app will not be immediately published on the Google Play Store or the App Store, which have selection and online policies that may initially be too restrictive for the needs of the project. This possibility will be explored in a second step when the application is stable and has passed all the verification steps of T5.4. Alternatively, the development team will use the beta testing tools made available by Google and Apple to easily deploy successive versions of the app, as well as to collect valuable feedback. Under iOS, the service is called **TestFlight**, while the equivalent under Android is **Google Play Console**. The publication process will be managed by LIST.

The server hosting the project data and directly used by the mobile app to generate passive recommendations will be hosted at LIST. It will be a Debian virtual server with dynamically scalable resources. It will be used throughout the project duration.

All the source code generated by LIST for the mobile app will be stored under an internal (LIST) Git server, to properly manage the successive versions of the source code. This source code will remain subject to the IP conditions set in the project.

The web dashboard will be entirely developed by CERTH on a server located at CERTH as well. Since it is a web application, distribution to end users will be done by creating a dedicated website with secure access (SSL certificate).

#### 4.5. Overall system architecture

The mobile app will be developed exclusively by LIST, while the web dashboard will be developed exclusively by CERTH. Therefore, all datasets collected through DALED will be stored in secured environments at LIST, accessible only by the participant and LIST. The full, anonymised datasets will also be shared with the partners involved in WP6, and CERTH, who is also responsible of T5.4 (verification of the tools).

Figure 8 below describe the high-level architecture of DALED and the various links between other systems. At once, DALED would be broken down into separate modules:

- A **data collection module**, which considers data from OBD dongle, mobile sensors and user input. Using an OBD dongle would be optional. The collected data will be accumulated in a local temporary “raw” database. It could be SQLite or a simple log.
- The data will be used as input for a data **interpretation module**, making it possible to create a local representation of the user's profile and distinguish different behaviours previously identified via laboratory tests and state-of-the-art reviews.
- Finally, a **recommendation module** will advise the user to adopt attitudes depending on his/her perceived behaviour. A flexible Human-Machine Interface will be used to supplement the existing driver information panel.
- A **synchronisation module** will send the collected trip information to the MODALES server hosted by LIST. When the stored information exceeds a predefined limit, the module should also decide which data to drop. Additionally, this module could also be charged of backing up other local information like the garage data and user profile.
- A **gamification module** could also be added in the future when the rules of the game are set.

Outside DALED, on one side the **LIST virtual server** (or **MODALES server**) will be able to communicate with each instance of DALED (probably with a REST API). It will provide the following services: authentication, session management and data management (create, read, update or remove aggregated information from trips, vehicles, and the user profile). This server will also contain a module that will periodically anonymise information from user trips and send it to the **LIST backup server** (maybe a simple FTP server is enough). On the other side, the **CERTH virtual server** will periodically gather data from the LIST backup server for later use on the web dashboard.



