D 9.1

Madrid: Demo Description and Implementation Plan

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Coordinator: UITP – International Association of Public Transport

SUMMARY SHEET

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Abstract	The overall objective of the Madrid demonstration, within the EU co-funded project EBSF_2, is the implementation of 2 advanced technological solutions dealing with the topical research area "Green Driver Assistance Systems". The demo team (Tekia, CRTM) is committed to: • develop and test in real-life operational conditions a Driving Style Indicator designed to (i) modify the driving style of drivers, (ii) obtain a quantitative indicator which allows a fair comparison among drivers and (iii) correlate fuel savings due to driving style improvement. • develop and test a method to estimate fuel savings with higher precision than traditional methods based on tank refill and comparison of similar periods of operations (same months, consecutive years). Deliverable 9.1 – Madrid: Demo Description and Implementation Plan, provides a description of the innovations to be tested, plans for implementation of the demonstration, relevant validation objectives and preliminary information about data to be collected.
Keywords	Public Transport, Bus System, Driver Assistance, Energy Efficiency

INTERNAL DISTRIBUTION

Participant N°	Participant organisation name	Country
1 Coordinator	Union Internationale des Transports Publics - UITP	Belgium
2	Régie Autonome des Transports Parisiens - RATP	France
3	Iveco France SA - IVECO	France
4	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. - FRAUNHOFER	Germany
5	Hübner Gummi- und Kunststoff GMBH - HUEBNER	Germany
6	DigiMobee SAS - DIGIMOBEE	France
7	Centro de Estudios e Investigaciones Técnicas - CEIT	Spain
8	Chalmers Tekniska Hoegskola AB - CHALMERS	Sweden
9	Compañía del Tranvía de San Sebastián, SA (CTSS) – DBUS	Spain
10	IRIZAR S Coop - IRIZAR	Spain
11	D'Appolonia S.p.A. - DAPP	Italy
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13	Volvo Bus Corporation - VBC	Sweden
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16	Actia S.A. - ACTIA	France
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35	Verband Deutscher Verkehrsunternehmen - VDV	Germany
36	Promotion of Operational Links with Integrated Services, Association Internationale - POLIS	Belgium
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39	Union des Transports Publics - UTP	France
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41	Commissariat à l'Energie Atomique et aux Energies Alternatives - CEA	France
42	Consorcio Regional de Transportes de Madrid - CRTM	Spain

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Entity	Short name	Country	Contact person
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1.0	16/12/2016	Final version	TEKIA & CRTM	Modifications based on quality check.

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ACRONYMS

GDAS - Green Driver Assistance System

KPI - Key Performance Indicator

PTO - Public Transport Operator

TI - Technological Innovation

TIMad1 - Technological Innovation Madrid 1 (new indicator for driving style)

TIMad2 - Technological Innovation Madrid 2 (method to estimate fuel savings)

VO - Validation Objective

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1 Executive Summary

The overall objective of EBSF_2 is to increase the attractiveness and improve the image of bus systems in urban and suburban areas. Accordingly, the project aims to test, evaluate and validate innovative solutions through demonstration in real service. Six key research areas have been identified to have the highest potential to impact:

- Energy Strategy and Auxiliaries;
- Green Driver Assistance Systems;
- IT Standards introduction in existing fleet;
- Vehicle Design (capacity, accessibility, modularity);
- Intelligence Garage and predictive maintenance; and
- Interface between Bus and Urban Infrastructure

These areas are to be further investigated in demonstrations sites (12) which Madrid is one.

The Madrid demonstration addresses the topical area "Green Driver Assistance Systems" by exploring the potential of new driver assistance solutions to influence the driving style of bus drivers. The solutions to be tested will combine two main features:

- Quantitative measures of driving efficiency using an intuitive indicator;
- Estimation of fuel savings due to the driving style improvements (and excluding other factors).

Deliverable 9.1 – Madrid: Demo Description and Implementation Plan, provides a description of the technological innovations to be demonstrated, plans for implementation of the tests, relevant validation objectives and data to be collected.

2 INTRODUCTION

The European Bus Systems of the Future 2 (EBSF 2) is an Innovation Action co-funded by the European Union within the Horizon 2020 Research and Innovation programme and coordinated by UITP – the International Association of Public Transport. The project, which runs between May 2015 and April 2018, capitalizes on the results of the previous EBSF project (2008-2013) and, as the former, aims to develop a new generation of urban bus systems by means of new vehicle technologies and infrastructures in combination with operational best practices, and test them in operating scenarios within several European bus networks.

The need for more cost-effective and energy efficient bus systems has led to the identification of a set of technological innovations (TIs) and strategies with a strong potential to optimize mainly energy and thermal management of buses (in particular auxiliaries such as climate systems), green driver (eco driving) assistance systems, intelligent garage and maintenance processes, IT standard equipment and services. Moreover, to effectively address the need to move quickly from laboratory research to actual innovation of the bus fleets in operation in Europe, the technologies to be tested have been selected according to their technological maturity (and not only because of their potential) in order to ensure a short step to commercialisation once the project ends. The use of simulators and prototypes has been conceived as a preliminary step for the validation of the innovations in real operational scenarios, performed within the project as well, or as a necessary task to prove the potential of more futuristic solutions currently implemented at early stage of development (e.g. modular bus).

2.1 Organisation of Deliverable

The deliverable is organised as follows:

- Chapter 3 presents the context where the Madrid demonstration will take place;
- Chapter 4 introduces the objectives of the demonstration;
- Chapter 5 describes the two TIs and how they will be tested;
- Chapter 6 presents the plans for the demo implementation and the demo team;
- Chapter 7 describes the partners' contribution to finalise this deliverable.

3 DEMO BACKGROUND AND CONTEXT

3.1 Geographical and Urban Context

The city of Madrid is the capital of Spain and largest city in the Madrid Region by population. Madrid Region has about 6.5 million inhabitants (and thus it is the third more populated region in the country) in an area of 8,028 km^2 and counts 179 municipalities. The region is split into three zones, or “rings” (see Figure 1):

- Madrid City (Ring A), the main municipality of the region which concentrates the economic activities.
- Metropolitan Ring (Ring B), which consists of a number of large and medium size entities around the municipality of Madrid, with significant mobility flows to and from the central area.
- Rest of the Region (Ring C), with small and medium size municipalities.

