PlastiCircle

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D 3.3
Truck Traceability System

Authors: Jerónimo Franco, Belén Miranda,
Patricia Escobar, Francisco Ample and Emilio Chapí (SAV)

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Author: Jerónimo Franco, Belén Miranda, Patricia Escobar, Francisco Ample and Emilio Chapí (SAV)

Reviewers: César Aliaga, Ana Moya (ITENE), Mirjam Britovšek (VELENJE), Ola Martin Rennemo (SINTEF), Voinica Valentin (ALBA IULIA), Paul Sapsford (HAHN PLASTICS)

Abstract

The objective of deliverable 3.3 is to present the Truck Traceability System developed in the Task 3.4 of the PlastiCircle project. The truck traceability system aims to reduce the economic and environmental costs, in terms of fuel consumptions and GHG emissions, as well as to improve the productivity and to have a complete control over the fleet.

Vehicle emissions depends on driving behaviour such as acceleration and speed. Monitoring the speed, excessive idling, unnecessary accelerations and braking will give information that can be used to significantly reduce the fuel consumption. An Android application was developed to manage the data from the GPS and the OBD II reader from the vehicle. The data is sent by the application to the remote server via 3G.

The truck traceability system allows to monitor the speed, acceleration, RPM and engine load. The system allows to detect speeding, high acceleration and braking during a route. Monitoring the speed, RPM and engine load allows to identify interesting events as container emptying and excessive idling. The truck traceability system allows to monitor the engine load from the OBD II protocol. This is useful for the optimization of the engine performance during a mechanical process as the use of the power take off.

Abbreviations

CAN: Controller Area Network

DTC: Diagnostic Trouble Codes

ECU: Electronic Control Unit

GHG: Greenhouse Gas

GPS: Global Positioning System

HTTP: Hypertext Transfer Protocol

IC: Integrated Chip

ID: Identification

JSON: JavaScript Object Notation

OBD: On-board diagnostics

MSW: Municipal solid waste

PID: Parameter Identifiers

PTO: Power take off

RPM: Revolutions per minute

SAV: Sociedad de Agricultores de la Vega de Valencia

SDK: Software Development Kit

Partners short names

1. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA
2. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
3. UTRECHT : GEMEENTE UTRECHT
4. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
5. POLARIS: POLARIS M HOLDING
6. MOV: MESTNA OBCINA VELENJE

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1. Introduction

The management of the Municipal solid waste (MSW) contributes to the generation of emissions to the atmosphere of GHG in each one of the stages: collection, treatment and elimination, due to the use of fossil fuels, the combustion of the waste or the formation of methane by the fermentation of organic matter in landfills.

Diesel engines used in the collection of waste are considered one of the largest contributors to GHG emissions and environmental pollution, caused by exhaust emissions, and they are responsible for several health problems. Thus, one of the biggest problems is that diesel combustion produces and emits particles [1] and compounds recognized as carcinogenic [2].

In order to meet the emission levels set by Brussels for vehicles, high efficiency catalytic exhaust control devices that limit the emission of particles, NOx and hydrocarbons have been installed in vehicles. It is true that these technologies reduce emissions to the atmosphere, but they add considerable weight increasing the demand of fuel and the cost of collector vehicles [3]. There is no doubt that the collection of MSW has a significant carbon footprint and that fuel consumption is an important aspect to take into consideration in the costs of collection.

GPS and CAN bus vehicle tracking systems can significantly help to reduce the economic and environmental costs of waste collection, in terms of fuel consumption and GHG emissions. Fuel consumption and vehicle emissions depends on the driving behaviour. Speeding, excessive idling [4] and unnecessary accelerations and braking produce unnecessary use of fuel. Monitoring these parameters can help to reduce fuel consumption between 5% to 20% [5,6]. Vehicle tracking with efficient driving system can alert the driver with an alarm when a parameter exceeds the correct driving behaviour. In addition, fleet tracking allows to have a complete control over the fleet [7], to take corrective actions and to generate reports.

Optimizing the driving behaviour in fleets is an important task for the environment, since approximately 27% of the total carbon dioxide (CO_2) emissions are result of the combustion of fuels from vehicles [5]. It also improves road safety and prevent accidents.

1.1 Objective

The objective of deliverable 3.3 is to present the Truck Traceability system developed in the task 3.4 of the PlastiCircle project. Efficient driving and the driving behaviour guidance, also included in task 3.4, will be presented in the deliverable 3.4 "Driving behaviour guidance".

The truck traceability system aims to optimize the performance of the vehicles and the driving behaviour of the driver. It is based on the information provided by the CAN-Bus of the vehicles of the waste collector fleet (speed, RPM excess, acceleration, sudden braking, fuel consumption, excessive idling or time of use of the power take-off). All these data are stored in the onboard system to be send via GPRS to the digital cloud platform.

The objective is to reduce the environmental costs, in terms of fuel consumptions and GHG emissions, and economic costs associated to the collection of packaging waste by improving the productivity, as well as allowing a complete control over the fleet.

This deliverable aims to present the developed truck traceability system as a part of PastiCircle project (Task 3.4). The system allows to store and monitor engine and driving parameters as excessive idling, speeding or use of unnecessary accelerations and braking. The truck traceability system will be implemented and tested in the pilot cities in order to assess its performance and the economic and environmental benefits. Efficient driving and driving behaviour guidance closely related with the truck traceability system will be presented in the deliverable D3.4.

1.2 Scope

This deliverable is structured in different chapters, including the different sections of the systems developed:

-The truck traceability problem: This section aims to describe the truck traceability problem and the advantages of using this system in terms of fleet control, productivity and reduction of fuel consumption and GHG emissions.

-State of the art: different solutions in the market are described together with the reason for developing the PlastCircle truck traceability system.

-System description: this section describes the different parts of the truck traceability system: CAN and OBD protocols, GPS and the on-board system. The IoT platform architecture is described also in this section.

-Methodology and results: this section describes the methodology and protocol used to test the truck traceability system. Results are presented and explained in this section.

2. The truck traceability problem.

2.1 Definition

Waste collection with trucks can experience tangible benefits with vehicle tracking. Fleet tracking allows complete control over the fleet in order to improve the productivity and to reduce the economic and environmental costs, in terms of fuel consumption and GHG emissions [5,6].

GPS and CAN bus vehicle tracking can significantly help to reduce fuel consumption and emissions [5]. Vehicle emissions depends on driving behaviour and vehicle parameters such as acceleration and speed. Speeding is a critical factor in fuel consumption in vehicles. Maintaining a proper speed reduces significantly the fuel consumption. In addition, excessive idling and unnecessary accelerations and braking produce unnecessary use of fuel. Eco-driving instructions [8-10] can reduce fuel consumption between 5% to 20% [5,6]. It encourages drivers to avoid unnecessary accelerations and to anticipate the road ahead to avoid unnecessary abrupt braking in order to maximally conserve momentum. It also encourages minimising idling or to take measures focused in the reduction of fuel consumption as minimising unnecessary weight or ensuring tyres are inflated to their maximum advisory pressures.

Vehicle tracking can alert the driver with an alarm when a parameter exceeds the correct driving behaviour. In this way, the driver can amend the driving behaviour to the correct way reducing the fuel consumption and emissions. Fleet tracking allows also to assess driver behaviour [11] and to take corrective actions when a driver ignores the efficient driving behaviour. It allows also to reward good work [12, 13] and to eliminate bad habits that increase fuel consumption and GHG emissions. Optimizing the driving behaviour in fleets is an important task for the environment, since approximately 27 % of the total carbon dioxide (CO2) emissions are result of the combustion of fuels from vehicles [5]. It also improves road safety and prevent accidents.

Vehicle traceability system can also help to improve the security of the fleet. Speed of vehicles is recorded allowing to check if the driving behaviour agrees with the safety guidelines. In addition, if a vehicle is stolen, the GPS tracking can help to locate where the vehicle is.

The truck traceability systems provide information about: the driver activity, excess of speed, excessive idling, location of every vehicle in the fleet in real time, etc... It has also the advantage of generating reports.

GPS provides a valuable information regarding driving behaviour as location, speed, acceleration and production time. CAN bus data provides many information of the vehicle including speed, RPM, engine load, consumption rate, engine coolant temperature, fuel pressure, etc...

2.2 State of the art

There are lot of providers in the market offering fleet tracking software and solutions [14]. Most of them provide fleet tracking and traceability of the vehicles just from the GPS information. Some providers focus on the management of the fleet while others focus on the driving behaviour and the reduction of the fuel consumption. Solutions based only in the GPS data are affordable and cheap. But solutions that provide data from the CAN bus or OBD II are expensive and they need hardware installations in the vehicles.

