GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE GRADO

Diseño de un Producto Conectado

CONNECTED WHEEL

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Madrid

Julio de 2020

Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título: DISEÑO DE UN PRODUCTO CONECTADO: CONNECTED WHEEL

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de otros documentos está debidamente referenciada.

Fdo.: Alberto Mejía Guinea   Fecha:21/07 2020

Autorizada la entrega del proyecto

EL DIRECTOR DEL PROYECTO

Fdo.: Álvaro Pérez Bello   Fecha: 21/07 2020

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ONNECTED WHEEL

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ABSTRACT

The Internet of Things is a new concept that is changing society in many ways. It is a new developing technology with the potential to improve all our customs and ways of life. Therefore, this project will focus on developing a connected product that can change society in terms of drinking and driving: The Connected Wheel.

This product will consist of a breathalyser incorporated into the car that, through the use of 4.0 technology, will control and reduce the consumption of alcohol at the wheel in Spain, a serious problem that causes many deaths every year.

But this project not only aims to design and manufacture a connected product, but also focuses on forming all the bases to build a potential start-up around this product. For this reason, this report will not only define the design and manufacture of the Connected Wheel but will also set out the objectives and financial requirements necessary to create a company with the potential for success.

RESUMEN

El Internet de las Cosas es un nuevo concepto que está cambiando la sociedad en muchos aspectos. Es una nueva tecnología en desarrollo con el potencial de mejorar todas nuestras costumbres y formas de vida. Por eso, este proyecto se va a centrar en desarrollar un producto conectado que puede cambiar la sociedad en cuanto a los consumos de alcohol al volante: Connected Wheel.

Este producto consistirá en un alcoholímetro incorporado en el coche que mediante el uso de la tecnología 4.0 hará que se controle y se reduzca el consumo de alcohol al volante en España, un grave problema que causa muchas muertes cada año.

Pero este proyecto no solo tiene el objetivo de diseñar y fabricar un producto conectado, sino que también se centra en formar todas las bases para construir una potencial start-up alrededor de dicho producto. Por eso, en esta memoria se verán definidos no solo el diseño y fabricación del Connected Wheel, sino que también se expondrán los objetivos y requerimientos financieros necesarios para crear una empresa con potencial de éxito.

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INTRODUCTION AND CONTEXT

The "Internet of Things" is a concept that is very present today and refers to the interconnection of devices and objects through the Internet. In this way, these can interact with each other, without the need for human intervention. These devices are called connected products. A connected product can be any type of object, from industrial machinery to any every day or household utensil.

All this has been possible thanks to the rapid evolution of the Internet focused on improving both daily life and the business world. Nowadays there are already many applications of the IoT (Internet of things) opening the door to an infinity of possibilities that can mean great changes for society ("Smart Cities", "Smart Buildings"...).

The technology associated with the IoT makes it possible to collect and send data to the network for analysis. Communication between devices ("the language" they speak to each other) is the main aspect of the development of this technology.

Using this concept and technology as a basis, the project to be carried out consists of choosing a connected product and making an initial prototype. However, it will also go beyond the realization of a prototype as it will propose a business model, will study possible markets and business opportunities to focus the product, will analyse the competition ... All this with the aim of completing the project with the basis for a potential start-up.

More specifically, the connected product in question is a breathalyser incorporated into the a car with the function of performing an alcohol test on the driver. If the driver passes the test (giving an amount less than the maximum allowed by law) the steering wheel or the start button will be unlocked, and the driver can start driving. Otherwise, if he gives a higher amount than the legal one, the steering wheel will remain locked and the car will not start. However, this device will have more functions that will be explained later.

This idea has been obtained through a measure imposed by Uber in the United States in order to carry out a campaign against driving under the influence of alcohol in which Uber drivers attending events for work would perform alcohol tests on their guests, giving them a trip in Uber to their homes in case of a positive alcohol test.

MECHANICHAL DESIGN

The protype product Connected wheel consists of several parts: the **mechanism of support** and the **alcoholometer**. The mechanism of support is the one in charge of holding the alcoholometer and dispensing the mouthpieces.

We are going to have two different design areas of design. In the first one we are going to use Solid Edge to design the whole support system and the alcoholometer's case. And finally, once these both are designed, the electronics', firmware and cloud application design.

<u>MECHANISM OF SUPPORT</u>

Firstly, we are going to design the device´s holder or support. This is where the alcoholometer is going to be kept along with its corresponding mouthpiece replacements. To design the support, I have used Solid Edge to design some parts of the mechanism of support so that it is easier to obtain the design plans. This mechanism consists of 4 main elements represented and explained below:

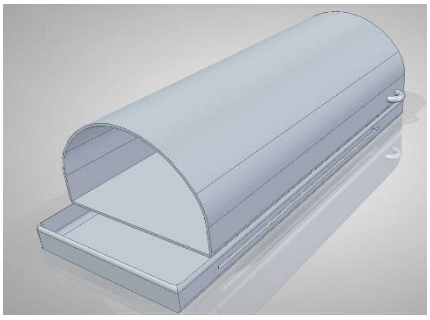


Figure 1. Support case

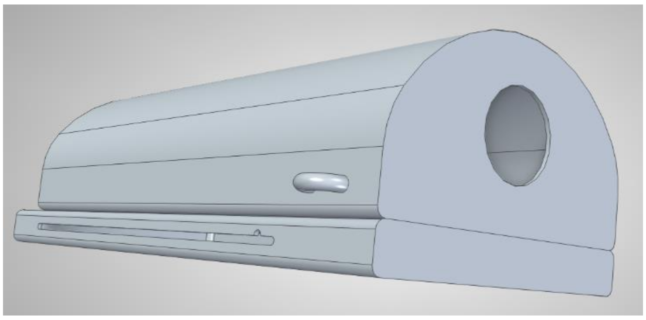


Figure 2. Support Case2

Figure 3. Mouthpiece recharger

Figure 4. Mouthpiece recharger

1. **Box**: the box is the main feature of the mechanism; it is where the alcoholometer is

going to be stored and where the mouthpieces are going to be stored and dispensed. The box has basically **two compartments** (figure 1 and 2), one for each of its functions just explained. Apart from these two, it includes the following elements:

b. **Spring Dispenser**: This mechanism will include a spring attached on one end to the back of the inside of the box, and on the other end, to a lid so that it pushes the replacements forward when one has been taken out (figure 1.a).
c. **Hole**: there is a hole on the back of the box for some reasons like security and cable connectivity.
d. **Lock**: this lock is a semi-ring located on one side of the box, another security measure so that the device does not get stolen.

2. **Security string**: There will be a security string (like shown on figure 4) that will be wrapped around the **lock** and attached to the alcoholometer. It will be flexible so that the alcoholometer can be taken out for its use and then be put back in its box.

Apart from the 3D sketch just explained, it is necessary to give the alcoholometer holder a size and measurements. Measurements that have been decided according to the size of a regular car glove box (more precisely a Renault Zoe and Kia Niro) so that the mechanism fits perfectly.

It is relevant to highlight that these sketches and blueprints are part of the design and might not be the final result, but it is the starting point from where to start the construction of our prototype. The blueprints can be found on Annex 1, where all the measurements and details of the design are presented.

ALCOHOLEMETER CASE

This section if focused on the design of the case of the alcoholmeter. The electronic components that make the alcoholometer will be inside this case. As explained earlier, this design has been made with Solid Edge. The measurements of the alcoholometer have been chosen taking into consideration the space in the support mechanism designed for it.

This design has two principal features: the **blowing conduct** and the **display**. The first one is a tube that comes out from the inside of the alcoholometer, where the mouthpiece will be introduced, so that the air of the user can go inside for its evaluation. The display is basically a whole on the case that will allow the display to show the results of the tests. Blueprints of the case are also attached on Annex 1.