In turn, the population of Madrid city is almost 3.2 million inhabitants (being the third-largest city in the European Union, after London and Berlin), accounting for 49,8% of the region’s total population in a surface of 606,4 km^2. Its central core, the so called “Central Almond”, is home to 31% of the region population and provides a large proportion of region jobs.

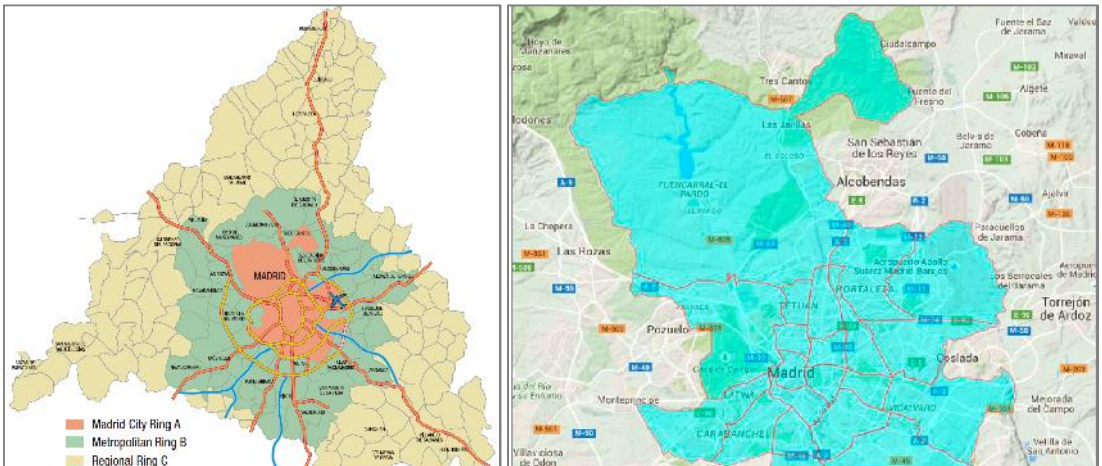


Figure 1 – Territorial Structure of Madrid Region and Madrid City (Ring A)

The population growth in the Madrid city has shown a slightly increase until 2010, when the recession period started and the city lost 3% of inhabitants in 2014 compared to 2010. On the other hand, the population’s distribution in the metropolitan and region rings has shown a dynamic process characterised by a sharp increase of population, giving rise to radical changes in mobility in the region, with a significant increase in metropolitan journeys.

3.2 Mobility

The total number of journeys in Madrid City during a single working day (according to the last Synthetic Mobility Survey in 2014, ESM 2014) was 6.7 million, an average of 2.56 journeys per inhabitants. These journeys are distributed with prevalence of sustainable modes (74% of journeys); thus, 38% use public transport, followed by journeys made on foot 36%, and 25% in private vehicle (Figure 2).

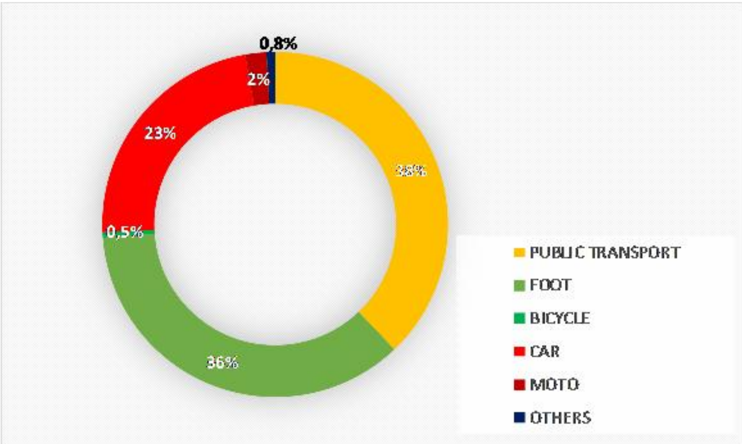


Figure 2 – Modal Split in Madrid City, 2014

If we look at the whole Madrid Region, the total number of journeys during a single working day was 12.9 million, on an average of 2.45 journeys per inhabitant (ESM 2014). Out of all journeys of the Madrid Region, 63.6% of them have origin/destination within Madrid Municipality (51.9% of internal journeys and 11.7% of external journeys). Regarding radial mobility between Madrid City and the Metropolitan Ring, there is almost a balance; 53% of journeys use private vehicles versus 41% public transport.

In conclusion, public transport in Madrid city is vital for daily mobility and competitive services is needed for their success.

3.3 PT Service Background and Context

CRTM (Consorcio Regional de Transportes de Madrid) is an autonomous agency of the Madrid Regional Government. It is responsible for providing and managing all public passenger transport services attached to the Madrid Region and to all the municipal councils in the region who transfer to CRTM their competences in urban transport (nowadays, all municipalities). The main functions of CRTM are: (i) planning public transport infrastructure; (ii) planning and organizing the coordinated management of transport services; (iii) elaborating the ticketing policy and financing; and (iv) global image and users.

The public transport system for the Madrid Region and City is a complex intermodal system, in 2014 there were 1,371.1 million of journeys (Figure 3). The system consists of various modes of transport which are operated by different companies, both public and privately-owned (Table 1):

- EMT, Madrid Municipal Company of Transport (Empresa Municipal de Transportes) is a public limited company owned by Madrid municipality, operating buses in Madrid city. It operated 204 routes with 1,907 buses and transported more than 402 million of passenger in 2014.
- Metro de Madrid S.A. is a public company under the Regional Government. It operates 12 lines, for a total length of 287 km in 2014. It transported in 2014 more than 563 million of passengers in 2014. Two societies operate under concession the extension of Metro Line 9 and the connection of airport T-4 terminal, the Railway Transport Society of Madrid (la sociedad the Transportes Ferroviarios de Madrid - TFM) and the MetroBarajas S.A. society, respectively.
- Renfe Cercanías is a public company owned by Spanish Government. It operates 9 lines, with a total network length of 391km and transported 184.3 million of passengers in 2014.
- 3 railway concessionaries operate 4 lines of light rails. They have a total network length of 35 km and 56 stations. Around 14 million of passenger were transported in light rails in 2014.
- Interurban buses and urban buses of other municipalities are operated by 30 private companies. They operate 109 urban bus lines and 328 interurban bus lines with a total network length of 9,050 km and transported more than 202 million of passenger in 2014.