Some of this tracking software solutions currently available are: Tomtom telematics [15] provides fleet management from the GPS and OBD II with improvement on driving behaviour and fuel saving. Go360 [16] provides tracking and traceability based on the GPS. Mapping Control [17] collects and analyses data from the GPS to reduce the cost of the fleet and increase the productivity. CalAmp's FleetOutlook Fleet Tracking software [18] offers fleet management and asset tracking features based on GPS. Teletrac fleet tracking [19] is a GPS based fleet and tracking software with real-time tracking, diagnostics and business reporting.

PlastiCircle aims to develop its own truck traceability system that requires low investment for the municipalities. The system has been developed ad-hoc considering the urban waste collection necessities.

In the next steps of the project, efficient driving system will be added to the traceability system prior to the pilot in the 3 European cities (Valencia, Alba Iulia and Utrecht). This system will produce sound alarms to the driver when driving parameters excess the correct eco-driving behaviour. In addition, the PlastiCircle truck tracking solution is designed and developed to be integrated as a part of the IoT cloud platform (Task 3.1) of the PlastiCircle project that SAV is already developing.

3. System description

3.1 CAN bus

Communication between the different sensors and actuators are realized through a Controller Area Network (CAN) protocol. This is a serial communication protocol that is documented in ISO 11898, for high speed applications, and ISO 11519, for low speed applications. The CAN protocol was originally developed by Bosch to replace large amounts of cable in automobiles [20]. A CAN bus system is a serial bus system with multimaster capabilities, all CAN nodes are capable of transmitting data and several CAN nodes can request data simultaneously to the bus, see Figure 1.

Figure 1: CAN-Bus interface to transmit and request data.

3.2 OBD II

The On-Board Diagnostic system (OBD II) is a standard which was developed by the Society of Automotive Engineers (SAE) [21] that usually works over the CAN bus. This specification was defined to ensure that the Environmental Protection Agency (EPA) standards, in terms of vehicle emissions, are met for all manufactured vehicles. The standard requires that vehicles have a 16-pin OBD II port, see Figure 2. Through this port, sensor data and diagnostic information from the electronic control units (ECU) of a vehicle can be monitored.

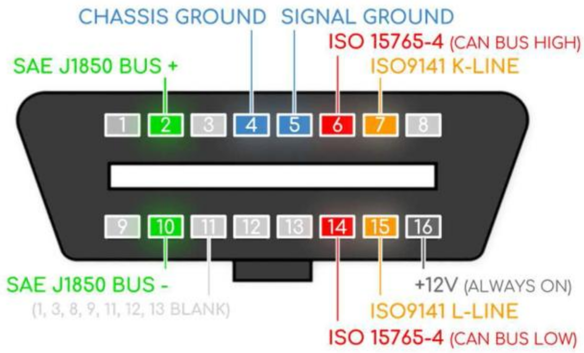

Figure 2: 16 pin OBD-II female connector.

Data from the vehicle can be obtained through a scanning tool. The scanning tool requests information from the ECU by sending a hexadecimal code associated with a specific parameter. These codes are defined by the SAE J1979 standard [22]. The hexadecimal code is interpreted according to one of five OBD II signalling protocols. The five OBD II protocols include SAE J1850 (VPW and PWM), ISO 15765, ISO 1941-2 and IS0 142300-4 [23]. The ECU finally sends back a hexadecimal code in response.

OBD II uses two types of codes to request ECU data:

- Diagnostic Trouble Codes (DTCs): to diagnose malfunctions in the vehicle.
- Parameter Identifiers (PIDs): to measure real time parameters. Besides the standard parameters, vehicle manufactures can define additional PIDs to make the system more sophisticated.

3.3 GPS

The Global Positioning System (GPS), is a satellite-based radio navigation system that provides geolocation and time information to a GPS receiver. The GPS is owned and operated by the U.S. Department of Defense but is available for general use around the world. GPS has now become sufficiently low-cost so that it is introduced in many devices as smart phones.

24 GPS satellites in orbit at 10,600 miles above the Earth are spaced ensuring that four or more are above the horizon. Each satellite contains a computer, an atomic clock, and a radio. Knowing its own orbit, the satellite broadcasts its changing position and time.

Any GPS receiver calculates its own position by trilateration of four satellites, see Figure 3. GPS provides the geographical position in the form of longitude and latitude.

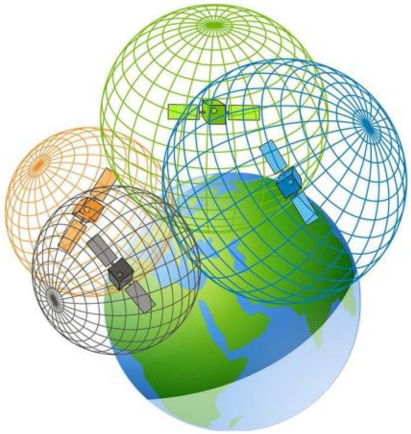

Figure 3: Scheme showing how location is achieved by trilateration of 4 satellites. Position is obtained where the 4 spheres intersect.

GPS satellites broadcast their signals in space with a certain accuracy, but final accuracy depends on additional factors including signal blockage, atmospheric conditions and quality and features of the receiver. GPS-enabled smartphones are typically accurate to within a 4.9 m radius under open sky. However, their accuracy gets worse near buildings or big objects that can block the signal. High-end users boost GPS accuracy with dual-frequency receivers and/or augmentation systems.

Assisted GPS (A-GPS) is a system that improves the performance of a GPS satellite-based positioning system. An A-GPS system is especially useful when the receiver is in a location where it is difficult for the satellite signals to penetrate. In addition to providing better coverage, A-GPS also improves the start-up time, which is the time required by the satellites and the receivers to establish a reliable connection. Cellular network towers have GPS receivers and those receivers are constantly obtaining satellite information and computing the data. This data handled by 3rd party computers is then passed on to the cellular phone, see Figure 4. In this way, the relevant satellites for the location are already identified. This produces faster location acquisition, less processing power and saving battery.

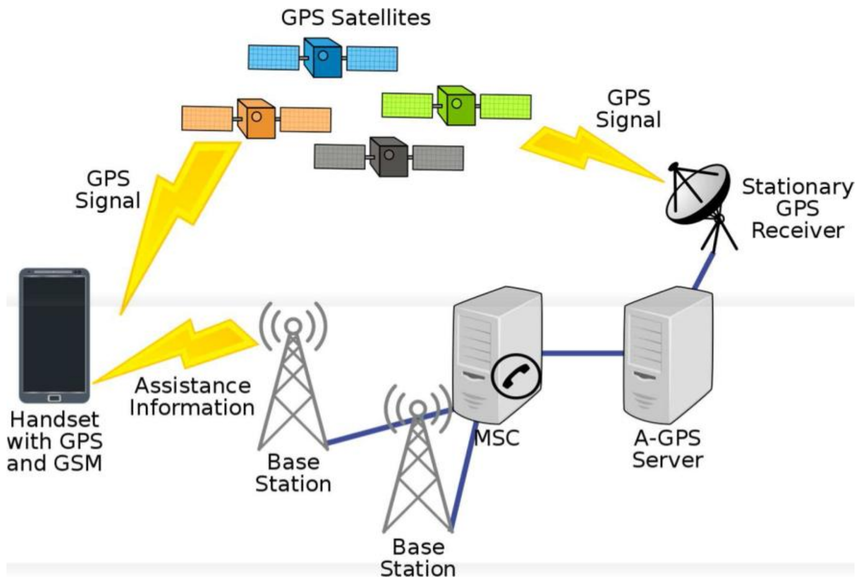

Figure 4: A-GPS scheme explaining the improvement of the performance of the GPS. Cellular network towers compute GPS data that it is passed to the cellular phone.

3.4 On board system

The OBD II reader used is an ELM 327 integrated chip (IC), see Figure 5, to interpret the CAN protocol. The OBD II reader is connected to the OBD II port of the vehicle to communicate with ECUs via OBD protocol. This device is robust and cheap as it can be bought by less than 10 euros. The OBD II reader is portable and does not interfere with the driving functions while connected. The device provides data from the vehicle as speed, RPM, engine load, ambient air temperature, fuel pressure, engine oil temperature, etc...

Figure 5: OBD II reader with ELM 327 integrated chip to interpret the CAN protocol with Bluetooth connectivity.

An Android application was developed by SAV for the PlastiCircle project (Task 3.4) to manage the data from the GPS and the OBD II protocol. The Android application sends OBD commands in queue to the OBD II reader via Bluetooth and reads the response, see Figure 6. The main features of the application are:

- the app is developed with the Android SDK
- it connects to the OBD II reader via Bluetooth
- A-GPS location from the Android device
- internal SQLite database to store persistent data
- in case of no 3G coverage, data is stored in the internal database
- data in the SQLite database is removed once the information is received in the remote server
- data is sent to the server in a JSON array
- data acquisition from the OBD II reader is obtained by an Android Service working in background to enable continue getting data if the application is closed or killed
- if OBD II data is not available, as old vehicles does not support OBD II protocol, then traceability is based in location and speed from the GPS.