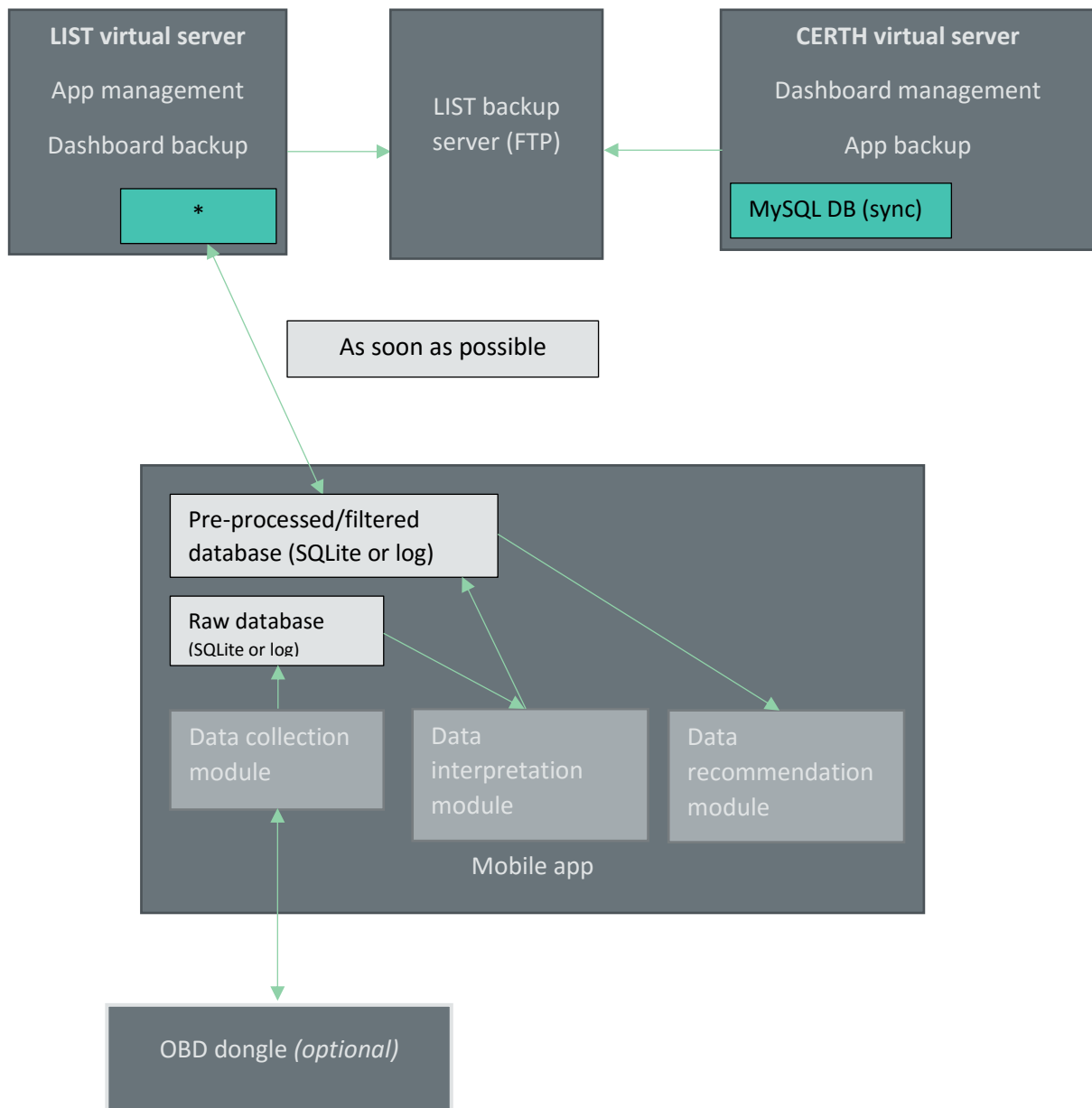


Figure 8: High-level architecture

#### 4.6. Web dashboard architecture

The system architecture design and implementation of the web dashboard will follow general guidelines like:

- Open Software Architecture. The software architecture design provides a system where adding, swapping and upgrading components is easy. Additionally, the open software architecture will ensure:
  - Interoperability and cooperation among different software components
  - Networking among applications and systems
- Modular. The system will be expandable, easy to add new components and modify existing components. The system can also receive upgrades and changes in discrete software modules and in the hardware modules.

- N-tier architecture. The system will follow the N-tier architecture in order to be flexible, provides workload balancing in the system's modules and workstations. The system will exploit efficiently the network, will be portable and extensible.
- Use of Relational Database Management System (RDBMS). The system will provide big data storage and analysis, increased availability, data integration and security.
- Use of Web Graphical User Interface for efficient usage and easy learning of the application.
- Use of Web standards for building the web interface. The proposed system should contain a web Graphical User Interface that is based on HyperText Markup Language (HTML5), Cascading Style Sheets (CSS3), Web Content Accessibility Guidelines (WCAG), JavaScript, JavaScript Object Notation (JSON), Extensible Markup Language (XML).
- Web Services. The system architecture will exploit web services for connection with mobile applications, existing systems and future systems.
- Data integrity, privacy and security

The system architecture will follow the N-tier architecture. The typical structure for N-tier architecture deployment would have the presentation tier deployed to a desktop, laptop, tablet or mobile device via a web browser utilising a web server. The underlying application tier (middleware) is usually hosted on one or more application servers. Finally, the data layer would comprise a relational database.

One of the most popular architectural styles for building web services is Representational State Transfer (REST) architecture. An application or architecture considered RESTful or REST-style is characterised by client/server, stateless, layered attributes and supports caching. Additionally, the state and functionality are divided into distributed resources and every resource is uniquely addressable using a uniform and minimal set of commands (typically using HTTP commands of GET, POST, PUT, or DELETE over the Internet). The system architecture will be comprised of RESTful web services. The web services will provide the functionality of automatically retrieve the data, exchange data with the web user interface, receive data from mobile application and possible other systems (in the future).

The software stack that will be used for each system layer is depicted below. The JSON technology will be used for data exchange between the application layer (also referred as Logic or Middleware) and presentation layer. The communication between the mobile application and the web services (middleware) will be also based on the JSON format.



Figure 9: Web dashboard software stack

The presentation layer can also be implemented based on the Grafana open-source analytics and visualisation software. Grafana offers an open-source tool for building dashboards, query data sources, explore, monitor and visualise metrics.