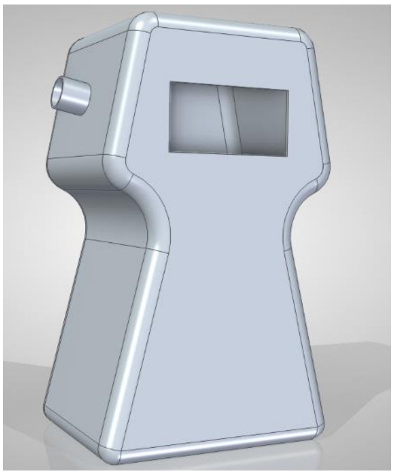


Figure 5. Alcoholometer case

ELECTRONIC DESIGN

This section consists of explaining the **electronic functions** of the Connected Wheel as well as the **firmware programming** design that would need to run properly. Since the design of the mechanism of support and the alcoholometer´s case has already been conducted above, the prototype will have electronic components on both pieces. Therefore, the design has the following module structure:

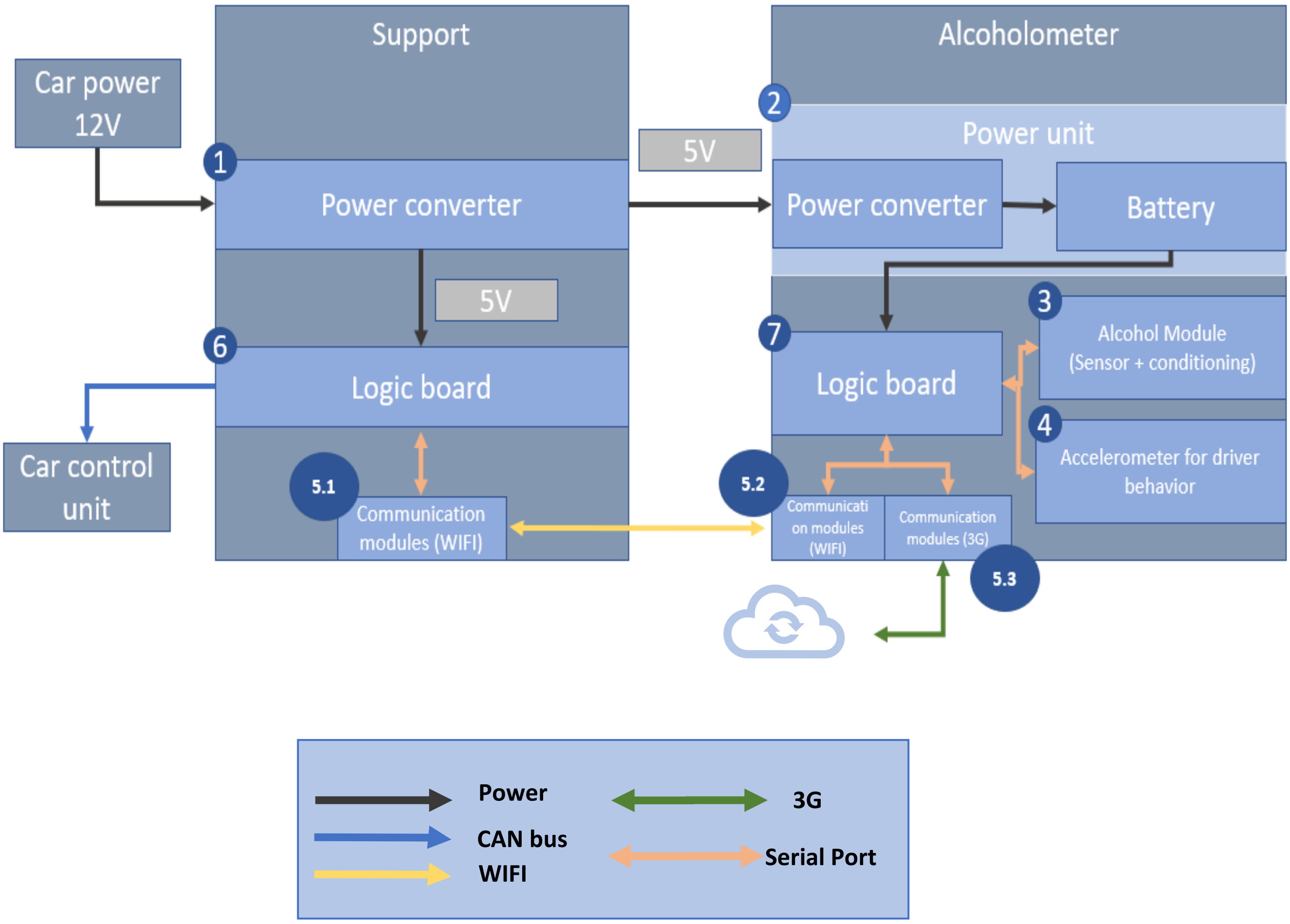


Diagram 1. Module Design

This module design explains every component of the electronics of our product and how they are connected together. As it is shown, the whole electronic technology implemented will be either on the **alcoholometer** or the **support**. The arrows connecting every module, are the different ways these are linked. If the arrow has two-ways, the link between those modules will be bidirectional. The modules and their connections will be explained below. All of the materials used in the design and the final prototype will come along with their datasheet in the annex and bibliography. The following sections will explain this module design more precisely separating **Hardware** from **Firmware.**

HARDWARE

1.Power Converter

The power converter is the one in charge to deliver the correct power voltage to our electronic systems. As the Connected wheel will be plugged into the car, the power converter will receive a **14V of direct current** (DC), and will supply only **5V of DC**, the required voltage for the other elements of the electronic system. More precisely, the power converter will be supplying power to **Logic board number 1** and to the **Power Unit**.

The converter could be bought directly from a store and it would be ready, or it could be done manually. If we would like to do it directly these would be some of the converters that could be used:

BRAND	Voltage conversion	POWER (W)	Intensity (A)	References
TRACO POWER	12V-5V	6W	1 A	(Traco Power, 2020)
RECOM POWER	12V-5V	3W	0.5 A	(RECOM, 2020)
Texas instruments	12V-5V	15W	3 A	(Texas Instruments, 2017)

Diagram 2. Power converters

After looking at these options, **Traco Powers** seems to be the best regarding Power, as the other ones are either low or too high (3W & 15W). A power of 6 W is the right amount for the electronic systems that are going to be used.

If it was decided to do it manually, the following circuit obtained through Schematic and wiring Blogspot (Schematic and Wiring, 2014) would be our 12V-5V converter:

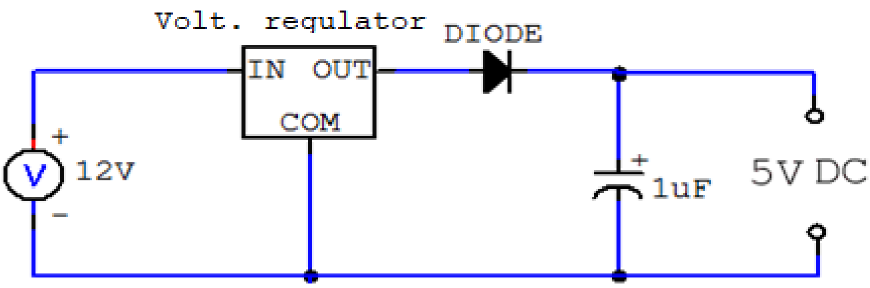


Figure 6. Power converter

It would be required the elements shown in this circuit: A **Diode**, a **condenser** and **voltage regulator**. We would need to elaborate this circuit on a **protoboard**, so that we can make the connections properly. The correct regulator for this circuit is **LM7812A**, given the input voltage (12V) and the intensity current that will run through it.

2. Power Unit

The power unit is located in the alcoholometer and oversees the power supply power to **Logic board 2**. It receives 5V from the power converters and it consists of a **battery** to supply power when the alcoholometer is unplugged.

The battery is not a regular battery, it is a rechargeable battery, similar to a drone rechargeable battery, with a voltage supply of 3,7V for its charging process (from power converter) and to supply power to **Logic board 2.** The battery used is the following:

Figure 7. Drone battery

The battery will receive power, charge, and supply 3,7V with 3000mA of current intensity. This way, the alcoholometer will be able to function perfectly when it is unplugged.

3. Alcohol module

This module is one of the most important ones, because it is going to be in charge of doing the alcohol test. It has a bidirectional communication with **Logic board 2** because it will send the results of the test and it will receive data so that the display can show the results of the test.

The module is basically a board with a circuit that will include the **alcohol sensor** and a **user interface** to control the alcoholometer. It contains the following elements: Green Led, Red led, yellow Led, 4 pin push button, alcohol sensor MQ3, resistances of different ohm values, 2x16 LCD Display and cables to do the connections. The specifics of each component will be attached on the annex (datasheets). Here are the components:

Figure 8. Cables

Figure 9. Resistors

Figure 10. Leds

Figure 11. Buttons

Figure 12. Alcohol sensor

Figure 13.display

It is important to highlight that the MQ3 sensor is the component in charge of the detection of ethanol concentration in the air, but in order to calculate the result of alcohol in blood, calibration is required.

The circuit would function in the following way: The button will turn on the alcoholometer, without pressing the button the alcoholometer will not work. Then, when the alcoholometer has warmed up, the red light will turn off, that means the driver can start blowing onto the mouthpiece so that the sensor can detect the alcohol, once the user has finished blowing, the user will have to wait for the result. This will send the data of the sensor to the logic board and once the logic board processes it, it will send back to the circuit the information so that the display can show the result. If the result is higher than the legally accepted, the red led will turn on and if the result of the test is negative or lower than the legal amount, the green led will turn on. Then the alcoholometer will turn off automatically, if the test has to be done again, the user must click the start button.