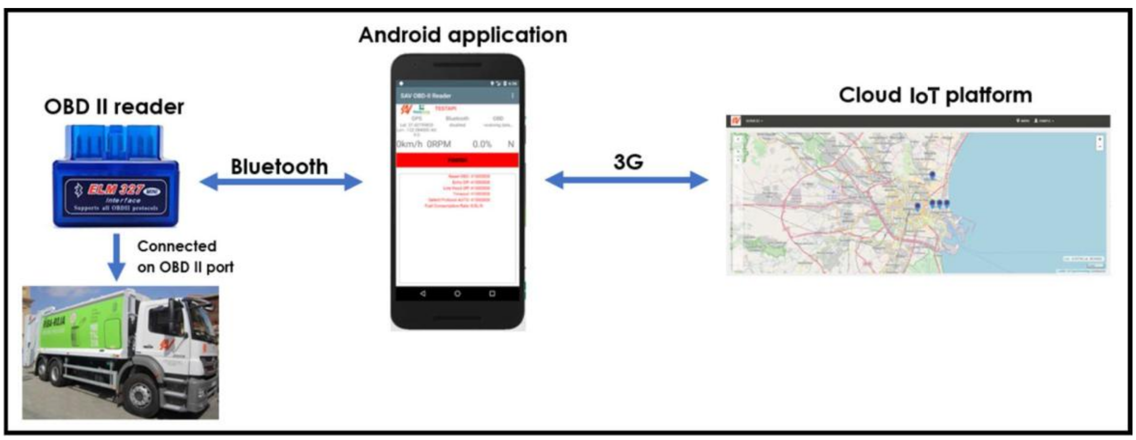

Figure 6: On board architecture for the truck traceability system. OBD II reader is connected to the OBD II port of the vehicle. Data from the ECUs is sent by Bluetooth to the android application which communicates to the cloud platform by 3G.

At this stage of the project, the Android application is easy to use. To start, the plate number or ID of the vehicle must be introduced in the application and the Bluetooth device must be selected. The driver just needs to press the start button when the route starts and press the finish button when the route ends.

In the meantime, data from the OBD II system is retrieved at 1 Hz. Each data is associated with a time and a GPS location provided by the Android device. In case of not GPS coverage, the data from the vehicle is still recorded. The data is temporarily stored in an SQLite database inside the Android application and sent to the remote server in packages of JSON arrays with a maximum of 100 elements when number of rows is bigger than 10. Each data package is submitted by means of a HTTP POST with a JSON array including the ID of the vehicle. In case of no 3G coverage, the data is stored in the internal database and automatically released to the server when the coverage is recovered. The data is removed in the application database once the application receives response from the remote server confirming that data is received. If data is not received and stored in the remote server then the application send the data again with packages of maximum of 100 elements.

3.5 IoT Platform

The extent of this chapter goes beyond the works of the task 3.4 (Truck traceability system and driving behaviour guidance), and some of the concepts represented here are still to be implemented, but their explanation is necessary to have a good comprehension of the platform as a backbone of the PlastiCircle project.

As for the truck traceability System, all the data obtained from the on-board system will be redirected to a platform that needs to store, manage and use the data obtained from the embedded truck systems.

The architecture of the platform can be conceptualized considering the extent of the whole project, as seen in the Figure 7.

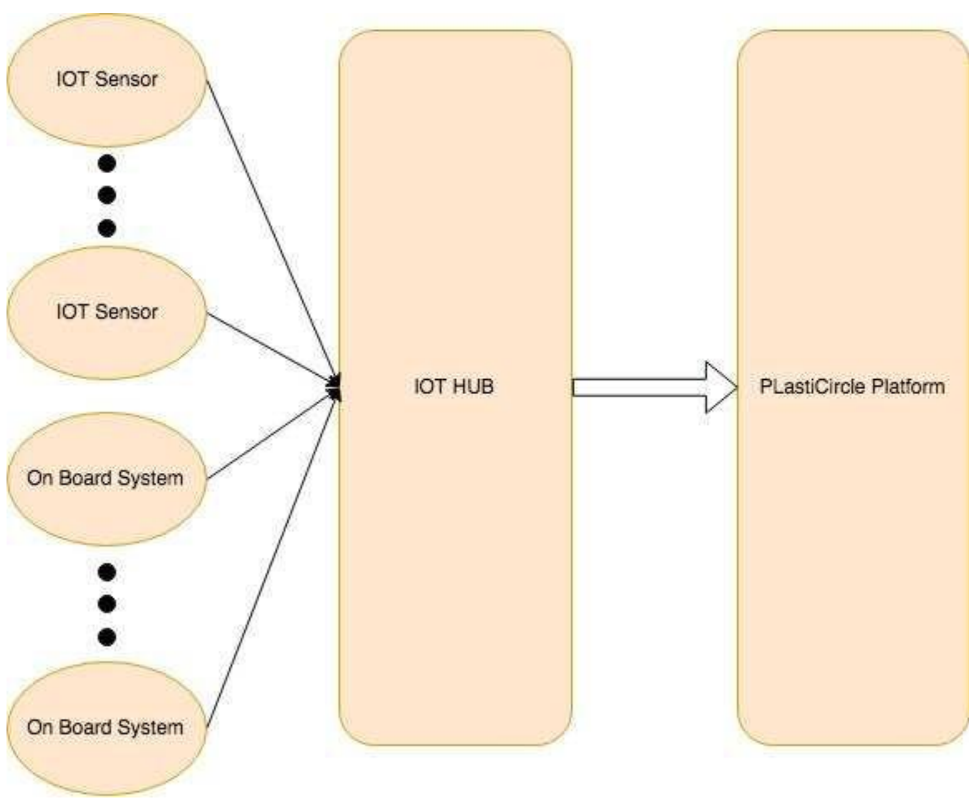

Figure 7: Platform architecture overview.

This means that the On-Board Systems can be seen as an IOT (Internet of Things) sensor, as well as the identification module and the filling level sensor of the Tasks 2.2 (Module for user identification) and 2.3 (Module for filling level measurement). This approach helps us construct a modular and scalable system where we abstract all the logic needed to manage the communication with the sensor from the business logic that will be implemented in the PlastiCircle Platform.

IOT HUB

The IOT Hub is a cloud-based service where the communications with the sensors are implemented and normalized prior they redirection to the PlastiCircle platform.

The IOT Hub, as we see in Figure 8, will allow us to add new sensor and new capabilities on the fly, making a robust and flexible system. Also, if the number of sensors increases we can add more resources to the system without compromising or stopping the platform. Also, although is not applied at this first step, a high availability HUB can be implemented in which various HUB work in parallel with a balanced workload being redirected to one of the multiple subsystems. Making it very scalable and prepared for a possible commercialization of the system.