#### 4.7. Security and privacy

The tools to be developed in WP5 will handle sensitive and personal data. Thus, it is fundamental to define its use, storage and access. Obtaining this data will involve human participants (adult healthy volunteers), personal data collection and processing. All the partners that will be involved in the development activities will comply with European regulatory standards and developments, with the General Data Protection Regulation (GDPR). The full list of data that will be collected by the mobile app is listed in Section 5.1.

As WP leader, LIST's Data Protection Officer will ensure compliance with the GDPR. LIST's team of experts working on these aspects will be consulted before the beginning of the data collection and then regularly during the project. To comply with the GDPR, LIST will prepare an explicit data protection policy based on the consent of the participants, the data minimisation principle and with possible anonymization of data. LIST will also request the participant's consent by presenting them the type of usage linked with their personal records (e.g., access, exploitation, commercial or statistical purposes). The processing carried out via WP5's tools will ensure the rights of the study participants, who will be informed of such rights (right to information prior to study enrolment, right to withdraw from the study at any time, right to access their personal data and to rectify or delete



them). The datasets generated during the project will be kept within the European Union. All open-data datasets resulting from the project will respect strict anonymization rules.

The project's data management plan and the data manager (LEEDS) will be consulted all along the data collection process.

The project team will implement data protection and security by design and apply all basic security principles regarding the encryption of communications, storage, and what follows.

## 5. Data specification

In this section we describe different aspects related to data: how it looks like, where we plan to get it from, how we plan to obtain it, how and where are we going to store it, how are we going to process it and what we expect to use it for.

### 5.1. Data sources

Mobile devices have become an irreplaceable part of people's daily life and embedded with a wide array of sensors. This study will investigate the possibility of using information from several sources to enable a comprehensive dataset. These sources include mobile sensors (e.g., accelerometer, gyroscope, compass, barometer), OBD dongles, user input, external services (e.g., weather and map services), and inferred from the car model (that can be obtained either from the VIN with OBD dongles or from explicit user input).

We will collect or compute factors that we consider necessary to offer recommendations to the driver. We divided these factors into four categories: environmental, vehicle, driver profile and driver behaviour. The environmental category covers everything related to the context surrounding the driver and the vehicle and are factors that the user cannot control. The vehicle category includes factors that describe the state of the vehicle mostly in a static manner. Similarly, the driver profile category covers static aspects of the driver. Finally, the driver behaviour category includes factors that change continuously during a trip and define how the driver is performing. Some of these factors will be used to give recommendations while driving, and others for recommendations offered after the trip is over. Table 21 describes each of these factors with more detail. Some of these factors will be aggregated and presented in the web dashboard. Additionally, in Table 22 we describe extra information that might be used for statistics that will not be shown to the driver.

Category	Factors that influence low-emission driving	Possible values	How to get this data?				Will it be used for scoring and active recommendations? (i.e. while driving)	Will it be used for passive recommendations? (i.e. post-trip reporting)	Web dashboard (CERTH's server)
			From OBD/J1939	From mobile sensors	From user input	From car model			
Environmental	Type of road	Class. Example: rural, urban, highway		Bluetooth and WiFi traces + classification model (ground T: OpenStreetMap) OR GPS + offline map data			GPS + Map service (e.g., OpenStreetMap)	X	X
	Speed limit	Integer. Example: 30-50-...-130		GPS + offline map data			GPS + Map service (e.g., OpenStreetMap)	X	X
	Road surface conditions	Score that represents the state of the road.		Further experimentation is required so that vibration patterns recorded by the phone sensors (when in a fixed position) can be analysed.				X	
	Wind	Float. Km/h					GPS + Real-time weather service (e.g., OpenWeatherMap)	X	
	Slope	Float. Angle/Slope Class		GPS: computation based on elevation or phone's compass OR GPS + offline map data			GPS + Map service (e.g., OpenStreetMap)	X	X
	Congestion	Float. Approximate congestion around the vehicle. Might be computed in the form of a score (0 = free; 100 = fully stopped)		Bluetooth and WiFi + regression model (ground T: HERE.com or Tomtom dev.) OR based on the vehicle' speed.			GPS + Real-time road traffic service (e.g., HERE.com or Tomtom dev)	X	X
	Light conditions	Float. Percentage of light (0 = night; 100 = sunny)		Estimation from Time + Date (Season) + GPS -> Public algorithms exist (according to Guillaume)			GPS + Real-time weather service (e.g., OpenWeatherMap)	X	X
	Temperature	Float. °C.					GPS + Real-time weather service (e.g., OpenWeatherMap)	X	
	Humidity	Float. %				X			
	Raining	Boolean. Yes / no				X			
Snowing	Boolean. Yes / no				X				
Vehicle	Vehicle type	Class. N1/N2/N3; M1/M2/M3 ; ... Full list: <a href="https://en.wikipedia.org/wiki/Vehicle_category">https://en.wikipedia.org/wiki/Vehicle_category</a>	VIN		X	X	VIN (user input OR OBD) + a web service to access the car model (e.g., <a href="https://vindecoder.eu/">https://vindecoder.eu/</a> )	X	X
	Engine type	Class. Petrol, Diesel, etc.			X	X		X	X
	Fuel consumption label	Class. Urban/Extraurban/Mixed			X	X		X	X
	Emission label	Class. Euro4/5/6			X	X		X	X