Given the module´s functionality, it would require a board with a circuit connecting the materials listed above. To simplify the explanation of this module, the circuit will be shown below divided in several parts, the **user interface** and the **alcohol tester**:

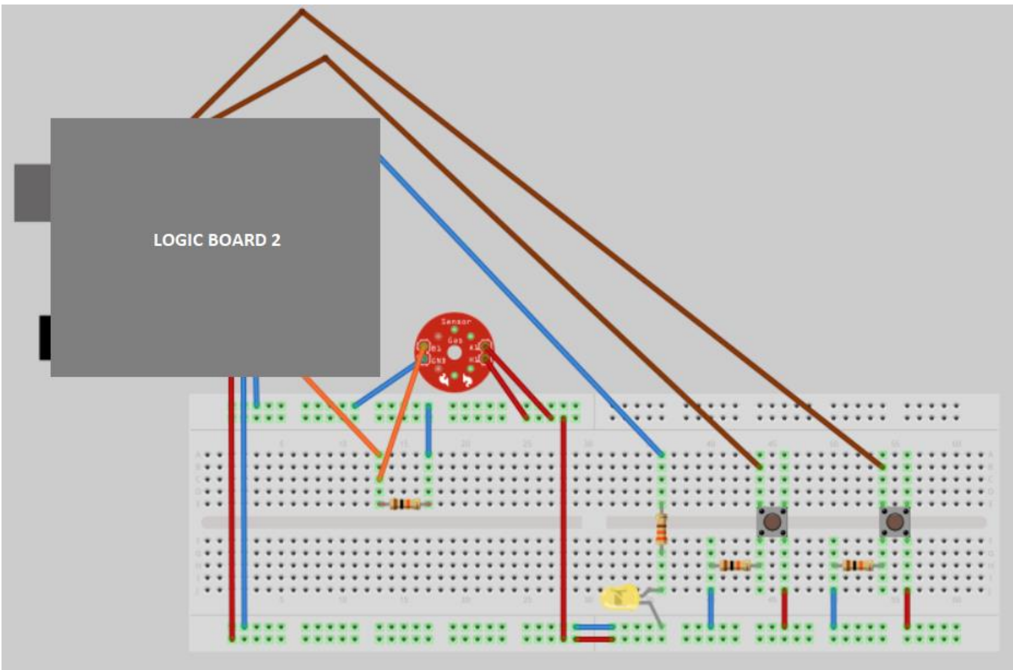


Figure 14. Sensor Design

The **alcohol tester** includes the MQ3 sensor, the turning on led explained above, and both buttons, the one to save your test and the on/off button. This circuit has been obtained through another alcoholometer project (link will be attached in the bibliography) as it has similarities with the design of the Connected Wheel´s alcoholometer.

Moreover, in the **user interface** the test saved will be then shown by the display, which will require the following circuit:

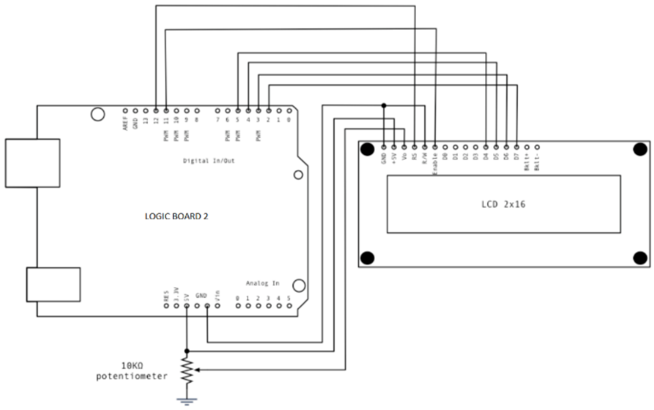


Figure 15. Display design

This circuit will receive data directly from Logic Board 2 and will display it, so that the user can read the result of the test. And finally, and also part of the **user interface**, the LEDs that show green light if passed and red light if failed have the following circuit:

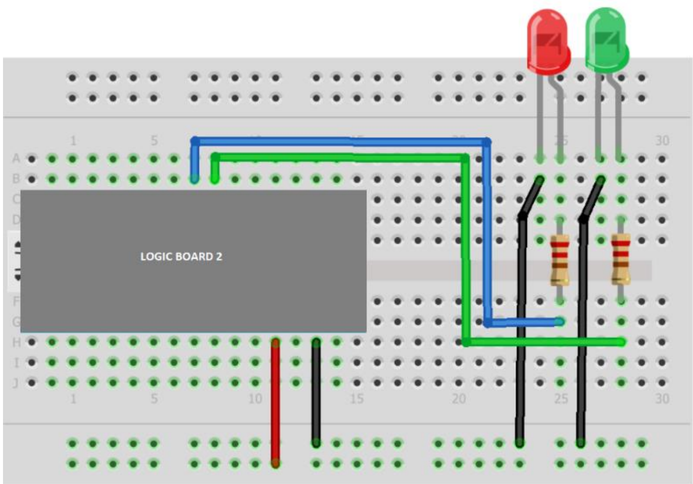


Figure 16. Led design

This circuit has been obtained from a project of a different test regarding other types of sensors, where the LEDs show if the test has passed or failed. The project in question is from Hobbyist (HOBBYIST).

4. Accelerometer for driver behaviour

A very interesting feature that will be an useful asset for our product would be an accelerometer. This way or product would not be only sending data of alcohol tests but also data about the speed of the driver, therefore controlling the two principal car accident provokers.

For this module we will only need cables for the connections and an accelerometer (usually accelerometer/gyroscope). The accelerometer chosen is the **MPU6050** (NA, 2020) (capable of resisting a car speed and acceleration) and its functionality is based on an IMU (Inertial Measurement Unit), that has 6 degrees of liberty combining a 3-axis accelerometer and a 3-axis gyroscope. This component is often used in navigation and stabilization systems.

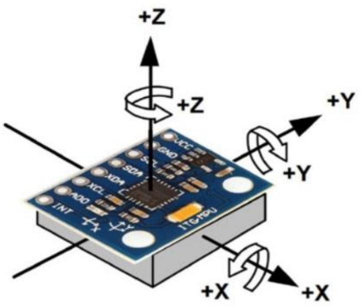


Figure 17. Accelerometer

As it is shown, the accelerometer detects both 3D turns and 3D movements, saves that data through time to calculate linear and angular velocities and accelerations.

The implementation of this module only requires the accelerometer and cables to connect it to the **Logic Board 2**, it would look like this**:**

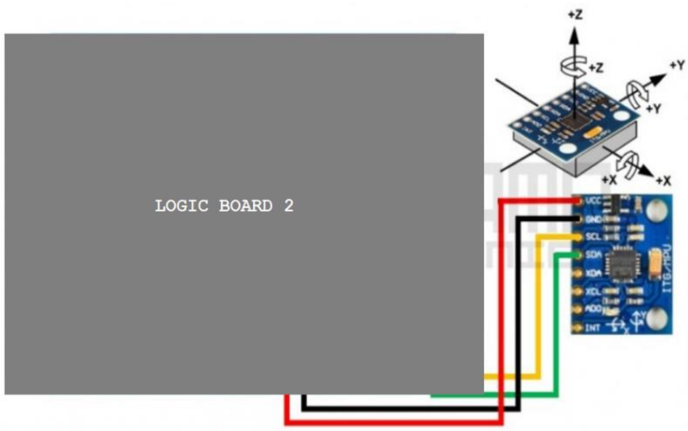


Figure 18. Accelerometer design

5. Communication modules

There are 3 communication modules in our electronic design, two of them inside the alcoholometer and the other one in the support. Each of them will fulfil a different task. The two communication modules inside the alcoholometer will communicate bidirectionally with **Logic board 2** via Serial port, where the result of the alcohol test and other data will be exchanged. The communication module in the support will be connected to **Logic board 1** via Serial port as well. More specifically, there will be **2 WIFI modules**, one in the support and the other on the alcoholometer. These two modules will communicate between them via WIFI. The WIFI modules that will be used are AZ Delivery ESP8266 ESP-01S:

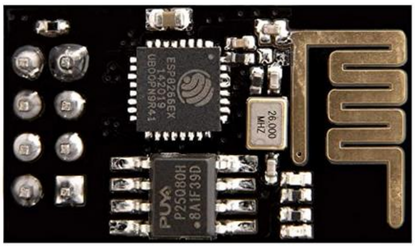


Figure 19. WIFI module

However, we do not only need the WIFI component, we also need cables and resistances for the module to work, this is what the module circuit would look like:

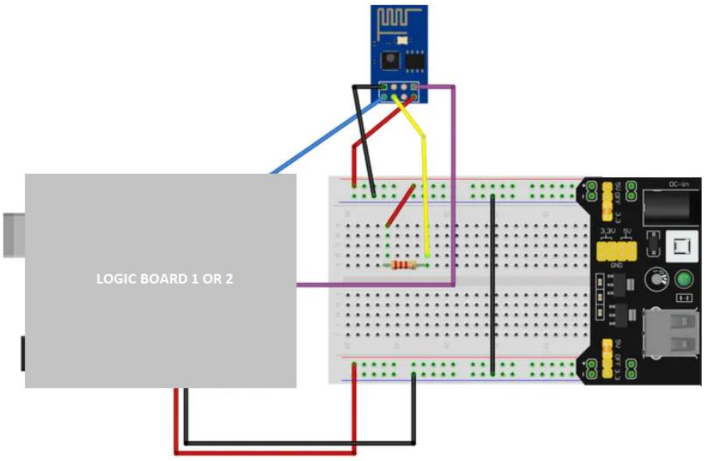


Figure 20. WIFI module design

The other communication module in the alcoholometer is a 3G module. It will handle the communication with the cloud. It will receive data from **Logic board 2** via serial port and it will send data to the cloud using 3G connection. The module used is a Gowoops Quad-Band GSM GPRS SIM900 module:

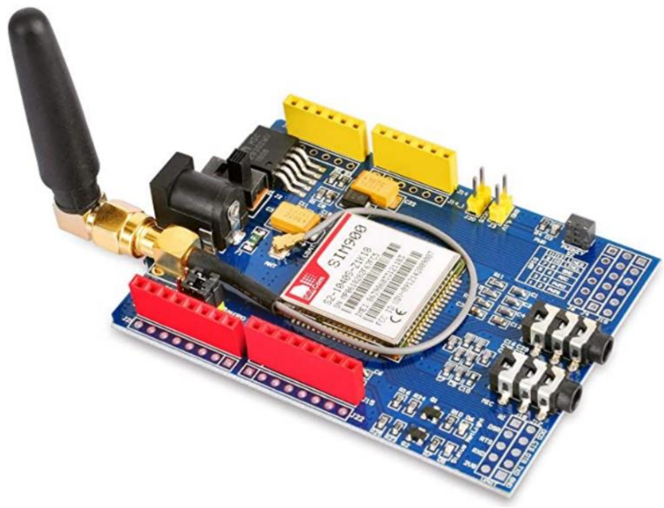


Figure 21. GSM

This module contains a SIM card to enable the 3G connection and an antenna to send the data over to the air. It is important to highlight that this module can also receive data from the cloud, making the communication bidirectional. The module circuit is the same as the one shown for the WIFI module.

FIRMWARE

6.Logic Board 1

This module has the objective of unifying all the other modules to make them work properly. It is in charge of all the programming (loop program) required. More precisely, this logic board, power supplied by the power converter will be handling only a **WIFI Module (5.1)** and sending the command of prohibiting or permitting the car to drive.

Firstly, we need to receive data via WIFI from the other **WIFI module (5.2)** in the alcoholometer of the result of the test. The program will be receiving blank data when the program is running but when the result of the alcohol test has been saved, it will receive via WIFI the result and if this result is a pass, the program will send a drive granted access to the car control unit. If the test results are a fail, it will send a deny message to the car control unit so that the user cannot drive given their circumstances. To do so, it is required to download a WIFI module library, so that the program understands the coding language.

7. Logic Board 2

This module, just like Logic Board 1, includes all the programming (loop program) required for the other modules to work properly. More accurately, Logic Board 2 will be in charge of the alcohol module, accelerometer and two communication modules. Receiving power from the **Power Unit,** the board will include the following logics:

1. Alcohol module: starting with the **alcohol tester**, the logic board has to receive data from the sensor and send it back for it to be displayed. The loop will not start until the ON/OFF button is pressed, and it will stop when it is pressed again. Once the button has been pressed, the sensor circuit will receive current and it will start detecting alcohol in the air. There will have to be a **Caudal Meter** to detect when the user starts to blow, so that he cannot fool the test by not blowing. When the user has blown, he will press the button and, in that moment, the maximum value of all the data saved while the user was blowing will be the one processed for it to be sent to the **user interface.** Until a level of alcohol is saved, the display will not show any value but when a test is recorded, it will be displayed for several seconds with a program delay. At the same time, the result of the test will be compared with

the legal value of alcohol in blood. Depending if the test is a pass or a fail, the green or the red LEDs will turn on for a few seconds with another delay.

2. Accelerometer: what we want to obtain from this module is the speed of a car. Therefore, we are going to use the velocity´s formula $v=v_0+a*t$. Once the loop starts, the accelerometer is going to give data of acceleration of the car constantly (every time the loop starts again) so another loop is required to save the previous speed of the car to calculate the current one using the most recent acceleration. In terms of the value of t, it will be the time the loop takes to be completed (0.01 approximately).

3. WIFI and 3G modules: In order to send data via WIFI or 3G, we need to use the logic board. First it is required to download a WIFI library (ESP8266 serial library) so that the program understand the coding language. Then, we need to set the “host” and the “slave”. Once that has been done, we can send or receive the data. In this case, the WIFI and 3G modules will act as hosts and will send the data given by the logic board (collected from other modules) to the other WIFI module (slave) and to the cloud, respectively. Every loop there will be data sent, so that the data is updated. To be more specific, the data that the logic board is going to send through to the cloud and to the other WIFI module in Logic board 1, is mainly alcohol tests and speed parameters.

PROTOTYPE CONSTRUCTION

Based on the design of the prototype carried out earlier, we can build a solid first version of the Connected wheel. Due to different issues and circumstances, some materials or features may differ from the prototype designed. All the **materials** used to develop the prototype will be attached on the **Annex** along with their corresponding **datasheets**. The prototyping will be divided in 3 sections: **Hardware construction**, **Firmware** and **Webb application.**

<u>HARDWARE</u>

Starting with the Hardware involved in the Connected wheel, a simpler concept has been developed than the one designed. There is only one **Logic Board** rather than the two suggested in the design and there will only be **one WIFI module** for this first version of the product. However, all the features and materials used in the construction of the prototype will be explained in this section.

Similar to the concept described in the design, the actual **alcoholometer** will have two parts: the **user interface** and the **alcohol sensor.** Moreover, there will be a **power supply system** to power up the whole product and a **WIFI module** to secure the connection to the cloud. All these elements will be connected to an **Arduino Mega**, the one in charge of the logic of the product.

To get a better idea of the elements and processes carried out, the prototype that has been built will be explained by showing different **sketches** using **Fritzing** (electronic sketching program). This way, the understanding of the different connections between elements becomes much easier than with simple pictures of the prototype. All the sketches represent exactly the prototype created. Here are the different elements of the prototype along with their corresponding sketches:

1. **User interface**: this part of the prototype is very similar to the design explained earlier. It consists of 2 LEDs, red and green, that will show the different phases of the alcohol test as well as the result in the form of light; a button, so that the user can turn on the alcoholometer when the test is required and a 16x2 Display (regulated with a potentiometer) so that the user has the proper instructions and information to carry out the test. The circuit developed for the user interface is the following (there are other secondary elements involved, those will be included on the material list):

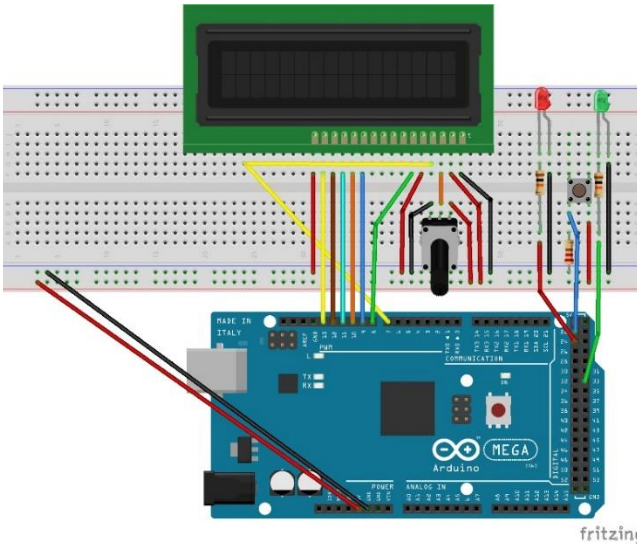


Figure 22. User interface diagram

2. **Alcohol sensor**: This part also follows thoroughly the design previously made for it. It consists of a **MQ-3 sensor** (alcohol sensor), to record the level of alcohol in the user's breath and a **caudal meter** (YF-S201) to detect the breath of the user, so that the test cannot be fooled by not blowing. This way, the user will have to blow through the caudal meter, which is just above the alcohol sensor, to complete the test. The prototype will not proceed until the caudal meter detects the air flow of the user. The circuit built for this module of the Connected Wheel is the following:

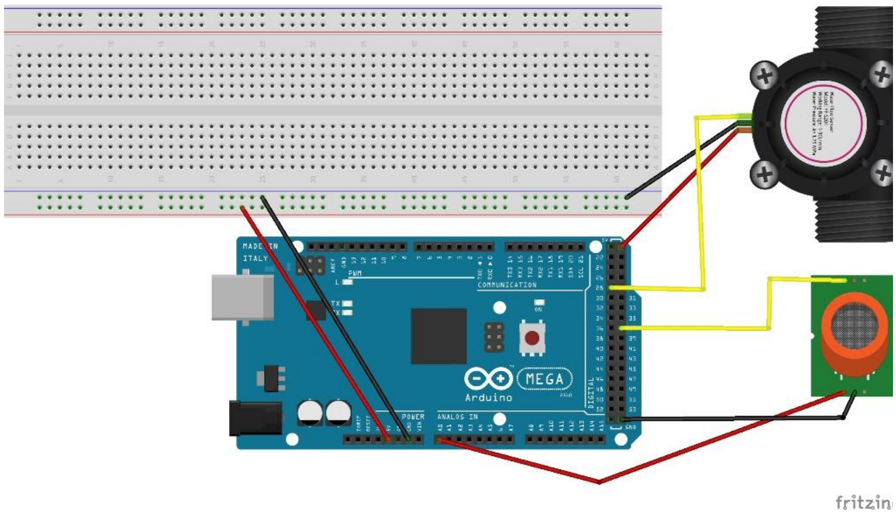


Figure 23. Alcohol test diagram

3. **WIFI module**: to connect our prototype to the cloud, so that we can send data, we need a WIFI module to have internet connection. Other Arduino boards like Arduino UNO, have built-in WIFI modules, but Arduino Mega does not include this feature. This is why, it is required to introduce an external WIFI module. In this case, the one used is an

ESP8266. This module is not physically compatible with a protoboard, making it difficult to connect the different pins properly. Because of that, the ESP8266 had to be welded (red boxes on figure) onto a Bread board adapter using a solder. Here are both the sketch and welding carried out to successfully implement this module onto the prototype:

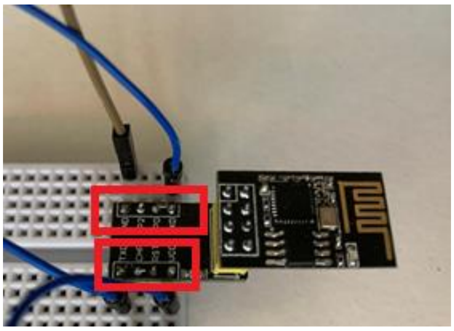


Figure 24. ESP8266 solder

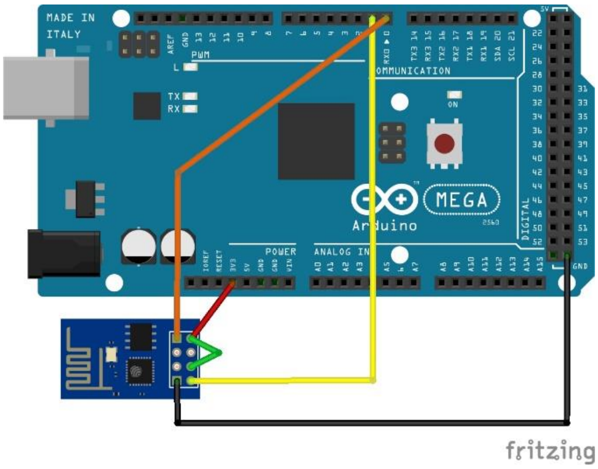


Figure 25. WIFI diagram

4. **Power supply:** The Connected wheel needs to be powered up every time a user needs to do the alcohol test, and therefore, it need a reliable power supply system. Due to the fact that in this first version there is only one logic board (there were 2 in the initial design), the power supply system can be much simpler. It will not require power converters, and because of that, it will be using a rechargeable battery. This **rechargeable battery** is a 9V battery that recharges via a USB port that comes from the car and supplies power to the alcoholometer via a **battery adapter**. This way it can be unplugged from the car when doing the alcohol test and plugged back in easily. The two components used are the following:

Figure 26. Rechargeable battery 9V (Hobby King, s.f.)

Figure 27. Battery adapter for Arduino (Tiendatec, s.f.)

After analysing separately, the different elements that form the prototype, it is important to highlight that there are many differences if we compare it with the initial design. The accelerometer and the power converters are proof of that. However, this first prototype is completely functional, and it offers a solid number of functionalities taking into consideration that it is only a first model. Here is a complete sketch replicating the first model of The Connected Wheel:

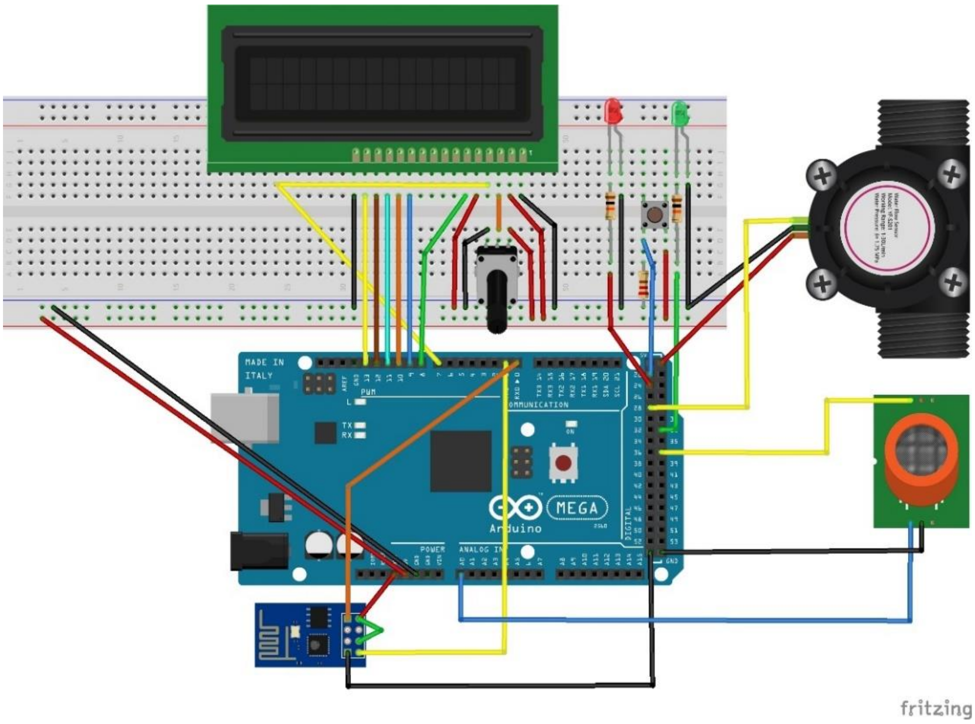


Figure 28. Prototype diagram

The **next steps** to upgrade the first prototype just explained would be to create a **PCB**, so that all the components are well organized, optimizing in space and tidiness. The PCB has not been built, but it has been designed using Fritzing. Here is what the Connected Wheel´s PCB would look like:

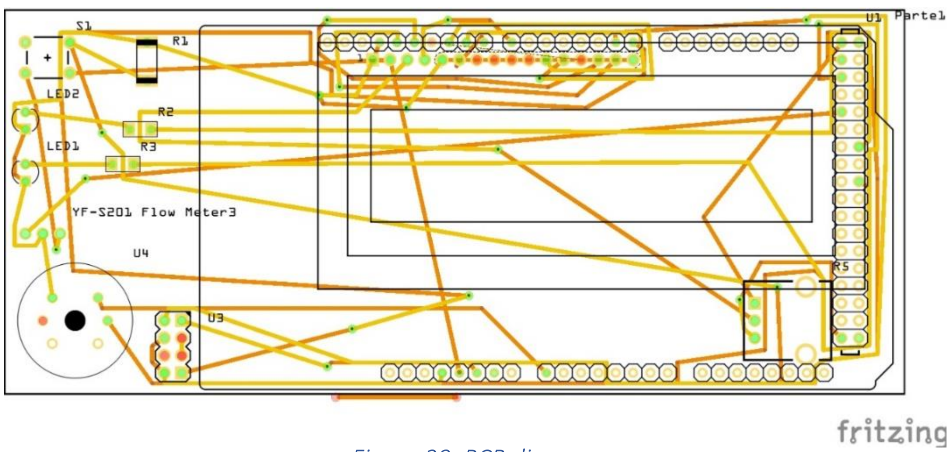


Figure 29. PCB diagram

FIRMWARE

The logic behind the prototype has been developed using Arduino IDE. Since there is an external WIFI module, there has to be **two different codes**: one in charge of the **main program** that will be uploaded onto the **Arduino Mega** and the one in charge of **sending the data** to the cloud, uploaded to the **esp8266 WIFI module**. Starting with the **main code**, to simplify it, the structure of the whole program consists of different functions called from the **main (Logic_design)**. Each function carries out a very specific task within the whole program and can be called several times. Here is a table with the different code functions and their objective in the prototype:

Functions	Description
Logic_design	This function is the **main** one. The rest functions will be declared and called in Logic_design. It consists of a setup (void) to establish all the pin modes and a loop, which corresponds to the main program of the alcoholometer.
display	This function is only in charge of displaying the correct message on the 16x2 LED depending on the moment of the program. That is why this function will be called several times from the main. Depending on what values the function receives from the main, the display function will display different message by using several **if-else**.
f_interrupt	This is a very basic function that controls the initial **button**. This button, when pressed, **turns on** the alcoholometer so that the test can be carried out.
warmup	The warmup function is in charge of **warming up** the alcohol sensor (MQ-3), because when powered up, the values measured by the sensor **fluctuate** for a undeterminate time until they start to **stabilize**. This function is called from the main at the start of the program and it will return the **stabilized value**, so that it can be compared properly with the value measured when the user blows. The stabilization is based on a loop reading he values of the sensor each second and comparing them with prevoius ones. Once the sensor reads he same value certain times, we can say that it has been stabilised.

alc_test	Alt_test will be called when the alcohol sensor wants to measure the level of alcohol in the user´s breath. It will read several times and will always save the **highest value**. At the end, it will return the highest level of alchol read. This will be the **result of the user´s test**.
getQ	This function and the next one are the ones in charge of the implemetnation of the caudal meter onto the product. The caudal meter works by impulses. When fluid runs through it, it sends and impulse to the Arduino. In getQ, we enable the **interrupts**, function that enables the Arduino to receive impulses. Then we read the function CountQ constantly until an impulse is received.
CountQ	CountQ, very related to the one above, is only incharge of **counting an impulse** with a counter. When the interrupts are enabled, when an impulse is received, the counter will increase.
SERIAL	This function will be in charge of sending the data via serial comunicaction to the WIFI module. When the test has been completed, the result is sent to the module for it to be uploaded to the cloud.