PUBLIC TRANSPORT SYSTEMS OF MADRID REGION (2014)

Transport Modes	No. Lines	Length of network (km)	Length of lines (km)	Stations/Stops of network	Stations/Stops of lines	No. vehicles	Vehicles-km (Millions)
Metro	12+1	267.9	267.9	235	285	2,326	164.1
Urban Bus Zone A (EMT)	204	1,531.7	3,621.0	4,630	10,653	1,907	88.9
Urban Bus other municipalities & suburban	437	9,049.7	20,746.0	6,947	20,964	1,813	170.2
Light rail	4	35.8	35.8	56	57	220	12.7
Other rail concessions (TFM)	2	19.0	19	6	6	21	3.5
RENFE suburban train	9	391	778.3	92	166	1,127	146.5

Table 1 - Public transport offer by mode in 2014

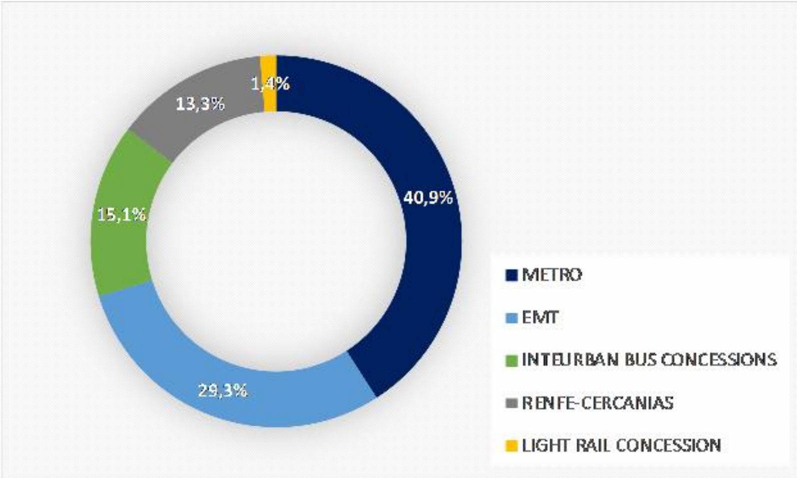


Figure 3 - Distribution of public transport demand by mode in Madrid City, 2014

Focusing on Madrid demo, the driver assistance system is going to be tested in urban buses of Madrid City. Urban buses in Madrid are operated by Empresa Municipal de Transportes (EMT). All the data included is referred to 2014. Bus network in Madrid City consists of 204 lines, covering a distance of 3,621km. Daily, there are made around 1,266,638 journeys, equivalent to an annual demand of 402 million journeys. Yearly, there are made 127.71 journeys in urban bus per inhabitants. The average rate of passenger per veh-km is 4.52. All EMT data refer to 2014.

The standard features of an EMT bus route are the following:

- Average distance coverage: 9,000 metres
- It serves 25 bus stops in each direction located at intervals of 330 metres.
- The average distance per passenger is 3.0km
- Average speed in line is 13.39km/h
- Peak times headways for daily routes are shown in the following Figure 4. During peak times, 29% of routes operates with a headway less than 8 min.

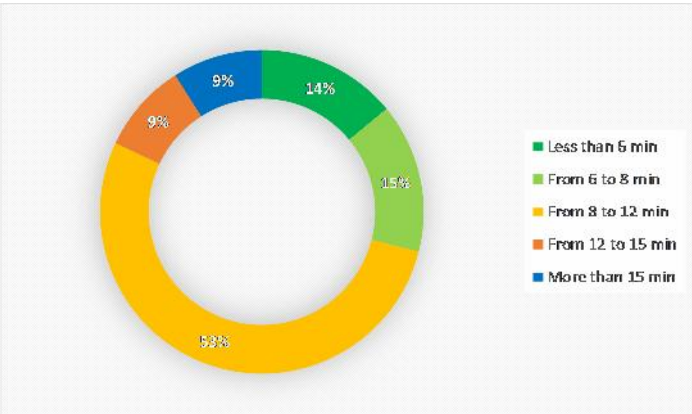


Figure 4 - Peak times headway for daily routes

Regarding the fleet, EMT operates 1,907 vehicles with an average age of 7.6 years and 100% with low floors. The fleet type by fuel consumption is composed by:

- 767 powered by compressed natural gas
- 23 are hybrid diesel-electric engines
- 20 buses are electric
- 1,097 are diesel,

all them fulfil at least EURO V emissions standards.

The energy consumption registered in 2014 for the total fleet was more than 641,600,000 kWh, corresponding to an average of 665 kWh/100km. Average energy consumption per type of vehicle in 2014 are shown in the following Table 2.

	Consumption per 100km (kWh)				Daily journeys/vehicle	Occupation rate
	Diesel	Natural Gas	Electric	Hybrid		
2014	565.43	799.64	89.35	597.51	20.30	48.59%
	Total consumption (kWh)					Average kWh/100km
	Diesel	Natural Gas	Electric	Hybrid	Total	
2014	305,758,419	331,323,666	225,389	4,325,585	641,633,059	665.00
2013	322,125,083	318,211,398	241,178	4,171,289	644,748,948	651.30

Table 2 – Energy consumption by type of bus (EMT fleet)

Electric buses are, within the EMT fleet, the most efficient energy consuming, with 89.35kWh every 100km.This is one of the drivers behind the plan of EMT to renew the whole vehicle fleet to electric in the coming years. But, there are other strategies to reduce energy consumption and having an efficient bus fleet operation, such as driver assistance systems.

Figure 5 - EMT bus refuelling

4 DEMO OBJECTIVES

The demonstration in Madrid is committed to:

- Develop and test in real-life operational conditions, and in controlled conditions in the case of an HMI test, a driving style indicator designed to:
    - Contribute to improve the energy efficiency of the driving style.
    - Obtain a quantitative indicator which allows a fair comparison among drivers.
    - Show a clear correlation with fuel savings.
- Develop and test, with data previously obtained in real-life operational conditions, a method to measure fuel savings due to the driving style improvement by taking into account variations in routes, demand periods, use of A/C, route slopes and number of stoppings. This method will lead to more precise assessment of the fuel savings than the one achievable with traditional methods which are based on the direct comparison of the vehicles' fuel consumptions in similar periods (same months, consecutive years).

The implementation of the above technological development refers to a set of specific objectives:

- Reducing the consumption of conventional fuels per vehicle,
- Reducing air emissions,
- Improving the overall bus energy efficiency by increasing green driving and improving driver's compliance with green driving procedures.