	Vehicle weight (empty vehicle)	kg			X	X			X	X
	Tyre information (brand/model, year)	Tyre type, pattern size, radium, width, etc.			X				X	X
	Tyre pressure	Psi							X	
	Vehicle km	km			X				X	X
	Use of retrofits	Retrofitted / non-retrofitted								X
Driver profile	Gender	Boolean. Male, Female			X				X	X
	Age	Date. Birthdate.			X				X	X
	Use of vehicle	Boolean. Professional / non-professional			X				X	X
	Driving experience	Date. Driving licence application date.			X				X	X
	Driving behaviour	Acceleration	m/s <sup>2</sup>	PID90 (Relative accelerator pedal position)	Accelerometer, GPS speed (the phone needs to be in a fixed position)				X	X
Deceleration		m/s <sup>2</sup> (negative)	PID90 (Relative accelerator pedal position)	Accelerometer, GPS speed (the phone needs to be in a fixed position)				X	X	X
Speed		km/h	PID13 (Vehicle speed)	GPS speed				X	X	X
Engine torque requirement		% of maximum torque	X					X	X	X
Engine rpm		number of revolutions	PID12 (Engine speed)					X	X	X

Table 21: Data for generating recommendations

*Red lines might not be estimated by the app.*

Metrics	How to get this data with OBD-II?	How to get this data with J1939?	How to get/estimate this data with mobile phone sensing?	Other calculation means?	Web dashboard (CERTH's server)
Steering wheel angle		PGN 61499 / SPN 1807 Steering Wheel Angel PGN 61449 / SPN 1808 Yaw Rate PGN 61449 / SPN 1809 Lateral Acceleration PGN 61449 / SPN 1810 Longitudinal Acceleration PGN 61499 / SPN 1811 Steering Wheel Turn Counter			
Engine power		PGN 65214 / SPN 166 Rated Engine Power			
Gas pedal position (%)	PID 47-4C, PID 8D (accelerator pedal position)	PGN 61443 / SPN 591 Accelerator Pedal Position 1			X
RPM	PID 0C (A, B)	PGN 61444 / SPN 190 Engine Speed			X
Gear position	PID A4	PGN 61441 / SPN 523 Current Gear		Speed + RPM might be used for estimating the gear position	X
Fuel consumption	PID 5E,9D	PGN 65257 / SPN 182 Trip Fuel PGN 65266 / SPN 183 Fuel Rate PGN 65266 / SPN 184 Instantaneous Fuel PGN 65266 / SPN 185 Average Fuel Economy			X
Mass Air Flow (MAF)	PID 10 (A, B)	PGN 61450 / SPN 135 Inlet Air Mass Flow Rate			
NOx sensor	PID 83 (B,C,D,E) (NOx sensor concentration), PID A1				X
Vehicle speed	PID 0D (A)	PNG 65132 / SPN 1624 Tachograph vehicle speed	GPS (float, float)		X
Engine Coolant Temperature	PID 05 (A)				
Steering wheel angle	Not standard with OBD; manufacturer specific		Based on Gyroscope + GPS		
Catalyst Temperature Bank1, sensor 1	PID 3C (A, B)				
Catalyst Temperature Bank2,	PID 3D (A, B)				



sensor 1					
Catalyst Temperature Bank1, sensor 2	PID 3E (A, B)				
Catalyst Temperature Bank2, sensor 2	PID 3F (A, B)				
Orientation			Compass (float, float, float)		X
Air pressure	PID 33		Barometer (float)		
Passive network data left by Wi-Fi, Bluetooth and cellular nodes			Wireless interfaces (raw data)		
Location + elevation			GPS (float, float, float, foat)		X
Exhaust temperature before SCR	PID 46 + PID 68			Based on the temperature sensor	
Engine out NOx emission	PID A1				X
SCR parameters					
Vehicle parameters	At least partly through the VIN + web service			Manufacturer	
Elementary composition of brake disc				Manufacturer of brake system	
Material parameters of brake				Manufacturer of brake system	
Contact surface geometry during braking				Manufacturer of brake system	
MODALES advisory message				To be generated by the mobile app (= recommendations)	X