Diagram 3. Code description

Now that all the functions have been explained, the functioning of the program as a whole can be explained. The alcoholometer will be turned off until the user presses the ON button. This is done by calling **f_interrupt** at the start of the **main.** Once the user has pressed the button, the program will enter a **while loop** where the whole code will be developed. Once inside the loop, the red button will turn on, as well as the MQ-3 sensor. This will be followed by calling the **display** function, that will show a "Hello, wait for warmup" message.

At this moment, the **warmup** function has been called in the main and the alcoholometer is being stabilized. The program will not continue until the alcohol sensor is completely stabilised. When the stabilization has been completed, the red LED will turn off, and the display function will be called again to display the following message: "Ready: Now blow strongly for 5 s".

Now, the caudal meter is in charge of stopping the program until it receives an impulse indicating the user has started to blow. This way, the user cannot fool the alcoholometer by not blowing and passing the test. This is done by using a while loop that will call the function getQ and it depends on the counter explained in the function CountQ.

Once the user has started blowing, the function **alc_test** will be instantly called to measure all the levels of alcohol through several seconds. Afterwards, the result of the test (maximum value) will be returned to **main**.

The result that the MQ-3 sensor reads is not given in any kind of measure system like grams of alcohol per litre of blood. So, a **calibration** is needed so that the final test value is according to the typical alcohol test value. This is achieved by comparing the **result measurement** will the **stabilized value** retrieved from the **warmup**. By comparing these two values, the result is adapted to a more coherent result.

Finally, once the result has been retrieved and calibrated. We use and if-else function to determine whether the test has been **failed or passed**.

1. **Pass:** If the test has been passed, the green LED will turn on and the display function will be called to show: “Test result: 0.00, PASS: drive!”.
2. **Fail:** if unfortunately, the test has been failed, the red LED will turn on and you will see tis on the display: Test result: <actual test result>, FAIL: try again”.

After this, the display function will **turn off the screen**, and the whole program will have ended. Here is when the serial communication sends the test result over to the esp8266 module so that it can be uploaded to the cloud. If you want to take another test, you can **restart** by pressing the **button** again. Check Annex 3 to see the full code.

Once the main program has been completed and the results of the test have been sent to the **WIFI module**, it has to be **uploaded to the cloud**. In order to do so, the WIFI module has to be connected to a WIFI connection first. Once it has been connected, since the data will be transferred via **MQTT protocols**, it will have to connect to an **MQTT broker**. Once it connects to the WIFI and broker, it will have to **publish** the data received form the main program onto a **topic**, where the data will be sent and saved.

The program developed for the WIFI module will **notify** when the **connections** to the WIFI and MQTT broker have been **successfully made**, and it will display on the COM port the data transferred to the cloud. The following picture shows an example of what this program displays:

```
WiFi: Connected, ip : 172.20.10.8
WEB: Updater ready, open http://ConnectedWheel_1.local in your browser and login with username '' and password ''.
MQTT: Connecting to broker @mqtt.eclipse.org ... ok.
MQTT: Subscribed to [Alcoholtest]
MQTT << [Alcoholtest] This is confirming message
MQTT >> [Alcoholtest] This is confirming message
This is confirming message
```

Figure 30. COM port MQTT and WIFI

The figure shows the messages sent to the Serial Port from the ESP8266 module, confirming when it is connected to WIFI and to MQTT Broker. It also shows a message of error when some of those connections gets lost. The program is attached on the Annex.

TARGET MARKET

When developing a new product for its further sale, choosing a suitable target market is crucial for a successful business. A target market is a group of potential customers selected by the company to sell their product. Once this group has been selected, it is vital that the firm makes an acquaintance in order to know as much as possible about the chosen market. This way, we can adapt the product to the customer´s needs and preferences, we can develop a customized marketing strategy and therefore, be much more successful.

Focusing on this project more specifically, we have a product that is flexible enough for us to have several ways to focus the target depending on the type of sector we want to do business in:

Business to Consumer (B2C): In this case, our potential clients would be directly the consumers, they would be the ones to buy the device, and use it for personal consumption.

Business to Business (B2B): This option implies selling the Connected wheel directly to companies that might be interested in implementing our device on their fleet of vehicles.

Deciding between these two business strategies requires a lot of thought since the whole business plan, marketing strategy and even the product itself will be different depending on what alternative to implement.

B2C ANALYSIS

In a B2C mindset, marketing strategies should be much more aggressive due to the fact that you will be able to sell one or two devices at most per customer. therefore, you must reach a much bigger number of possible clients in order to achieve the sales target. This will make marketing campaigns much more expensive and challenging.

As the company is the direct link between the production and consumption, they would have to take care of the selling points (online and retail stores), the device´s installation and logistics as well as the 1^{st} level support to customers. These factors imply higher investment and costs such as manpower for stores, warehouses, transportation... However, the selling price of each product would be higher due the fact that the product will be sold individually, and the costs involved in the process. This strategy would make the company reach higher margins of sales, but it would also provoke an increase in the demand uncertainty.

B2B ANALYSIS

If the chosen strategy is a B2B approach, we do not have to take care of some costs involving retail stores or first-line support and it might not be necessary to invest a huge amount on publicity campaigns, but landing a client that is going to invest a huge amount of money on your product is a very challenging task. Numerous meetings and qualified commercial-profile employees and some requirements of this type of business.

However, when selling B2B, you receive orders of around hundreds or even thousands of units and therefore the price per unit will be lower than a single unit sale; meaning that some costs may be lower, but the selling price will also be inferior and therefore margins might not be as high as in the previous option.

In addition, a B2B market is more stable and predictable than others because big companies sign long term contracts with specific prices and terms. This way it is easier to predict future changes on the demand and adapt as efficiently as possible.

CONCLUSION

After analysing the assets and setbacks of both tactics (B2B & B2C), we are going to give the Connected Wheel a B2B target market that mainly consists of numerous companies that use cars to offer services and that might be interested in our product for different reasons.

Moreover, a game changing factor to choose a B2B strategy is that, when starting a new company, the most challenging part is getting money off investors. If the chosen strategy was a B2C, the initial investment would be higher due to many factors explained earlier. In a B2B mindset, the level of qualification required might be higher, but the initial investment would not be as high as the one needed in B2C.

Now that the target group has been selected, we must take them into account for all the decisions to be made from the design of the product all the way to the business plan in order to create an attractive device with options of success.

MARKET SIZING

Once the target market has been selected, it is ought to dig into its size in order to be aware of the dimension of the business, its possibilities and limits. Our main target companies will be Carsharing companies and companies that offer Taxi services.

With a global increase on the concerns about Earth's environment preservation and the electric automotive sector´s solid improvements during the last decade, comes a promising future for the Carsharing business full of opportunities and growth. As society´s mindset changes rapidly, so does the way people move around the cities. Moreover, car insurance fees, parking meters, repairs and fuel are some costs of a car ownership that people are starting to not be willing to take care of, letting Carsharing companies the way in.

Car sharing is a very general market, where there are many modalities of car sharing depending on product offering, pricing, vehicle type… Peer-to-peer, Stationary, Ridesharing and Free-floating are these main modalities. Peer-to-peer consists of a community where car owners lend their personal cars to other members of the community, whereas Stationary and Free-floating do not make use of personal cars but use cars only destined for rental.

However, it is relevant to highlight that in this specific project we are going to focus on the companies which, as mentioned above, are part of the Car sharing market but more precisely, two of the different sectors within this market. The first one refers to companies that do business by renting cars parked around the city charging a fee per minute. These types of services are known as **Free-floating** car sharing. The other type of client that we targeted is what is called **Ridesharing**.