The Technological Innovations (TI) that will be implemented in Madrid Demo are labelled according to the definition and the coding agreed within the project task "Definition of Validation Objectives and Test Scenario", namely:

- Driving Style Indicator (**TIMad1**)
- Estimation of Fuel Savings (**TIMad2**).

Both TIs are extensively described in section 5 - Demo description. For each of them a set of Validation Objectives has been identified coherently with the methodology developed by the EBSF_2 Evaluation team (ref. Annex · - List of EBSF_2 Validation Objectives).

5 DEMO DESCRIPTION

5.1 Rationale

Green driving, or eco-driving, is a term used to describe the energy efficient driving of vehicles by adopting smoother driving styles which avoid excessive harsh manoeuvres or aggressive driving behaviours. Green driving benefits include GHG emissions reductions, fuel cost savings, as well as greater safety and comfort for on-board passengers. The main objective of Green Driver Assistance Systems (GDAS) is therefore to help drivers to achieve a more efficient driving, mainly by informing them about their driving style both while driving and afterwards, allowing them to learn how they can improve their own driving style.

The effect of GDAS on drivers' behaviour is limited, as other important factors such as the motivation of the driver and the design of line schedules affect significantly the driving style. Discouraged drivers or tight schedules can hinder any improvement of driving. For this reason, GDAS should also consider the following factors:

- GDAS should provide the PTOs with information that enables them to develop strategies to encourage drivers, based on incentives, driver coaching, or other. This information should allow to evaluate drivers fairly, and to measure the results in terms of fuel savings or other objectives related to driving efficiency.
- Drivers should be compared in similar circumstances, taking into account factors as delays and moments when restoring the schedule is more important than driving efficiently.

Accordingly, the technological innovations to be tested in the Madrid demonstration for a GDAS, focus on three essential features such systems should be able to achieve:

- TIMad1 – Driving Style Indicator:
    - **Modify the driving style of drivers to a more efficient one while driving.**
    - **Obtain a quantitative indicator of driving style which allows for a fair comparison among drivers.**
- TIMad2 – Estimation of Fuel Savings:
    - **Measure the results of improving the driver style in terms of fuel savings** taking into account specific features such as routes, demand period, use of A/C, route slope and number of stoppings.

5.2 Validation Objectives

The following Validation Objectives has been identified as relevant for the TIs to be tested in Madrid (TIMad1 and TIMad2) coherently with the methodology developed by the EBSF_2 Evaluation team.

VO - Validation Objective	
1	Improving the overall energy efficiency of fleets
3	Reducing the consumption of conventional fuels or electric energy

Table 3 – Validation Objectives for TIMad1 and TIMad2

Both TI's are expected to have also a positive impact on the following objectives as they are strongly correlated to the core VO in Table 3.

VO - Validation Objective	
6	Making driving safer
7	Making driving practice more environmentally conscious
17	Minimizing operating and maintenance costs
18	Improving on board travel comfort
28	Increasing economic efficiency

Table 4 - Validation Objectives related to TIMad1 and TIMad2

Although objectives 6 to 28 will not be directly tested, it is assumed that if fuel consumption is reduced due to a smoother driving, onboard travel comfort will be improved, maintenance costs will be reduced due to less use of brakes and less strain of the drivetrain and wheels, drivers will be more environmentally conscious when informed about the fuel savings they have produced and probably accidents will be reduced due to the reduction of harsh menouvers. In summary, all these validation objectives are assumed to be related to fuel savings when savings are produced with a GDAS.

5.2.1 Approach to testing

In order to measure fuel savings, the basic test procedure consists of comparing fuel consumption in the « before » scenario (without EBSF2 GDAS installed on buses) and «during» the test (EBSF2 GDAS installed). However, it is worth higlighting that it is not possible to set a fuel saving target a priori as further explained in the following.

The difference in fuel consumption depends on the level of efficiency of driving « before » and the level of compliancy of drivers with the GDAS « during». The level of driving efficiency « before » is represented as level D in Figure 5. The level achieved « during» is limited by line schedules (level A in the figure) as driving too smooth will probably cause delays. This means that EBSF2 GDAS will have to be configured to require drives to drive as in level B in the figure, below A. However the level of compliancy of drivers will generally be lower than B (level C in the figure).

Consequently, the fuel savings that will be achieved will be the result of the difference between levels C and D, none of which is known a priori. If drivers selected for the test happen to be harsh drivers « before » that comply with EBSF2 GDAS indications « during », it is likely that significant savings will be achieved. However, if drivers selected for the test are already used to drive smooth, and line schedules are so tight that do not allow for smoother driving, it is likely that no significant savings will be achieved with the tests. .

In summary, fuel savings achieved in the test will largely depend on the drivers selected (harsh/smooth, compliant/noncompliant). For this reason, the EBSF_2 test is not focused on measuring fuel consumption, but on measuring the **correlation between fuel savings and improvement in driving styles**, as described in the following sections.