Table 22: Additional raw data to be collected by the app

## 5.2. Data collection parameters

The tables presented in the previous subsection not only describe the data needed for the tools, but also give a hint on how to collect or compute that data. In this section we describe the various parameters that can affect the data collection. We present possible values for these parameters, but experimentation will be needed to select final values:

- **Sensor sampling rate:** based on the prior art, it was found that data was captured at 20Hz for the accelerometer and gyroscope, and GPS at 1Hz.
- **Time window size:** for the purpose of offering recommendations while driving, the accumulated data will be aggregated with a small window. The size of the window should take into consideration the sample rate of the different sensors, and that they might not be necessarily synchronised. But the size should not be too big, otherwise precision is lost. Hence, a window of several seconds (e.g., 5 seconds) could be enough, but experimentation is needed. On the other side, for recommendations offered after each trip, and for analysing metrics in the web dashboard, different aggregation levels can be implemented (e.g., per trip, per day, per month, per year).
- **Server synchronisation time and storage limit:** data would be captured in continuous matter and could extremely consume the device resources. Ideally, we could send the accumulated information to our server after a certain amount of time or a certain number of entries is reached, but connectivity cannot be guaranteed. Hence, we propose to queue packets of information to be sent as soon a Wi-Fi connection is available. In the meantime, if the accumulated information exceeds a storage limit (to be defined, depending on the mobile device or a configuration parameter), information can be dropped. In that case, we should also define a strategy for keeping or dropping information (e.g., keeping only the “interesting” events).
- **Execution time and time complexity:** all the computation can be performed directly on the mobile as several studies showed the possibility to achieve this task on the smartphones without overhead in terms of power and computations (Zheng et.al., 2016; Yu et al., 2016; Xie et.al., 2018). Since many sensors and I/O operations will be involved, calculating theoretical time complexities might not be very useful, but at least we should expect the mobile app to perform without “freezing” for more than a second. Intensive testing should be carried out with different devices, but if necessary, we can indicate that “old devices” are not supported.

## 6. Driving recommendations

### 6.1. Data interpretation

In this section, we will describe how we plan to use the collected or computed data. But first, we need to make a distinction between the experimentation and implementation phases. In the experimentation phase, the profiling models, the recommendation system and some other parameters are not fixed yet. Additionally, the required work can be carried out with any analysis or modelling technology without many resource constraints (e.g., python, matlab, R, etc). In the implementation phase, the systems involved are the mobile app and web dashboard, which will be implemented with specific technologies and taking into consideration execution time, battery or storage constraints. However, both phases can feed each other during the whole development process in an iterative and incremental manner. For example, we could consider the input from other WPs as the initial experimentation phase. From there, we can develop a first implementation. After some testing, we can go back to another experimentation phase using the collected data. With the new conclusions we derive a new implementation, and so on. In any phase, the data will be used for two main purposes: define the driver's profile and offer recommendations based on it if the user's behaviour needs to be corrected to lower emissions.

#### 6.1.1. Driver profiling

The driver's profile will be characterised either with a driving score or with a multi-dimensional score. Once data is captured and stored, signal transformation processes that convert the raw information into features would carry out. This could involve the following:

- **Filtering:** based on the prior art (Johnson et al., 2011; Eren et al., 2012; Fazeen et al. 2012), the most common signal filters used were low pass, high pass, and Kalman filters, therefore, different experiments would be conducted to identify the most suitable filters for the real-life signal.
- **Time interpolation:** due to the limited accuracy of the smartphone sensors, the mobile would not be able to record data at a fixed sample rate (e.g., the time intervals between two successive acceleration or gyroscope values are not fixed). Therefore, time interpolation is required to ensure that the time period between two successive data points is always equal.
- **Segmentation:** classification approaches do not typically operate directly on time-series data and require data to be represented as a set of samples. The prior literature supports the use of segment-based approach as it appears to be more effective and stable (Johnson et al., 2011; Al-Naffakh et al., 2018). Therefore, the tri-axial raw format for both acceleration and gyroscope signals would be segmented, and it is essential to identify the optimal window size as indicated on Section 5.2.
- **Imputation:** in many cases factors can be missing. For example, for it could be an external factor that depends on sensors that are not available, or PIDs that the vehicle has not implemented. For those cases, we could use collected data to infer the missing values (a.k.a. missing data imputation). Another example is the use of wireless traces to estimate the density of mobile devices near the vehicle, which at once could be used to infer traffic congestion levels (Faye et al., 2017-2018).