Focusing now on these two target groups, we can calculate the particular market size that is relevant for our product. In order to obtain the market size, there are **3** steps needed**: retrieve all the competitors** (which are our potential clients in this case) within the market, find the **number of potential clients** that these companies have and multiply it by the **money invested by each of these potential clients** per year.

Since Ridesharing and Free-floating are part of the same market (Carsharing), the market size should be done using Uber, for example, as a competitor along with Zity. However, these two companies have completely different potential clients since the actual service is not quite the same. Due to this, we are going to separate those two concepts (Ridesharing and Free-floating) when doing the calculations. Furthermore, we are going to focus on Spain to calculate the size of the market.

Free-floating, as explained before, consists car fleet stationed on the streets of a city that any citizen can rent using an app to search, book, open and close a car. It is a considerably recent business (the pioneer was Car2go in March 2009) and, therefore, it is only installed in Spain´s Capital city Madrid. In this market, the competitors are shown in the following table along with some information about them (Launch date, Fees, Fleet of cars):

COMPETITORS	Launch Date	Renting fee	Fleet in Spain	Other comments
Car2Go	May of 2009	0,19-0,31 cents/minute	850	It operates in 20 countries around the world
Zity	December 2017	0,21-0,31 cents/minute	658	Partnered with Iberdrola and Telefónica
Wible	July 2018	0,25-0,31 cents/minute	500	Company handled by Kia and Repsol
Emov	May of 2016	0,25-0,29 cents/minute	500	First company to introduce 4 seat cars
TOTAL CARS			2508	

Diagram 4. Free-floating companies

Gathering some information about the competitors of a market makes it easier to achieve a realistic market size. Furthermore, knowing the volume of each company´s fleet is key since it is the potential sales target that our product can have. For instance, if we add up every car that each company has on the streets of Madrid (i.e. **Total cars** in table), we obtain a total of **2508** cars right now that could incorporate the Connected Wheel.

Taking into consideration that these companies only operate in Madrid, their area of reach is not the whole city (they do not reach the outskirts) and that people older than 55 and younger than 18 will not be potential client, we will proceed to calculate an approximate number of potential clients.

The city of Madrid has a population of around 3.2 million people (only Madrid, not the outskirts of the city) which of those, according to the INE, only 1,6 million are between 18 and 55 years old. Apart from this, we also must add the fact that only the 56,7% of Spain´s population has a car license, a compulsory requirement in order to rent a car. This leaves us with a number of **906,771 possible clients**.

Now that we have the number of potential customers, we have to multiply it by the average money spent by each customer in a year in carsharing rents. To do these calculations, we will use the data that Car2go offers us on their annual press releases. From this data we obtain that a car is rented 15 times a day on average, making it a total of 5475 trips per year and per car. If we multiply this by the number of Car2go cars available in Madrid (850) we end up having a total of **4,653,750 trips**. Moreover, Setting the average trip in **10 minutes**, which would be around **2.5**€ (0,25€ per minute approximately) and a number of **237,000 actual clients** we proceed to make the following calculations:

AVERAGE TRIP TIME	TOTAL CARS	TRIPS/DAY OF 1 CAR	TOTAL TRIPS	POSSIBLE CLIENTS (1.6 M x 56,7%)
2,5€	2508	15	4,653,750	906,771

Diagram 5. Free-floating

TOTAL CAR2GO REVENUE	SPENDINGS PER USER IN A YEAR	FREE-FLOATING MARKET SIZE
11.6 million €	50€	**45,338,550€**

Diagram 6. Free-floating

Multiplying the average trip time in euros by the number of total trips we would have a total revenue of 11,6 million euros as it is shown on the table above. However, we do not want to see Car2go´s revenues, we need this to calculate the yearly spending per client. To do so we have divided Car2go´s revenues by their actual clients (237,000).

Finally, we have all the data necessary to give a value to this market. the table above shows **906,771 potential clients** spending **50€** each year on Carsharing adding up to an amount of **45,338,550€**. This is the value of Free-floating in Madrid. This is a considerably high value considering that it is only operating in Madrid.

Moving on to Ridesharing, in Spain there are 2 main competitors that offer rides to people as if it were a taxi. Moreover, as we could compare this way of carsharing to a Taxi service, it would be a good opportunity to unify both in the same market sizing to give the connected wheel more business opportunities by, for example, persuading the government to enforce Taxis to implement an alcoholometer in their cars. Those companies are (Ridesharing and Taxi):

COMPETITORS	Operates in	Renting fee	Fleet in Spain	Other comments
Uber	700 cities	Depending on supply and demand	10,125	It is available in 56 cities in Spain
Cabify	10 Spanish speaking countries	Depending on supply and demand	3,000	It is available in 5 cities in Spain
Taxi	Whole world	Different fees for day and night services	70,000	
TOTAL CARS			83,125	

Diagram 7. Ridesharing &Taxi

To calculate the market size of these two companies in Spain plus Taxi services, we are going to follow the same procedure as we did earlier. However, the potential client can be anyone with a mobile phone that is able to download apps. This way, the target group would be people between 15 and 70 of the cities that these two companies work in. According to the INE this target groups has a size of **25 million** people, approximately. Using Uber as reference, they have 10,125 drivers in Spain, with 250,000 users. Approximately, each user does 50 rides in Uber per year and the average uber ride price is 8 €. This means that each customer of this market spends 400 € per year. This values just explained are shown in the next two tables:

ACTUAL UBER USERS	TOTAL CARS	TRIPS/YEAR OF 1 USER	TOTAL TRIPS	POSSIBLE CLIENTS
250,000	83,125	50	12,5 Million	25 Million

Diagram 8. Ridesharing

AVERAGE RIDE PRICE	SPENDINGS PER USER IN A YEAR	FREE-FLOATING MARKET SIZE
8 €	400 €	**10 billion €**

Diagram 9. Ridesharing size

Now that we have achieved a market sizing of **10 billion €** of these target groups, we can compare and evaluate each of them for further decision makings and strategies. Clearly, the **Ridesharing** market seems massive compared to the other one with over 9 billion euros of difference in terms of market sizing.

Another interesting value for us to know the **possible sales target** of our product is knowing how many cars these two target groups have and multiply it by an estimated price of the connected wheel. We know that there are 83,125 Uber, Cabify and Taxi drivers in Spain and setting a product price of 200€, this would mean a value of **16.625 million** euros in possible sales. On our other target, there are, as documented above, 2508 cars in Madrid (Being this the number for Spain as well). Carrying out the same calculation we obtain a value of **501,600** euros. This **possible sales target** is presented in this table:

Price per unit of the Connected wheel	FREE-FLOATING	RIDE SHARING
200€	**501,600 €**	**16.625 million €**

Diagram 10. Market sales

To conclude, both estimations done in this market sizing show that Ridesharing (Taxi services included) seems to be a humongous market compared to Free-floating in terms of potential clients and number of cars. This conclusion leads us to focus more on the biggest one rather than the other market because it has more business opportunities and therefore, we should take important design, business and sales decisions regarding priority for Ridesharing.

Moreover, given the magnitude of the market it is important to set the goal of what percentage of the **market share the company should aim to obtain**. With the numbers presented and the possibilities of cars to implement the Connected Wheel on, a **50%** on the **first three years** is a reasonable market share. This way on the first three years half of the Carsharing and Taxi services in Madrid should be using the Connected Wheel and up to an **80-85%** by the next **6 years.**

MARKET RESEARCH

After acknowledging the size of the targets markets that the Connected Wheel is going to set all of its focus to and the features of our prototype have been developed, it is crucial to investigate how the product can perform in the markets presented earlier, Carsharing and Taxi services. The most resourceful tool to carry out this investigation is the **market research.**

To conduct a successful market research, we need to determine the **purpose** and **objectives** of the research, as well as the **target audience** of the research:

Purpose

Know the **feasibility of launching the Connected wheel** in the Carsharing and Taxi market.

Objectives

Study the **different competitors** if they exist and find out the **opinion and impact** of the Connected wheel on the Carsharing and Taxi services **clients**.

Target audience

Citizens **of Madrid from 18 to 60** years old that are clients of either Carsharing or Taxi services

Diagram 11. Market research

Now that we have set these points, we can proceed with the market research. Firstly, focusing on the first objective, we need to seek information that already exists, **secondary information**. The best way to know your competitors and retrieve a general idea of how the market players are working, is by doing a **competitive Benchmark.** On the other hand, if the desire is to obtain relevant information to your research that does not necessarily has to be linked to the different market competitors, the tool to be executed is the **Web research**.

COMPETITIVE BENCHMARK

Competitive Benchmarking is a process in which the products, services or processes of a specific company are compared to other similar companies in the industry that have superior performance in order to identify internal opportunities for improvement. By describing the other companies' strategies and understanding its success, it is possible to implement changes that will lead to significant improvements and will let the company become a more important one within the market.

Focusing on the Connected Wheel, the goal of a benchmark would be to find the companies that have launched a product which is similar to the Connected wheel. This way, **analysing** the different **competitor´s** experiences, ideas and mistakes, we can obtain **useful information** on what the best approach is for the Connected wheel.