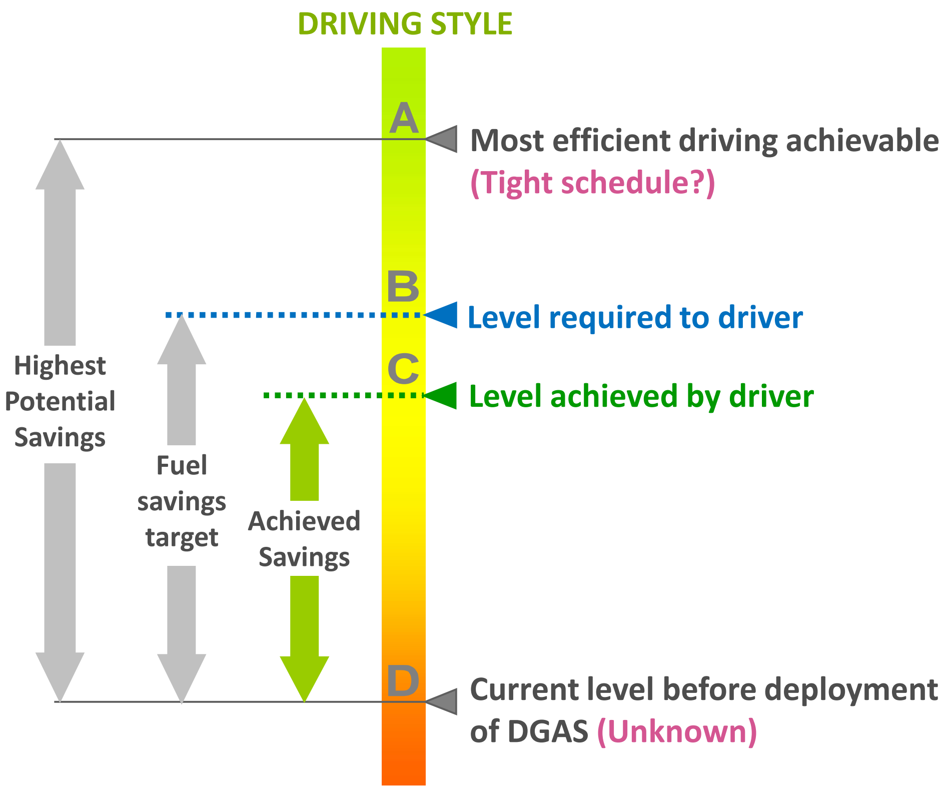


Figure 6 – Estimating a target for Fuel savings

5.3 Driving Style Indicator (TIMad1)

TIMad1considers two main requirements:

- The system should be able to inform the driver, while driving, about the efficiency of his driving style, so that he can improve it.

- The system should be able to measure to which extent the drivers have followed the driving efficiency indications, so that the drivers, and the PTO, are informed about how they have driven during a period of time.

As a result, the following concepts applies to the demo:

- **Driving_in_Green (DiG).** This concept represents the time the driver drives efficiently. It is measured in time units (i. e., seconds). The GDAS measures in real time (onboard) when the driver is driving efficiently taking into account the type of bus movement (stopping, approaching to a stop, in traffic…) and the maneuvers (longitudinal or lateral accelerations, speed, idle, braking). A Green indication is given to the driver while he is driving efficiently.

%Time_in_Green (%TiG). This concept is used in back-office to measure drivers' compliancy with onboard Driving_in_Green indications. It is the ratio of Driving_in_Green time with respect to the total driving time:

$$\%Time\ in\ Green = \frac{Total\ time\ \boldsymbol{Driving\ in\ Green}}{Total\ driving\ time} \times 100\%$$

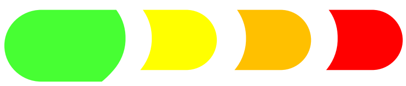
Driving_in_Green time may be calculated in back-office differently than onboard to take into account the demand period, as well as other factors, and using different acceletarion profile thresholds. This is because while the main purpose of the Driving_in_Green calculation onboard is to improve driving style in real time, the purpose of the Driving_in_Green calculation in back-office is to serve as a fair indicator of compliancy that allows comparing different driving styles.

5.3.1 Testing and validating the Driving_in_Green concept

5.3.1.1 Description of Test

The purpose of the direct evaluation of the Driving_in_Green concept is to validate that indications offered to drivers are effectively related to their driving style and not affected by other factors (road slope, bumps, vibration or others). This test will be done as follows:

I. A bus equipped with GDAS HMI will be driven along a route with two experts onboard. An expert is a person with experience in ecodriving designated by the PTO, belonging to the Training Department. The HMI will have four indicators.



- Green indicates Green driving.
- Yellow indicates that the current driving style is about to "loose green". It is just a warning (Yellow and Green are shown simultaneously because the driver is still driving in green).
- Orange indicates that the current driving

style is not green anymore.
- Red indicates a very inefficient driving.
- The times it takes to go back to green from Orange or from Red depends on the energy that has been wasted when green was lost.

II. Experts will ask the driver to drive harsh or smooth and perform different maneuvers (acceleration, braking) under different circumstances (different speeds, with positive slopes, negative slopes and flat, approaching and departing from stops)

III. Experts will look at the indications provided by the GDAS HMI and will judge, from 1 (no correlation) to 5 (perfect correlation) how good indications correlate with the driving style under different circumstances.

IV. Driving_in_Green time will also be calculated and shown in real time to the experts onboard. The experts will also take into account the value of this parameter to confirm that:
   - it is correlated with the indications given to the driver
   - it is larger when driving smooth and
   - the difference in its value is related to the difference in driving styles.

5.3.1.2 Goal

It is expected that an a score above 3/5 will be obtained averaging the experts scores in all circumstances.

5.3.1.3 Test conditions and Fleets/ Vehicles/ Lines /Drivers involved

- 1 bus, Diesel (Iveco Cyticlass)
- 1 driver and two experts in eco-driving training.
- Bus not in service (no passengers on board)
- 1 day duration
- Test perfomed on 1 Line with flat and sloped routes.

5.3.1.4 " No EBSF_2 scenario" vs "EBSF_2 situation"

Testing of the the Driving_in_Green concept is carried out independeltly of the « before » (without EBSF2 GDAS installed on buses) and «during» (EBSF2 GDAS installed) periods in order to validate the indications given to drivers.

5.3.1.5 Data collection plan

Relevant data for the Driving_in_Green concept test includesScores given by experts
These data will be recorded onboard during the test.

5.3.1.6 Risks assessment

No relevant risks have been identified for testing and validating the Driving_in_Green concept

5.3.2 Testing and valitading the « %Time_in_Green » concept

5.3.2.1 Description of Test

The %Time_in_Green indication is a way to characterize the driving style with a single number. The following features have to be tested in order to validate this concept:

- « %Time_in_Green » effectively characterizes driving styles, being larger when driving styles are smoother and viceversa.
- « %Time_in_Green » is correlated with fuel savings obtained due to an improvement in driving efficiency, so that the larger its value, the greater the efficiency.

If both features are validated, the « %Time_in_Green » indicator will be proved to be a valid indicator to measure driving efficiency, allowing to know to which extent drivers have followed the driving efficiency indications (level of compliancy) and, together with TIMad2, to know also how much fuel have been saved due to the driving improvement, and how much fuel could have been saved.

The first feature will be already validated in the previous test (Testing and validating the Driving_in_Green concept) since:

- "%Time_in_Green" is obtained from "Driving_in_Green"
  ($\%Time\ in\ Green = \frac{Total\ time\ \mathbf{Driving\ in\ Green}}{Total\ driving\ time} \times 100\%$)
- "Driving_in_green" will be shown to be correlated to driving styles.