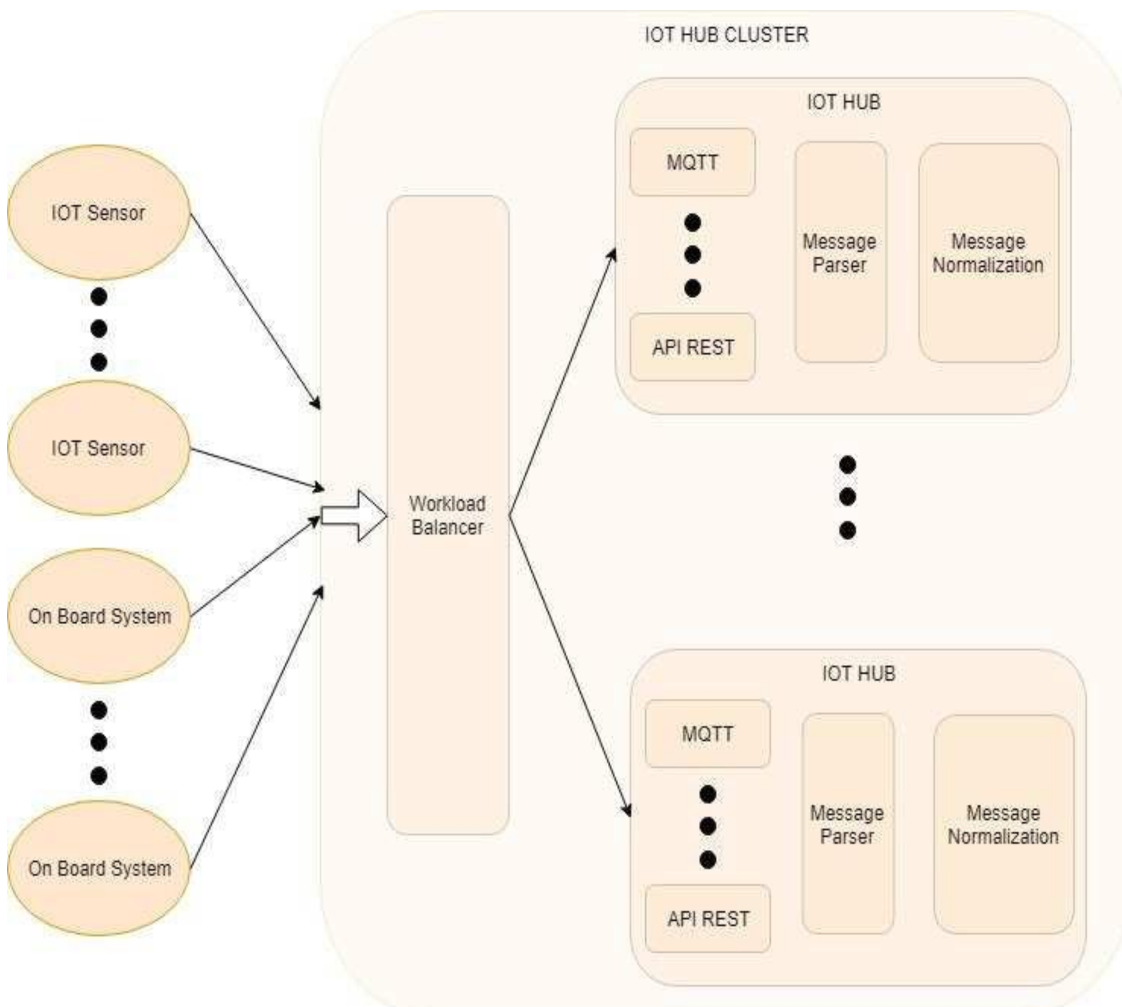

Figure 8: IOT HUB Scalable Architecture.

As it can be seen in the figure, an array of IOT HUBS can be constructed and provisioned depending on the demands of the IOT Devices deployed in the project. It also makes the HUB Cluster robust and a high availability system since one of the HUBs can stop working without compromising the functionality of the system. The workload balancer will redirect the messages treated by that hub to a less busy module.

Since the beginning we had in mind that our system had to have the capability to grow and to adapt to new sensor in this new and exciting field of the IOT.

PlastiCircle Platform

As for the PlastiCircle platform itself; all the functional necessities described has been implemented following a DDD (Domain Driven Design) as it can be seen in the Figure 9.

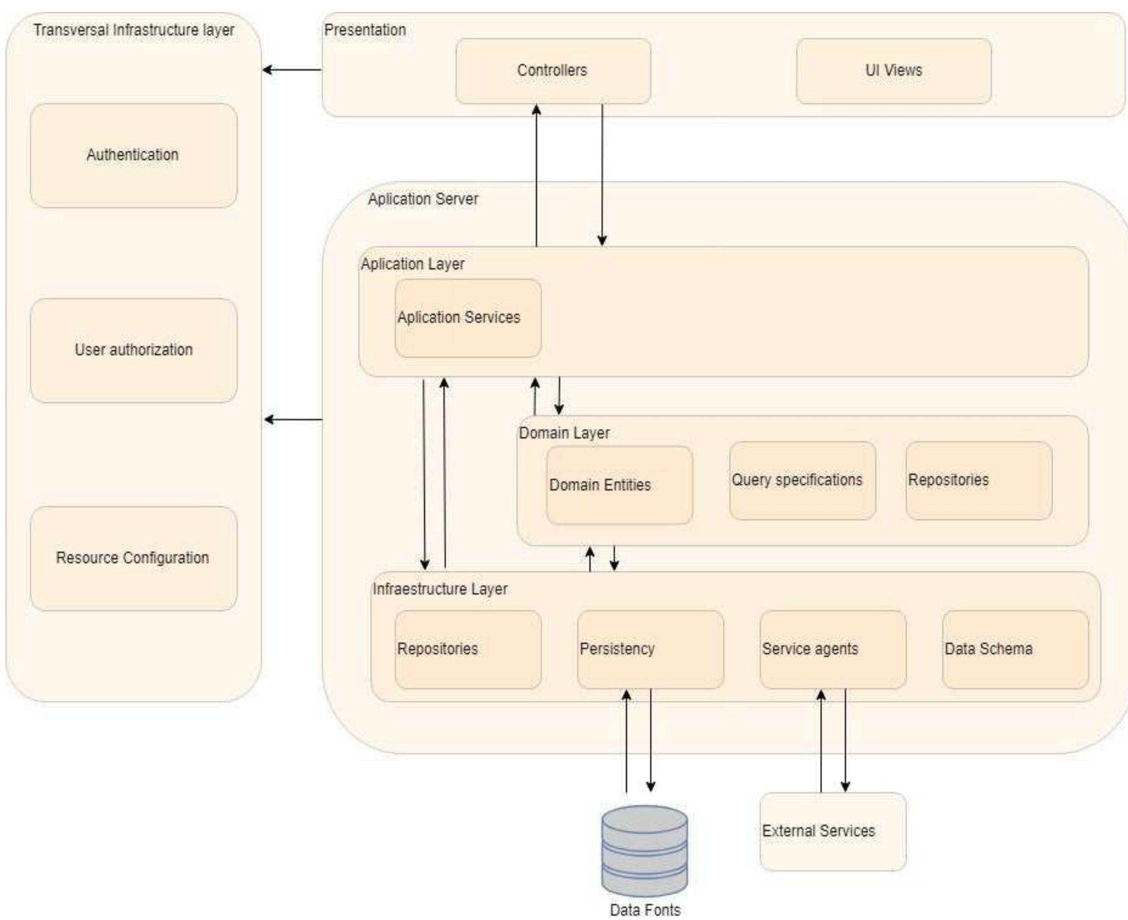

Figure 9: Domain Driven Design.

The Domain Driven Design binds the Domain modelling with the software design to create a rich model domain that evolves through the iterations of the design.

Having this in mind, the platform has been implemented with an agile methodology, and a tight relationship between the developers and the domain experts.

With this architecture we have managed to isolate the domain from the implementation of the dependencies, disengaging the Database technology, the libraries and the rest of technologies injecting dependencies. This eases the scalability and increases the flexibility without affecting the domain.

Web Interface

As for the presentation layer, the user interface is implemented following an adaptable web design (responsive). This implementation allows to adapt the look and feel of the platform to the device it is been used. Nowadays the range of devices used have grown exponentially, each of them having different screen sizes and resolutions, ranging from smartphones, tablets, laptops, workstations or even screen arrays in control rooms. This approach allows the interface to be seen correctly in each and every one of the devices.

This approach improves the user experience while minimizes the development and the maintenance costs. Also increases the usability standardizing the experience for all the users.

It also allows a novel enterprise practice: bring your own device. The final users is no longer chained to his workplace desk, increasing the productivity.

Platform Capabilities

The PlastiCircle platform, as have been said, is comprised by several modules, each one of them is be responsible of one of the Platform capabilities. We now will detail each of them.

- Platform User definition and authentication module:
  This module is responsible of the authentication of the users in the platform, also it defines the level of access of the users. This means defining profiles of access and what parts of the platform each user can see and operate.

- Container module
  Since the project is based in the development of a smart container solution, a well-defined container database is needed. This module allows the authorized users to see, create, modify and delete the containers in the city, see Figure 10. The common data of the container includes static data (in the meaning that it does not vary in real time, nor it depends on the information of the sensors) as geographic position, container capacity, container type, container integration id, etc. And real time data: Filling level, number of usages, last time collected...

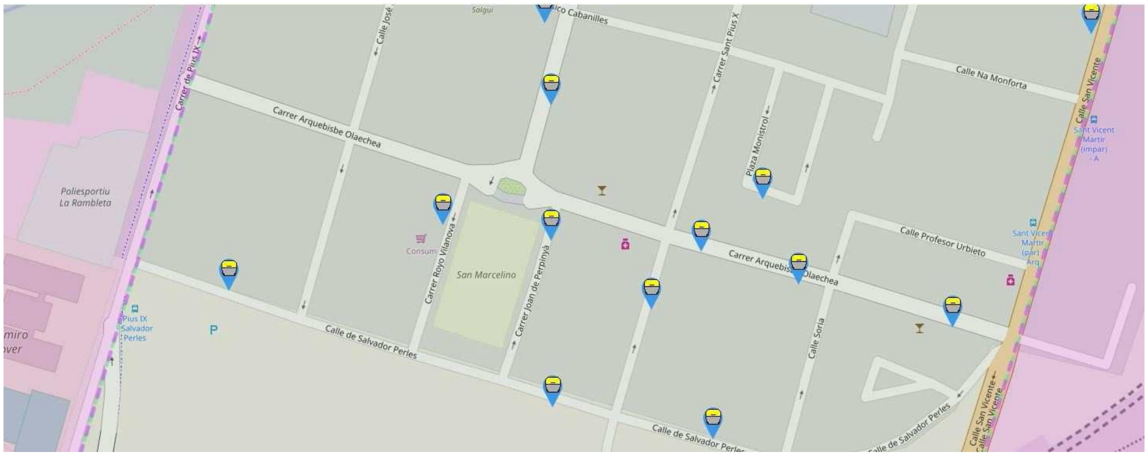

Figure 10: Container database user interface.