- **Dimensionality reduction:** (e.g., PCA, t-SNE, autoencoders) can be used to obtain more meaningful features from more compact spaces to be used as inputs for other methods.

### 6.1.2. Recommendations

Recommendations will initially be given by a rule-based system, where each rule is checked sequentially (thus defining priorities between them). Rules consist of factors, thresholds and logical operators. When the conditions of a rule are not met, a recommendation is triggered. The creation of these rules is heavily dependent on the knowledge gained from previous work packages.

If possible, this system can be improved after collecting initial data by experimenting with several machine learning techniques. For example, one possibility could be clustering drivers with similar profiles and assign similar recommendations by cluster. Another similar alternative if the amount of data allows it, is implementing actual recommender systems.

### 6.1.3. Web dashboard

The web dashboard is mainly a presentation application. However, web dashboard will interpret based on time criterion, the selected indicator and several classes (categories). The classes are:

- Vehicle type
- Road type
- User specific characteristics (e.g., age, gender)
- Topography
- Number of trips
- A specific geographic region

The data interpretation will be based on descriptive statistics like:

- Total number of samples
- Minimum and maximum values
- Variability
- Standard deviation
- Median value
- Mean value
- Most frequent value
- Summation of samples

## 6.2. How to get users involved?

Getting users to adopt an application is a complicated process. While many strategies exist, one of the main techniques that might be experimented within the project is gamification, which uses game concepts to get users to use a mobile app.

The main purpose of this section is to explore ways of how gamification can be used in the context of MODALES. Three parameters should be considered through the process of developing gamification in the project, namely: autonomy, competence and relatedness (Rapp, 2015; Sailer et al., 2017):

- Autonomy shows the willingness to achieve a particular task. If tasks are done for interest or personal value, the perceived autonomy is high.
- Competence is about the feelings of efficiency and success to satisfy the user's need. The provided feedback could increase the level of competence for the user. This feedback can result in improving the user's driving pattern and learning new skills.
- Relatedness describes the feeling of connection and need to interact with other people. In the context of games, this relates to being able to interact with other players and share information with each other (Rapp, 2015).

The proposed system could include the evaluation of the following gamification elements:

- **Rewards.** Rewards is the most common gamification element to encourage customers to use the application effectively. It is basically designed in order to encourage the end user to complete a predefined task. Rewards can be designed in different forms such as points, achievements, badges and other types of positive influences for the user. In the context of MODALES, a driver could for instance receive a digital voucher as a result of their efficient driving style (i.e., low emission).
- **Competition.** Competition is about encouraging drivers to promote safe driving and motivating to continue improving their driving style in order to achieve a goal. This can be achieved by showing a particular score for each driver using our system and display the top five drivers that obtained the highest score over the day or week. It is essential to clarify or explain the process of making the decision, otherwise this could negatively influence the users.
- **Feedback.** Communication between the system and the end-user is considered as one of the most effective way to attract the user's attention. It could keep the user motivated and stay on the right path and continue improving.

In the context of low-emission driving and MODALES, concrete implementation of these gamification elements could lead to the following possibilities, which will be considered by the development team:

- We could investigate further the gamification features on the existing applications mentioned in Section 2. We could replicate these functionalities and improve them based on our experience after using the apps or based on the (negative) user feedback published online (e.g., in Google Play or the Apple App Store).
- Additionally, we could mimic gamification from other kinds of learning apps. For example, the language app *Duolingo* rewards users with experience after solving exercises. When the user accumulates a determined number of experience points, it reaches a new level. Users can then compare their global ranking levels or a custom ranking involving only friends from social networks. Similarly, we could make users compete based on their emissions scores.
- We could also define generic achievements or let the user define personal goals to reach each week or month (e.g., reduce 1% of the emissions). The user could accumulate badges when achieving these goals and then share them in public dashboards or social networks.
- We could also implement graphical elements in the mobile app in the form of a game. One of the possibilities that were discussed by the partners is, for example, to show a glass of water, with a balance and level that would change in real-time according to the user's driving profile.