Therefore, the focus of this test is to show the correlation between "%Time_in_Green" and fuel savings. This test is done together with the test of TIMad2 and therefore both tests are described jointly in Section 5.4 Estimation of Fuel Savings (TIMad2).

5.3.2.2 Goal

As described in *5.2.1 Approach to testing,* it is not possible to validate the GDAS based on a driving improvement target, because the room for improvement and the level of compliancy of drivers does not depend on the GDAS. However, based on our experience, it is expected that the "%Time_in_Green will be at least 10% larger with EBSF2 GDAS than without EBSF2.

The KPI choosen to validate the "%Time_in_Green" indicator is the correlation between this indicator and the fuel savings due to driving improvement. The target value for this correlation is at 0,7 (70%) or more.

In order to do this test correctly, the value of the fuel savings should be calculated from the fuel consumption diference due to differences in driving styles, and not due to other factors affecting fuel consumption. This calculation is the objective of TIMad2.

5.3.2.3 Test conditions and Fleets/ Vehicles/ Lines /Drivers involved

The data that will be used for the test was gathered from Line 113 of the Empresa Municipal de Transportes de Madrid in 2014

- **Line 113 info**:
  - Distances from Depo:
    - To header A: 3.925 Km
    - To header B: 10.343 Km
  - Total number of stops: 52 (2 stops in common at headers)
  - Route A-B: MENDEZ ÁLVARO
    - Length: 7,541 metres
    - Total stops: 27
  - Route B-A: PLAZA DE CIUDAD LINEAL
    - Length: 7,334 metres
    - Total stops: 27
  - Resources in high season

Figures per day	Monday to Friday **Working days**	Saturdays **Working days**	Sundays and holidays
Buses	9	5	4
Drivers shifts	22	13	10
Total journeys	204	130	105
Total hours/line	142,98	82,95	64,42
Total Km	1.517,66	966,88	781,04

Table 1 Line 113: resources in high season

  - Timetable per demand period and day type

Type of day	Departures **First service – Last service**		Programmed bus frequency	
	Mendez Álvaro	Pza de Ciudad Lineal	Hours	Frecuencies
Monday to Friday **Working days**	5:30 – 23:15	5:55 – 23:15	From 6 to 7 and 22 to 23 From 7 to 21 From 21 to 22	> Each 12-19 min > Each 8-12 min > Each 10-17 min
Saturdays **Working days**	5:30 – 23:15	5:55 – 23:15	From 6 to 8 From 8 to 23	> Each 17-28 min > Each 15-18 min
Sundays and holidays	7:00 – 23:15	7:00 – 23:15	From 7 to 21 From 21 to 23	> Each 17-20 min > Each 18-31 min

Table 2: Line 113: timetable

The GDAS data logger was installed in 10 vehicles Diesel Iveco Cityclass that were driven on Line 113 in normal service (with passengers). 25 drivers were trainned to use the GDAS HMI.

5.3.2.4 "No EBSF_2 scenario" vs "EBSF_2 situation"

In the « No EBSF_2 scenario » drivers are not informed about the trial, so they drive as they are used to.The GDAS data logger is installed on-board the test buses, but the driver HMI is not active (drivesr do not see any indication about their driving style).
In this scenario, data recorded are needed to calculate the %Time_in_green for each driver, measure fuel consumption in each type of bus movement (stopping, approaching to a stop, in traffic…) and maneuvers (longitudinal or lateral accelerations, speed, idle, braking) and (iii) normalize fuel consumption in order to estimate true fuel savings in the test period and includes:

- Contact on/off
- Doors open/closed
- Lights on/off
- A/C Compressor on/off
- Acelerator pedal position
- Speed
- Distance
- Three axis acceleration
- Brake switch
- Kickdown
- Total fuel used
- Fuel rate
- Fuel economy
- RPM

These paramenters are registered associated to events generated depending on vehicles movements.

In the test period or the „EBSF_2 scenario" drivers are informed about the test and trainned to follow the GDAS HMI instaled on buses used for the tests.
The data logger continues registring the same data as in the previous period

5.3.2.5 Data collection plan

Except for the HMI, testing of EBSF2 TI in Madrid will be done using previously collected data from Line 113 of EMT, selecting valid data for EBSF2 purposes.

Valid data was obtained with the following scope:

- 8 vehicles
- 22 drivers
- 6 weeks
- 16211 Km
- More than 2.000.000 events registered

During 3 weeks (W15, W16 and W17 of 2014) data was logged without the HMI activated. In week W16 some drivers were trained. Only drivers not trained on these three weeks will be selected for the no EBSF2 analysis.

Driver training to use the HMI was done in weeks W16 and W18.

HMI was activated at the beginning of W18 but not all drivers were trained yet. Only trained drivers will be selected for the “with EBSF2 GDAS” analysis.

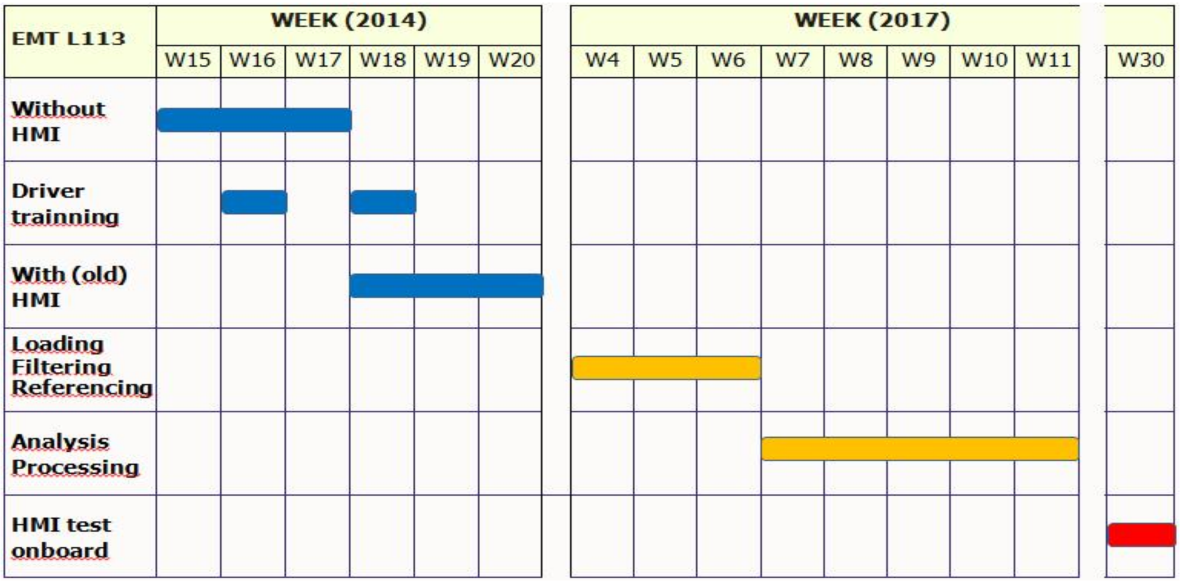


Table 5 – Data collection plan

5.4 Estimation of Fuel Savings (TIMad2)

5.4.1 Setup

The GDAS architecture for data collection and testing is composed of a vehcile subsystem and a back-office subsystem.