- Vehicle module
  This module is capable of maintain a vehicle database with a history of data gathered through the service. All the data explained previously is stored related to the vehicle and can be exploited in this module in order to improve the collection routes, giving that way a better service to the citizen and reducing the time of the collection and the fuel consumption, see Figure 11.

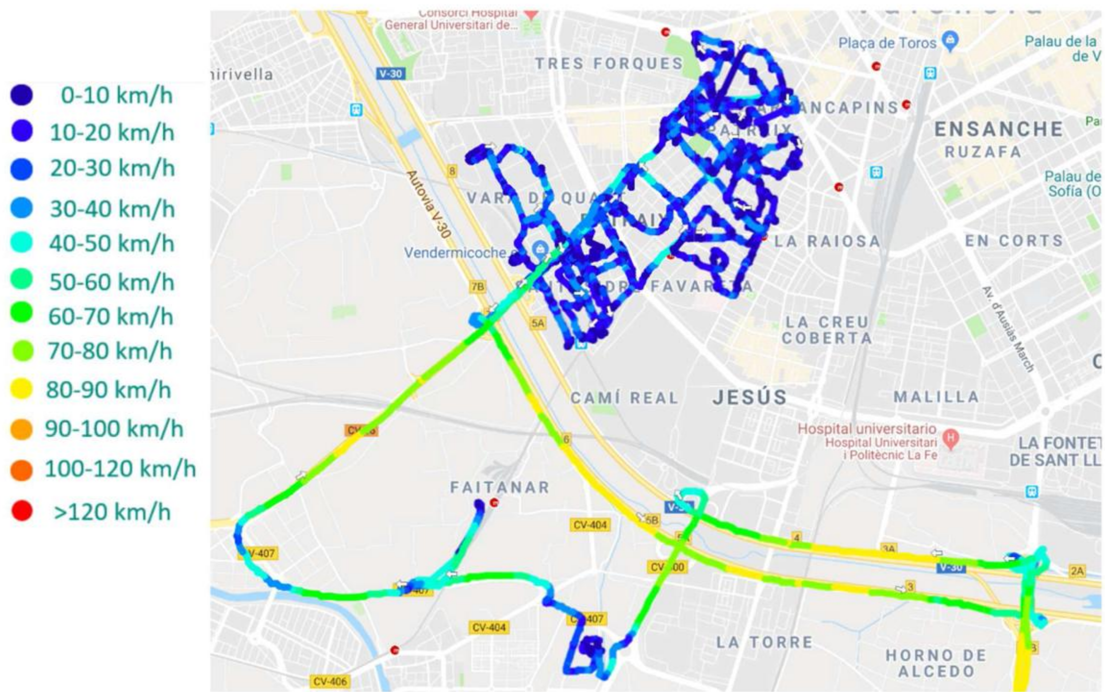

Figure 11: Truck traceability. Colour indicates speed of the vehicle.

- Citizen Identification module and waste characterization
  As the citizen uses the smart containers identifying themselves as will be developed in Task 2.2, the PlastiCircle Platform will gather and store the data in

a totally anonymous manner, this means that the only data from the citizen will be its ID. Also, the platform will have the capability of register the waste characterization as will be defined in Task 3.3 (Definition of the characterization protocol and compensation procedure). This pair (User, Characterization) will be used in Task 3.3.

- Filling Level module
  This module (not implemented yet) is related to the Task 2.3 and will manage the container filling level data.

- Route module
  The Route module will use the data from the filling level sensor and the route optimization implemented in Task 3.2 (Module of route optimization) to give the less consuming, and most efficient route to collect the containers.

- Efficient driving module
  This module will be in charge of making the drivers drive more efficiently. To do so, this module will have an interface for the engineers to input the parameters that define efficient driving and, together with the data from the truck traceability module, give instructions to the driver to minimize the fuel consumption and the CO2 emission.

4. Methodology and results

4.1 Methodology

The truck traceability system has been tested on SAV waste collection trucks. Two different trucks were chosen for the tests: a lateral load waste collector (Mercedes-Benz Atego 2532L), Figure 12 and a collector of voluminous waste (Mercedes-Benz Atego 1523), Figure 13. The first one supports the OBD II protocol, while the second truck does not support OBD. In this last case where the OBD II is not supported, the tracking was performed only by the GPS information while in the first case, the traceability is achieved by the GPS information plus the data coming from the OBD II. This will allow us to compare the two possible cases.

The OBD II reader was plugged in the OBD II port of the lateral load waste collector (Mercedes-Benz Atego 2532L), see Figure 12.

Figure 12: lateral load waste collector (Mercedes-Benz Atego 2532L) of the SAV fleet used during the tests. OBD II port and OBD II reader are shown at the right.

Figure 13: collector truck of voluminous waste (Mercedes-Benz Atego 1523) of the SAV fleet used to test the truck traceability system. In this case, the OBD II is not supported.

An Android tablet with the developed application was provided to the drivers of the 2 trucks. The tablet had GPS and 3G capabilities required by the system. The instructions for the drivers were just to start the application at the beginning of the route and to finish the application at the end of the route.

The truck traceability system was tested in both vehicles during a period of two weeks with a frequency of one route per day. During the routes, the application requested information from the OBD protocol and GPS with a frequency of 1Hz. The data stream was stored temporarily in the internal SQLite database of the Android application and sent to the remote server in packages of JSON arrays. The data is removed in the application database once the application receives response from the remote server confirming that data is received. In case of not 3G coverage, the application waits automatically for coverage to send the stored data packages. In case of not GPS coverage, the data from the OBD II is still recorded because the data is still valuable. As shown below, the GPS coverage was good enough with the A-GPS to obtain data streams with good quality even using the internal GPS of the Android tablet.

The data was received in the server and stored in a SQL database. The data streams can be plotted and analysed to obtain valuable information. In the next steps of the project, the visualization and analysis of the truck traceability system will be integrated in the IoT cloud platform that is being developed by SAV in the PlastiCircle project.

4.2 Results

As commented above, the data from the OBD II reader is received by an Android device via Bluetooth. To make this task, an Android application was developed by SAV. The data collected from the OBD II by the application is:

- GPS location
- speed (km/h)
- revolutions per minute (RPM)
- engine load (%)

New parameters can be added, if required, in the next stages of the project prior the pilot in the three cities: Valencia, Utrecht and Alba Iulia.

Figure 14 and 15 shows a route for a collection service of the packaging fraction waste managed by SAV with the lateral load waste collector. As shown above, this truck supports OBD II, then information of speed, RPM and engine load were tracked. The computed duration of the route was 6 hours and 17 minutes with a pathway of 96 km. The route shows a pathway for the collection of packaging waste in the center of Valencia, then travelling towards the sorting plant in Picassent and coming back to the SAV facilities. Colour in the pathway indicates speed of the vehicle. It was validated that the speed provided with the OBD II corresponds with the speed of the vehicle. As it can be seen in the Figure 15, the driver shows a good driving behaviour regarding the speed, as the velocity does not overcome the 90 km/h in the highway and 50 km/h in urban areas.

In order to reduce the consumption of fuel and emissions of GHG, the efficient driving system to be implemented in the next steps of the project will emit a sound alarm when parameters exceed the parameters established in the driving behaviour guidance. In the case of the speed, the application will emit a sound alarm when driver excess the correct speed. This boundary in the speed will depend of the type of road, for example, if the truck is driving on an urban area or it is on a highway.