As of November 2020, and in addition to gamification, other possibilities are still under consideration, such as:

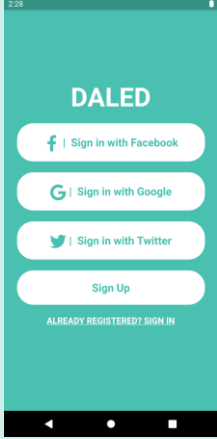
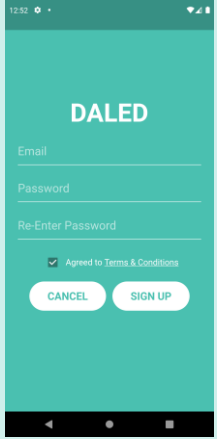
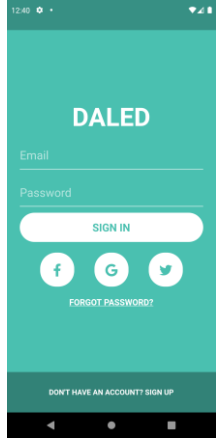
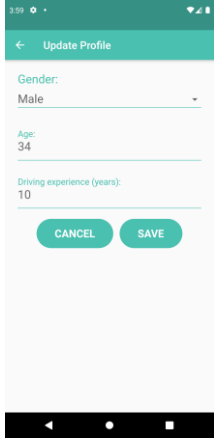
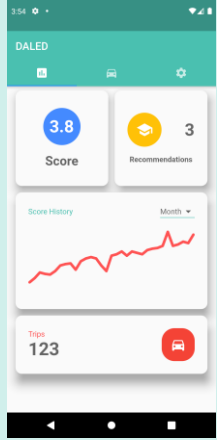
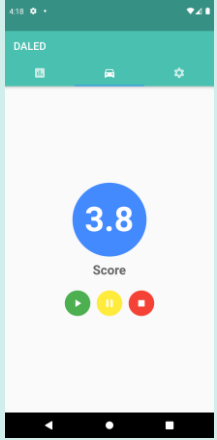
- The option of rewarding participants physically or with a specific reward, such as coffees at the local gas station and a free car wash.
- Setting up contextual notifications for encouraging the user to launch the application or automatically detecting when he is driving. Such a mechanism can be done using services implemented natively by Android and iOS, i.e., *ActivityRecognitionClient* and *CMMotionActivity* (Activity recognition APIs, 2020).

Gamification and, more generally, rewarding aspects are essential components of the project, but which cannot be or hardly determined solely on a theoretical basis. New ideas and possibilities might arise during the first iterations of the mobile app and the web dashboard. The final parameters will be selected in 2021 according to the observations made in the field and the budgetary possibilities.

## 7. Graphical user interface

### 7.1. Mobile app

Several screens that might be included in the mobile app are described in this section. Note that these screens are just mock-ups and their designs might be changed in the future.

Screen	Description	Screen	Description
	<p><b>Start session:</b> Gives the possibility to sign in with social networks, and to sign in or sign up with email and password.</p>		<p><b>Sign up:</b> Small form to register with email and password. The user also must agree with the terms and conditions, which can be shown either online or in a pop up.</p>
	<p><b>Sign In:</b> Small form to log into the system with email and password. The user can also sign in with social networks from here, reset his password or go to the registration screen.</p>		<p><b>Profile:</b> Small form with user information. Will be shown for the time right after registering. The information can be updated afterwards.</p>
	<p><b>Dashboard:</b></p> <ul style="list-style-type: none"> <li>• Current Score</li> <li>• Recommendations: could open a popup with text.</li> <li>• Score history plot: can be aggregated e.g., by last week, month or year.</li> <li>• Number of trips.</li> </ul> <p>More metrics can be discussed</p>		<p><b>Trip:</b> Simple start, pause and stop controls for the current trip. The score will be updated in real time, possibly changing colour and/or with sound queues.</p>