The vehicle subsystem includes a driving processor and data logger with the following functions:

- Obtain data from the vehicle chassis (CAN bus and discrete signals) and calculated (accelerations)
- Calculate “%Time_in_Green”
- Control the driver HMI
- Log data to be processed at the back-office subsystem

The back-office subsystem has the following functionality:

- Loads files generated by the vehicle driving processors
- Extracts data from files and structures it in the GDAS Database
- Obtains data from the AVMS database of the PTO and references GDAS data to AVMS data (lines, routes, stops, type of day …)
- Processes data (calculates « Driving_in_Green » time, « %Time_in_Green » and fuel savings)
- Generates reports

The components of both the Vehicle and the back-office sub-systems are shown in Figure 7.

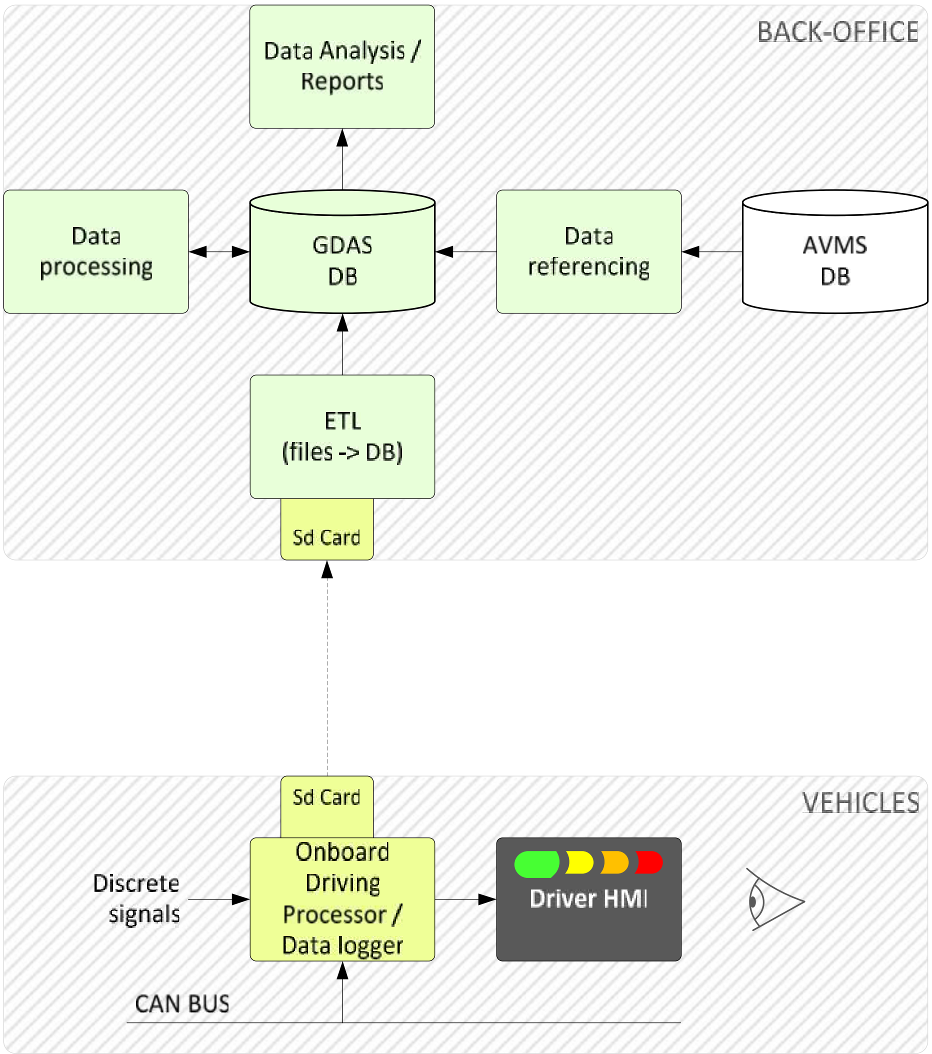


Figure 7 – GDAS Architecture

5.4.2 Description of Test

The traditional fuel saving estimation method, measuring tank refill and comparing similar periods, such as doing the test in the same month during consecutive years, do not take into account such factors as the number of stoppings done in each route or the distance traveled using the A/C or with the lights on by each vehicle, so the error in this estimation can be as large as the savings that could be achieved (between 2 to 10%) so no conclusions could be obtained.

Madrid will use a more precise method to estimate savings, comparing fuel consumptions in two periods, taking into account routes, demand period, use of A/C, number of stops and other factors, per type of vehicle, to normalize fuel consumption before it is compared.

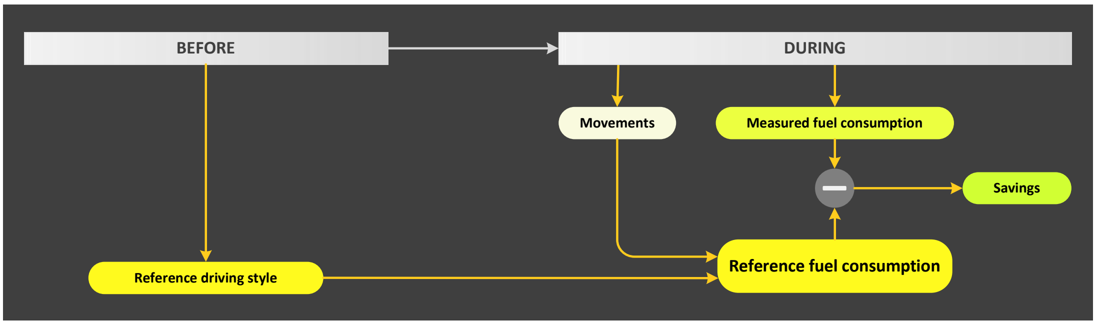


Figure 8 – Fuel savings estimation method

Fuel consumption measured in the “during” period is not directly compared with the fuel consumption measured in the “before” period, but with a normalized value of such consumption, called reference fuel consumption.