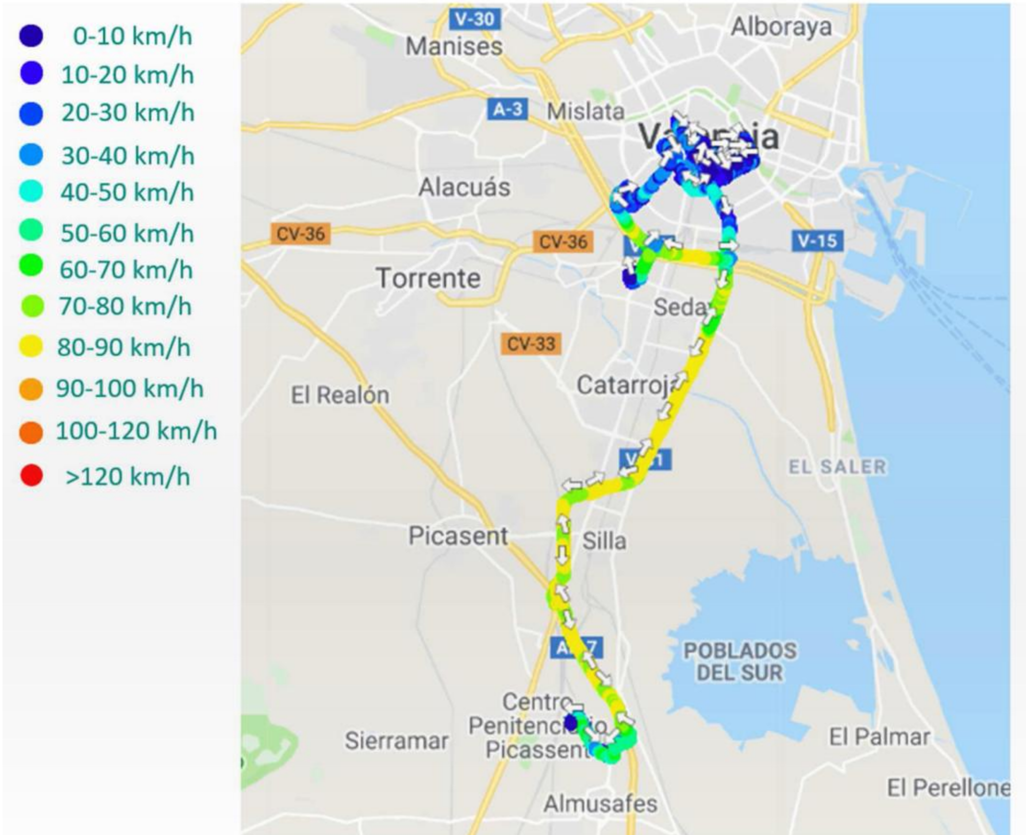

Figure 14: Pathway of a service managed by SAV of a packaging waste collection in Valencia. The route starts in the SAV facilities, the truck collects the waste in the center of Valencia, then it travels towards the sorting plant in Picassent and it finish the journey coming back to the SAV facilities. Colour indicates speed of the vehicle. Total duration of the route was 6 hours and 17 minutes with a pathway of 96 km. Maximum speed was 82 km/h.

Figure 15: Pathway of a route collecting packaging waste in Valencia. Colour indicates speed of the vehicle. Driver showed a good driving behaviour as speed does not overcome 50 km/h in urban areas and 90 km/h in the highway. Speed, RPM and engine load were obtained from the OBD II system.

Another important parameter affecting the consumption of fuel and emissions is the acceleration. Unnecessary accelerations and abrupt braking increase the use of energy. A good driving behaviour is the one that keeps the momentum to the maximum. The truck traceability system developed in this task of PlastiCircle allows to identify high accelerations and braking during a route, see Figure 16. As shown in the figure, no excessive accelerations and braking were produced during the waste collection process. In the next steps of the project, the efficient drive system will alert the driver with a sound alarm when acceleration exceeds the correct eco-driving. As previous studies showed [5,6], this is expected to have a significant impact on reducing fuel consumption.

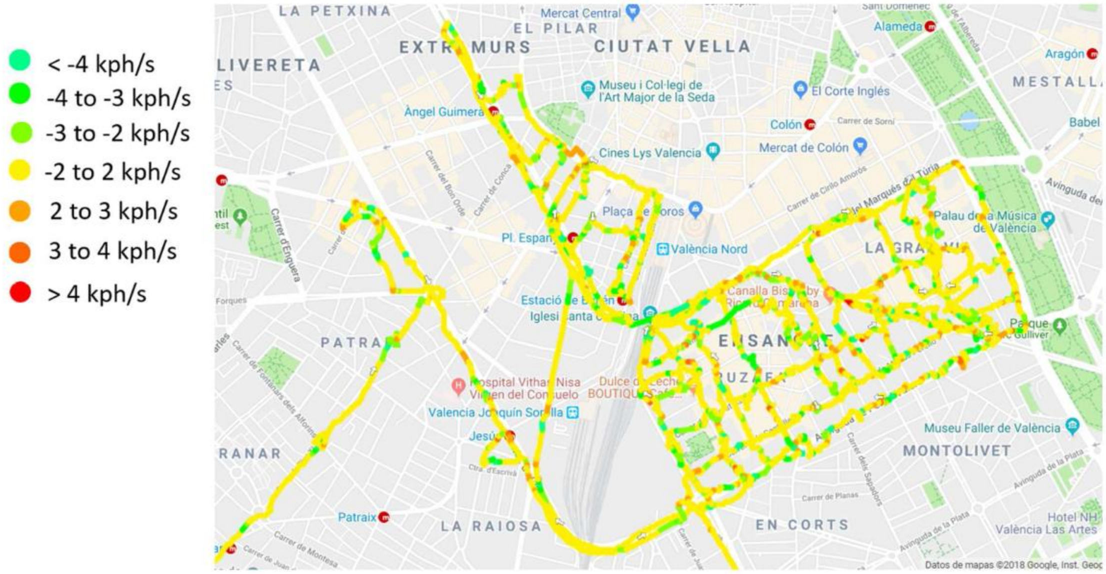

Figure 16: Computed acceleration for a route of packaging waste collection in Valencia. Colour indicates acceleration of the vehicle in kph/s.

The traceability system developed in this deliverable allows also to monitor the RPM of the engine along the pathway. This is interesting because the RPM of the engine is closely related with the consumption of fuel. Figure 17 shows the recorded RPM values of the motor during the collection route of packaging waste. The average computed value was 902 RPM and the maximum value 1952 RPM.

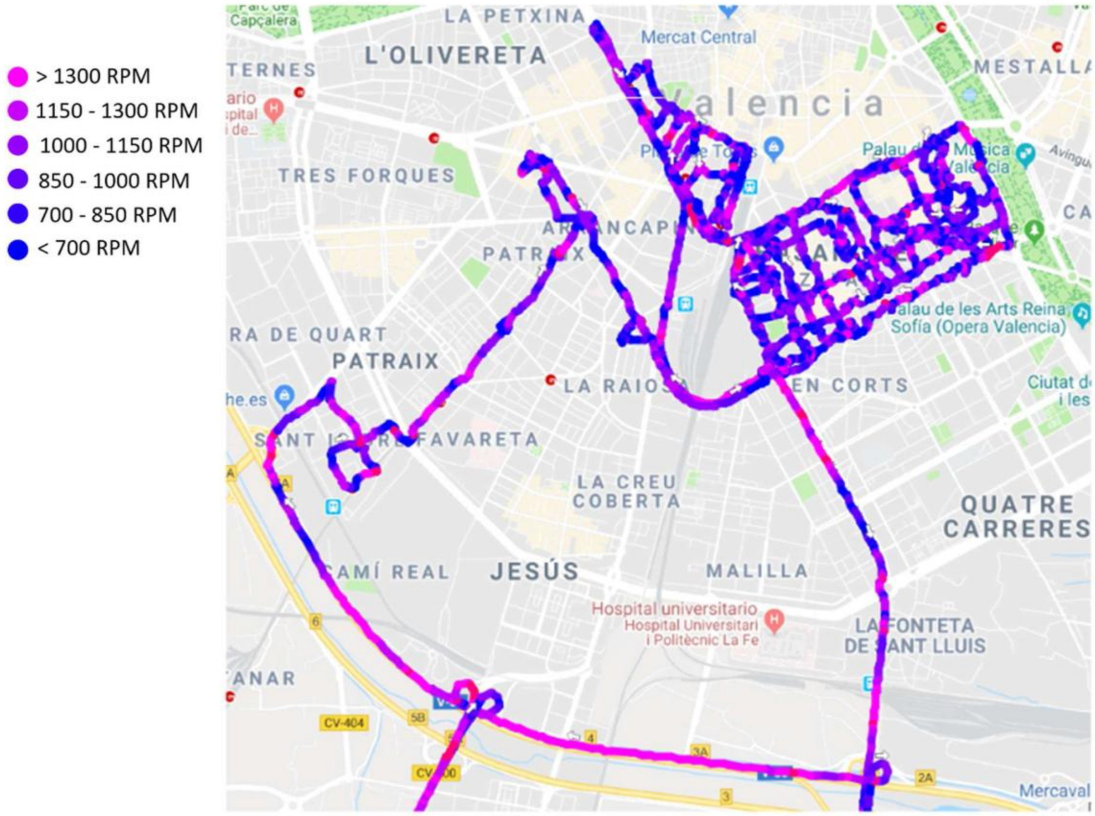

Figure 17: Registered revolutions per minute (RPM) for a route of packaging waste collection in Valencia. The average computed value was 902 RPM. The maximum revolutions per minute recorded was 1952 RPM.

Monitoring the speed, RPM and engine load allows to identify interesting events as container emptying, excessive idling or speeding. Excessive idling can be identified in the route as an event where the vehicle is not in motion (speed=0 km/h) and revolutions per minute are bigger than 0 and smaller than 800 RPM during more than 40 seconds. The condition of RPM < 800 is chosen to do not mix with events where the truck is emptying a waste container, as it will be shown below. Figure 18 shows positions where excessive idling is identified. For this pathway, few idling events were identified showing that the driver had a good eco-driving behaviour. The maximum computed idling time was 150 seconds.