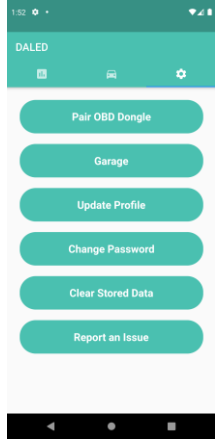
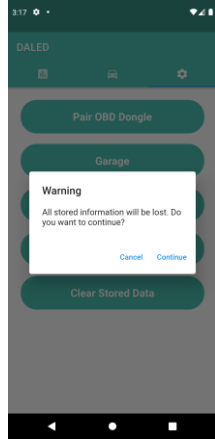
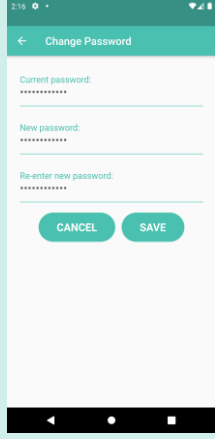
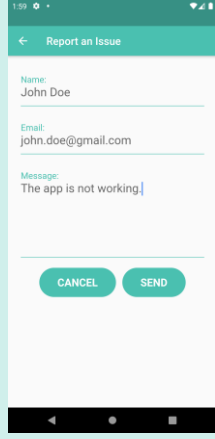
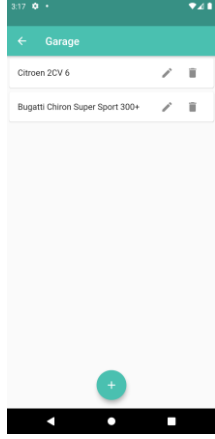
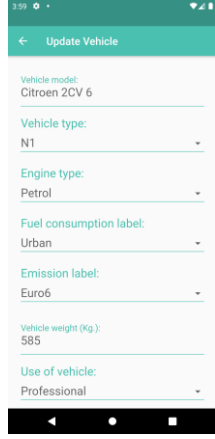
	<p>in the future.</p> <p><b>Settings:</b></p> <p>Simple menu to access other setting screens.</p>		<p><b>Clear Stored Data:</b></p> <p>Should ask for confirmation before clearing all the data.</p>
	<p><b>Reset Password:</b></p> <p>Simple form where the current and the new passwords are indicated.</p>		<p><b>Report an Issue:</b></p> <p>Simple form with a name, an email to reply and a message to send to us.</p>
	<p><b>Garage:</b></p> <p>Manage the registered vehicles. Each listed vehicle can be edited or deleted. Also new vehicles can be added.</p>		<p><b>Create/Update Vehicle:</b></p> <p>Long form indicating the characteristics of the vehicle. Some information could be filled (if possible) automatically when connecting the OBD dongle. If the form does not fit in the screen, the user should be able to scroll.</p>

Table 23: Mock-ups for the mobile app.

Active and passive recommendations to be fully experimented in T6.2 and T6.3 (see Section 6.2)

## 7.2. Web dashboard

The web dashboard would be composed of the following interfaces:

### Sign up

This form allows the user to create an account.



## Sign in

This form allows the user to sign into the system; this can be accomplished in different ways

- Social media account such as Google, Facebook, and Twitter
- Login using the Email address registered in the system.
- Account Recovery: to restore username and reset password using the Email registered in the user profile

## Dashboard

This is the main presentation layer of the application. It can be divided into four categories. The presentation layer may include (depending on the case) table (with data), graph, pie chart, gauge, bar gauge and text.

## Descriptive information

The “descriptive information” web page will contain visualisations like:

1. Table
2. Bar gauge
3. Text

## Aggregated indicators

The “aggregated indicators” web page will contain visualisations like:

1. Pie chart
  2. Graph
  3. Gauge
  4. Bar Gauge
  5. Table
- **Report:** a list of reports that the user can select. The reports are related to the descriptive and aggregated information.
  - **Share:** the user can select an element (like pie chart) and share it with another user.

## User(s)

The user can edit his/her information, while the administrator can manage the user accounts.

## 8. Conclusions

This document describes the specifications of the two main tools to be developed in MODALES, namely a mobile app and a web dashboard. The first will take the form of a driver profiling system using a user's smartphone sensors, with the possibility of joining data from external services and OBD dongles. The proposed system will help train new drivers by offering live recommendations and assisting them towards instant driving style adjustment. The second will be a platform showing aggregated and anonymous indicators to support public authorities and the project's awareness campaigns.

This deliverable came to the following conclusions:

- The mobile app will offer active recommendations during a trip in the form of a score, with visual cues indicating its change.
- The mobile app will also offer passive recommendations after a trip, which might consist of text indications for improving the user's driving behaviour.
- The tools will estimate and use three categories of indicators to offer recommendations (both passive and active), namely environmental, vehicle and user-dependent factors. Extra information from OBD dongles and external web services to display statistics on the web dashboard.
- The initial plan for passive recommendations is to compute them by implementing a rule-based system based on collected factors.
- Data can be collected from many sources, but most of them might not be available. This restriction depends on several aspects that cannot be controlled within the framework of this project, like the mobile phone model, the Internet connectivity and the vehicle model. The mobile app should therefore be prepared to be flexible for different configurations.
- We will experiment with machine learning models to impute factors when they are not available, like the estimation of a congestion level, which might be based on the vehicle speed or passive wireless traces.
- The development process should be iterative and incremental. This document is a starting point, but we must keep refining our understanding of the problem while working on it. In other words, the team involved in T5.3 will follow the specifications provided in the present document as a basis for development, which will evolve throughout the project according to the experimental sites' data.
- The dashboard, recommendation, and gamification modules still need further iterations and initial experiments and interactions with end-users. The mobile app's final parameters will be the subject of a separate document that will be delivered in M24 with release 3.

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