The reference fuel consumption is the fuel consumption that would have been measured in the “during” period if drivers had driven as in the “before” period.

5.4.3 Goal

Two correlations will be measured, namely:

- **« %Time_in_Green » vs Fuel Savings,** the fuel consumption measured in the “during” period is directly compared with the fuel consumption measured in the “before” period in Liters/100Km.
- **« %Time_in_Green » vs Normalized Fuel Savings,** the fuel consumption measured in the “during” period is compared with the reference fuel consumption.

It is expected that the first correlation will be lower than the second one, and the second one will be as high as 70%, indicating that both, the « %Time_in_Green » indicator and the fuel savings normalization, are good measurements of efficiency.

Test conditions and Fleets/ Vehicles/ Lines /Drivers involved, _" No EBSF_2 scenario" vs "EBSF_2 situation" and Data collection plan has been already describen in sections 5.3.2.3, 5.3.2.4 and 5.3.2.5 respectively as both tests use data obtained during the same period.

6 DEMO IMPLEMENTATION PLAN

Figure 9 shows the Gantt chart for the implementation of TIMad1 and TIMad2.

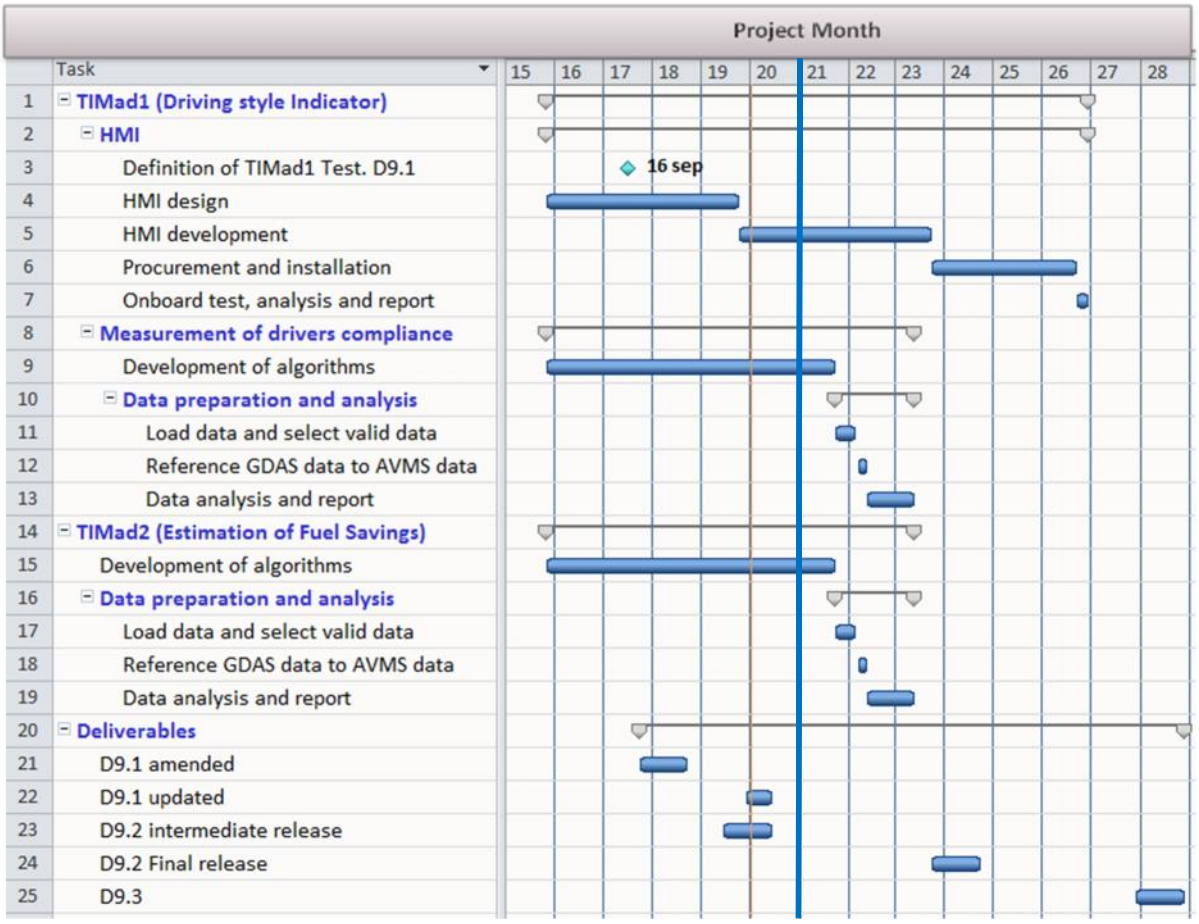


Figure 9 – Overall Gantt chart

6.1 Demo team

The companies and persons in charge of the implementation of TIMad1 and TIMad2 are shown in Table 6 together with the tasks they are responsible for.

Company	Task	Contact person
TEKIA	• Development and implementation of HMI • Development and implementation of fuel saving estimation algorithms • Data Analysis	Héctor Corazzini **hcorazzini@tekia.es**
CRTM	• Project coordination • Contribution to data analysis	Natalia Sobrino Natalia.sobrino@crtm.es Laura Delgado Laura.delgado@crtm.es
EMT	• PTO, bus and drivers provider for TIMad1test • Experts provider for TIMad1 test and validation. • Data for TIMad2 test • Contributtion to data analysis	Sergio Fernández **sergio.fernandez@emtmadrid.es**

Table 6 – Demo team

7 PARTNERS CONTRIBUTION

Company	Sections	Description of the partner contribution
TEKIA	4; 5; 6	Demo Objectives; Demo Description; Demo implementation Plan.
CRTM	1; 2.1; 3	Introduction; Background and Context of Madrid Demo; Support to Demo Objectives and Planning; Revision of the whole document.
UITP	Whole Document	Review of contents Quality check.

End of the Document