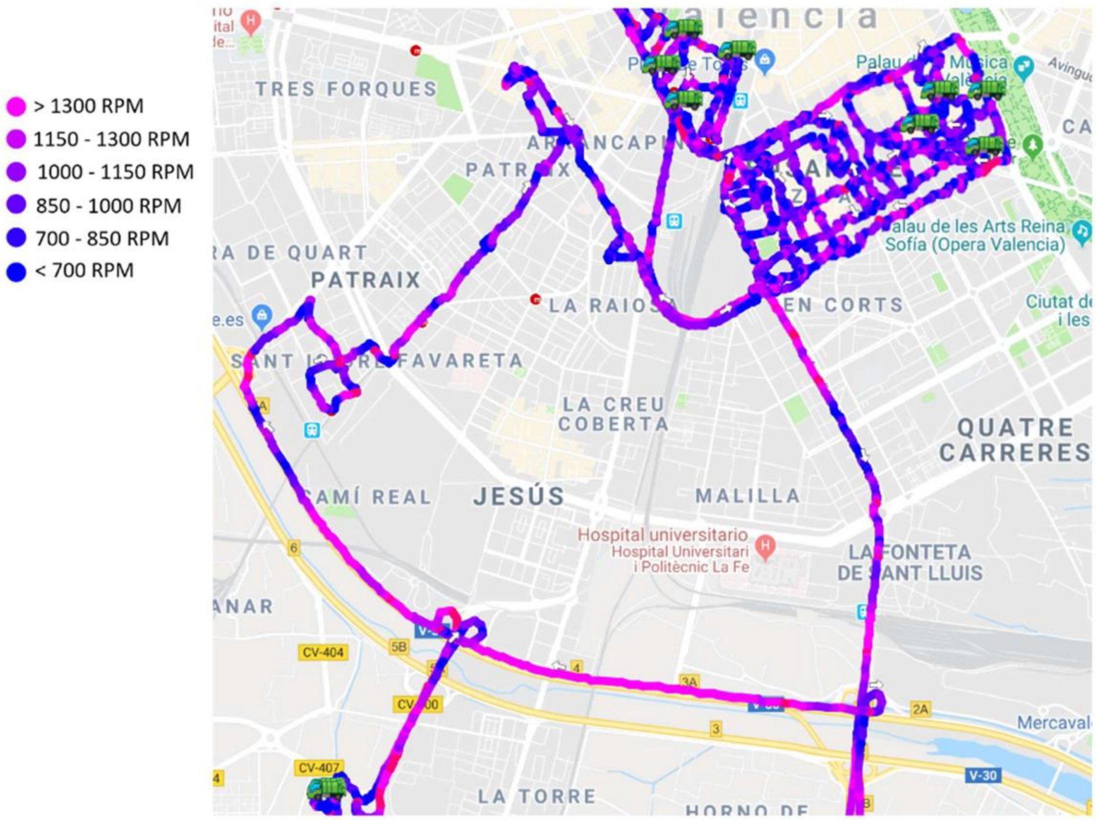

Figure 18: Use of excessive idling identified as green truck icons on the map. The maximum computed time of the engine running when the car is not in motion was 150 seconds at the beginning of the route in the SAV facilities (bottom left in the map).

Another very interesting event type that can be identified by the traceability system is the emptying of waste containers. This event can be identified when the vehicle is not in motion (speed = 0 km/h) and the RPM > 900 for a period bigger than 30 seconds. Figure 19 shows the locations where the system identifies that waste containers were emptied. These locations were validated with the positions registered in the SAV database, as it can be seen in the figure.

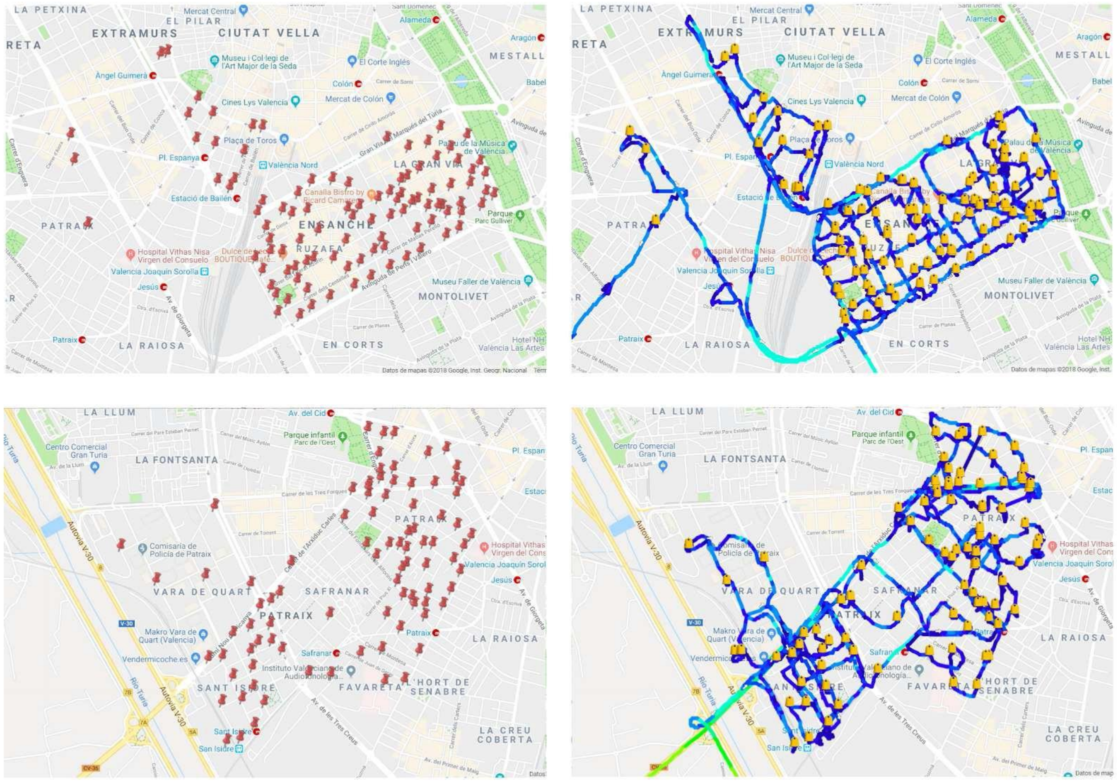

Figure 19: Positions of the packaging waste containers (left) as recorded in the SAV database and the pathway of a waste collection route (right). Locations where the truck emptied a container (marked with yellow icons) were identified by the traceability system as an event where speed=0 km/h, revolutions per minute > 900 RPM for a period bigger than 20 seconds.

RPM does not give information about the applied torque of the motor, but this information can be obtained by the engine load. The engine load gives a measure of the amount of air going into the combustion chamber, i. e. it is proportional to the amount of force put on the piston. Maximum power of the motor is produced when engine load rate is 100%. Then, there is a strong linear correlation between fuel consumption and engine load. Applying the optimal engine load during a mechanical process will produce significant fuel savings [24]. The truck traceability system developed in this deliverable allows to monitor the engine load from the OBD II protocol, see Figure 20. This is useful for the optimization of the engine performance during a mechanical process. The average engine load during this route was 27%.

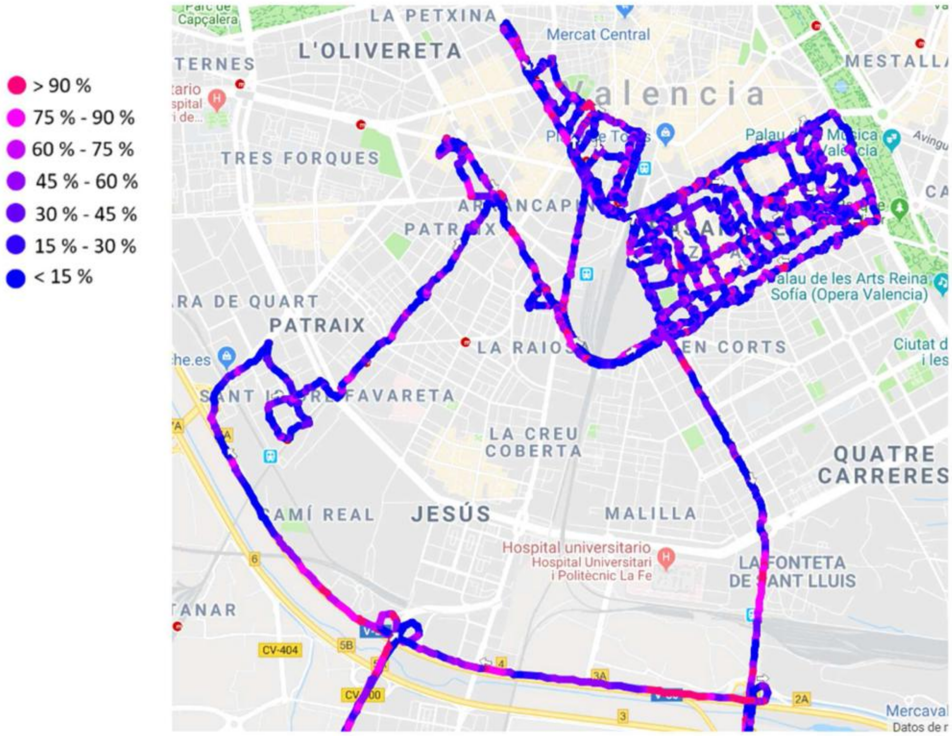

Figure 20: Registered engine load (%) for a route of packaging waste collection in Valencia. The computed average engine load was 27%.

Figure 21 shows the RPM and engine load measured during the emptying of a packaging waste container with the use of the PTO. The average engine load of the process was 40% witch it is a good indicator of the process as it is far from the maximum power at 100% of engine load. Peaks of the engine load over 70% are produced as consequence of increasing power required by the PTO during the mechanical process. As it can be seen in the figure, those peaks are associated with reduction in the RPM of the motor due that strong opposite forces are applied by the mechanical process of emptying the container.

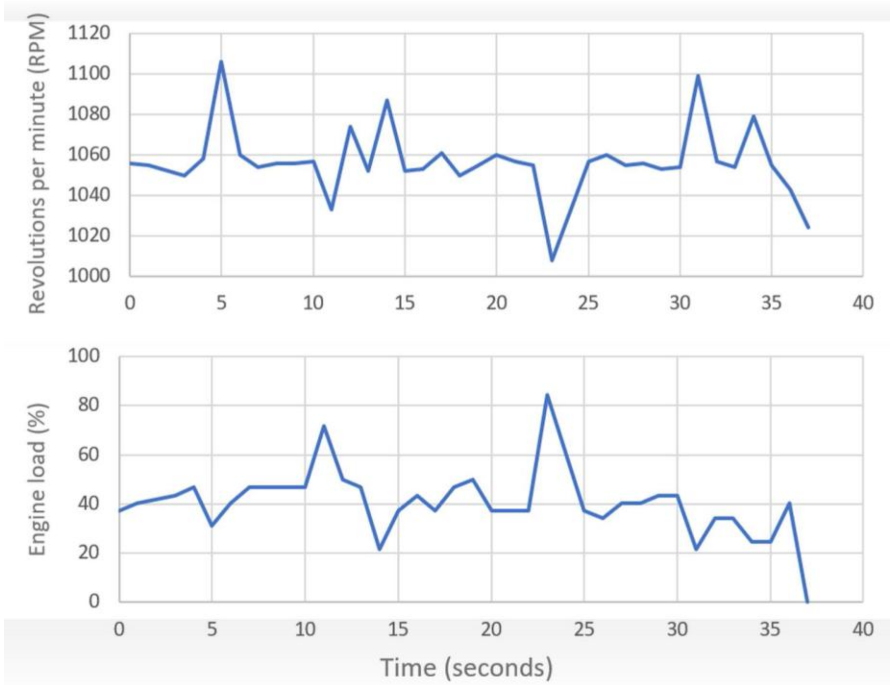

Figure 21: Revolutions per minute (RPM) and engine load (%) during the emptying process of a packaging waste container. The duration of the process was 37 seconds. The average engine load and average revolutions per minute of the process was 40% and 1057 RPM, respectively.

As commented above, old vehicles do not support the OBD II protocol. In this case, the developed application sends information of the vehicle based only in the GPS information provided by the Android device. The data received is not as completed as when the OBD II data is available, but the information is still valuable. Location, speed and acceleration are obtained from the GPS. As shown in Figure 22, a pathway of voluminous waste collection was registered with the Mercedes-Benz Atego 1523 (Figure 13) where the OBD II protocol is not available. Events as excessive idling or emptying of containers cannot be identified but events as speeding or unnecessary accelerations can be still identified.

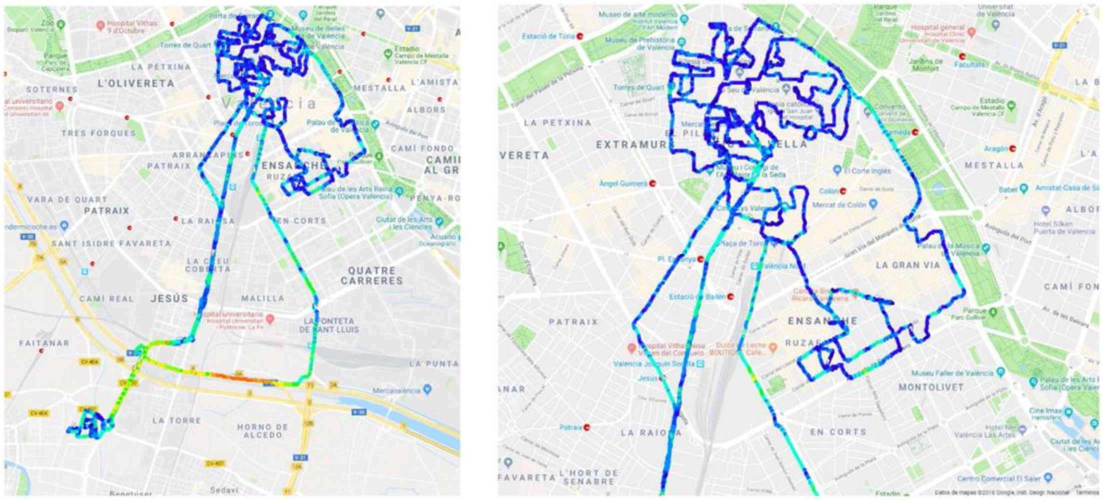

Figure 14: Pathway of voluminous waste collection route managed by SAV in Valencia. In this case, the vehicle did not support OBD protocol. The data was collected based in the GPS information. The route starts in the SAV facilities, the truck collects the voluminous waste in the city centre of Valencia, then it travels back towards the SAV facilities. Colour indicates speed of the vehicle with scale showed in Figure 14. Total duration of the journey was 6 hours with a pathway of 58 km.

5. Conclusions and Next Steps

5.1 Conclusions

GPS provides a valuable information of the location, speed, acceleration and production time. For another hand, data from the CAN bus provides many information of the vehicle including speed, RPM, and the applied torque, by means of the engine load rate.

Vehicle emissions depends on driving behaviour such as acceleration and speed. Monitoring the speed, excessive idling, unnecessary accelerations and braking can significantly help to reduce the fuel consumption [5,6].

An Android application was developed by SAV to manage the data from the GPS and the OBD II reader. This application communicates with OBD II reader via Bluetooth to obtain parameters in real-time from the vehicle. The data retrieved at 1 Hz was GPS location, speed, RPM and engine load. The data is temporarily stored in an SQLite database inside the Android application and sent to the remote server in packages of JSON arrays.

The truck traceability system allows to monitor the speed, acceleration, RPM and engine load. Regarding the speed, the system allows to detect when the speed exceeds the driving behaviour guidance. Unnecessary accelerations and abrupt braking increase the use of energy. The truck traceability system allows to identify high accelerations and braking during a route.

A measure of the torque of the motor can be obtained by the engine load. Applying the optimal engine load during a mechanical process will produce significant fuel savings. The truck traceability system allows to monitor the engine load from the OBD II protocol. This is useful for the optimization of the engine performance during a mechanical process.

Monitoring the speed, RPM and engine load allows to identify interesting events as container emptying, excessive idling or speeding. Excessive idling can be identified in the route as an event where the vehicle is not in motion, but the engine is running. Another very interesting event type that can be identified by the traceability system is the emptying of waste containers. This event can be identified when the vehicle is not in motion and the RPM > 900 for a period bigger than 30 seconds.

The truck traceability system has been tested on two different trucks, to compare the two possible cases: one that supports the OBD II protocol, while the other does not support OBD. In the case where the OBD II is not supported, the tracking was performed only by the GPS information. In this case, the data received is not as completed as when the OBD II data is available, but the information is still valuable. Location, speed and acceleration are obtained from the GPS. Events as excessive idling or emptying of containers cannot be identified in this case, but events as speeding or unnecessary accelerations can be still identified.

5.2 Next Steps

Efficient driving system is being developed in the PlastCircle project to be shown in the next deliverables. In this system, the Android application will emit a sound alarm when driver exceeds the correct parameters established on the driving behaviour guidance. It is expected to have a significant impact in the reduction of economic and environmental costs of the waste collection, in terms of fuel consumption and GHG emissions. Fuel consumption can be reduced between 5 to 20% [5,6].

Taking advantage of the use of a tablet on board of the truck, the optimized routes (in function of the filling level of the containers) will be displayed in the Android application together with the track traceability and efficient driving systems.

The truck traceability together with the efficient driving and route optimization systems will be implemented and tested in the city pilots as described in the PlastiCircle project.

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info@plasticircle.eu
@circ_economy & #plasticircle
linkedincom/groups/12055948
www.plasticircle.eu