After carrying out some secondary research on the possible competitors of the Connected wheel, the **Alcolock** was the **only** product that could be compared to the product of the project. The Alcolock is an alcoholometer that prohibits the driver to start the engine of the vehicle if he fails the alcohol test. This product has been used in several countries such as Finland, France and Denmark as part as legal measures only (Castillo grupo, 2018). In Spain, there has been attempts by the DGT and the State Attorney general to implement laws that oblige the use of the Alcolock in different sectors (School buses, people convicted for driving under the influence of alcohol…), according to the DGT (Rodríguez, 2008) .

To compare it properly with the Connected Wheel we are going to analyse the Alcolock based on these variables: **functionality and features** and **commercial approach**:

1. In terms of **functionality and features**, these are the main elements to take into consideration. The green tick shows that the product contains the given feature, and the cross shows that the product does not have that offering:

FEATURES	ALCOLOCK	CONNECTED WHEEL
Alcoholometer incorporated in the car (including basic features of a regular alcoholometer)	✓	✓
Automatic prohibition of the engine-start if necessary	✓	✓
IoT technologies implemented in device	✗	✓

Diagram 12. Benchmark

2. The features of these products might be similar; However, the **commercial approach** is totally different. The Alcolock has the objective of selling their devices mainly through a government law support, a law that might or might not come through. There have been some vague intentions to sell the Alcolock to private sectors with the signing of ALSA (OK Diario, 2018), but it is not their main focus. However, The Connected Wheel is also focused on selling the product to private companies that, by implementing the Connected Wheel, will add value to their services (Carsharing).

Before analysing the main difference between these two potential competitors, it is relevant to highlight the fact that this market is a completely **new** and **unexplored market** with **no economies of scale** because there are no big companies that dominate the market share and at the same time, it is not a highly divided market. This factor makes the market´s **entry barriers low** in terms of **competitiveness**, but **high** on other aspects such as **lack of suppliers** or **market ignorance** due to the newness of the market.

Finally, comparing both products in terms of **features**, they are basically equal except for one factor that makes the Connected Wheel stand out: **IoT**. The use of IoT technologies adds a considerable amount of value to a product like this in uncountable ways (Real-time data, unified control via Cloud…). On the other hand, the commercial approach of the Alcolock could be useful, because if a government law supporting these types of products comes through, the possibilities of success of the Connected wheel would rocket. It could be a reasonable idea to invest on the persuasion of the government to implement such laws.

WEB RESEARCH

A **web research** consists of analysing and reviewing existing information on the Internet in order to learn more about a specific topic, to understand the industry we operate in and get to who the competitors and consumers are.

In this particular case, the web research to be carried out is going to be focused on the impacts of **alcoholism while driving** in Spain. This will help finding out the impact that our product could make, not only on customers but on the whole citizenship.

After retrieving data from numerous web pages, these are the most important facts obtained:

1. According to the DGT, more than 40% of the drivers dead due to a car accident were driving under the influence of alcohol or drugs. (Delgado, 2019)
2. Two of every three young drivers have admitted to being in a car where the driver was under the effects of alcohol (La Vanguardia, 2018)
3. Out of the 535 drivers deceased in 2018 due to car accidents in Spain, 232 where tested positive in the alcohol test, being 90.7% men and only 9.3% women (Delgado, 2019)

Diagram 13. Web research

After carrying out these Web research, it is clear that driving under the effects of alcohol is a serious issue in Spain, meaning that the Connected Wheel can offer a solid solution to a very serious problem, making our product more necessary and valuable. However, one of the objectives set for this market research was to find information on the impact of alcohol on the markets and services that the product is focused on (Car sharing and Taxi), and that information is inexistent. There is no information on the impacts and causes of alcohol when speaking specifically about these sectors.

Consequently, as the secondary information available is very limited, a primary research needs to be conducted. This research will inform us about the specific and current situation of the issue of alcohol in the **Carsharing** and **Taxi services** sector in Spain. For that reason, a **survey** has been carried out in order to know **the impact and viability** that the Connected wheel could have in these markets. Once the survey has delivered the data, a **quantitative analysis** must be done to process the raw data that the survey supplies.

QUANTITATIVE ANALYSIS

To develop an interesting Quantitative analysis, an online survey was carried out, collecting answers from people between **18 and 60 years old.** The main focus of the survey was to ask the opinion of the different clients of both Carsharing and Taxi services about their thoughts on alcohol and driving, and what they thought the impact of the Connected wheel could do on these markets. Since the users might or might not be clients of all of the different services of our target markets, the survey is divided into three sections: **Taxi clients, Carsharing clients (Uber) and Free-floating clients**. The questions of the online survey will be attached in the Annex.

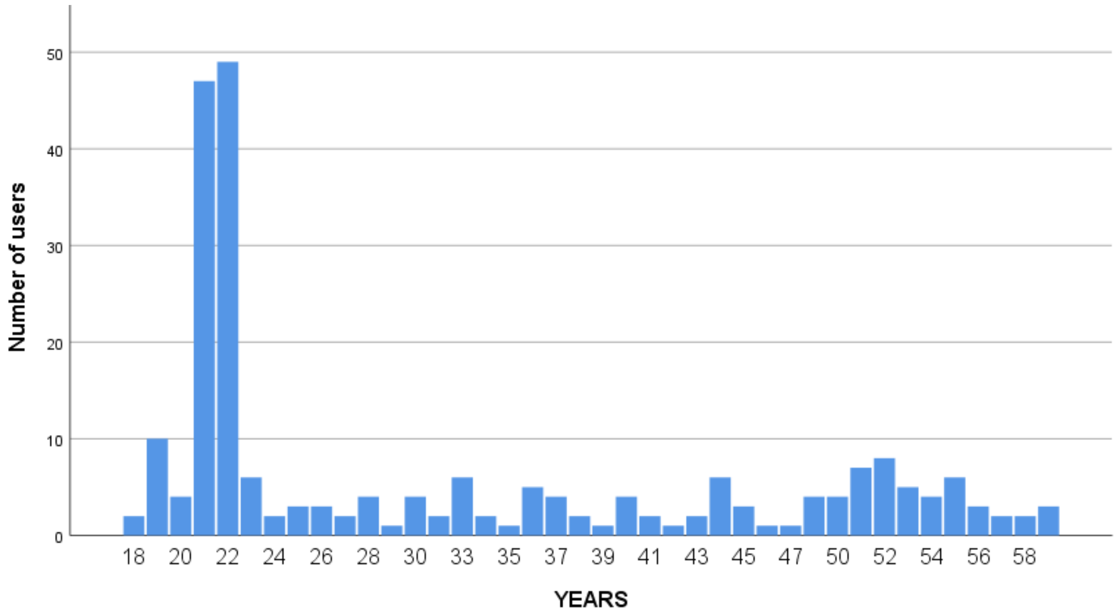


Diagram 14. Histogram

After grouping all the surveys answered, the number of responses was **228**. All the data obtained was processed using PSSE, so that we could obtain conclusions out of raw data. Here is a histogram of the ages of the 228 users that answered the survey:

As it is shown, the sample **fashion is 22** years old and the **mean** is around **32** years old. However, since we can use PSSE to obtain different variables, the sample will be divided into intervals to obtain the most relevant data out of the sample.

Starting with **Free-floating**, the most interesting age group to focus on was the users between 18 and 25 years old because **79,5%** of the people that age are Free-floating clients, whereas in other age groups that percentage is much lower.

The first relevant issue obtained studying this age group is the percentage of users that have driven a Free-floating car under the influence of alcohol. This is shown in the following graph:

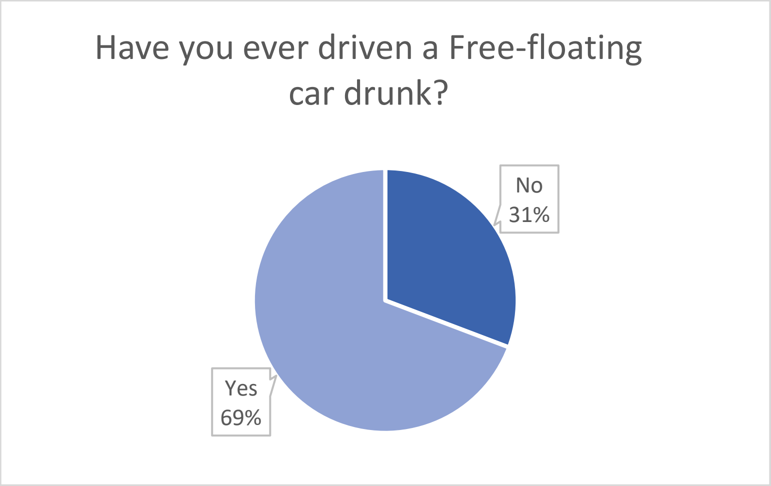


Diagram 15. Free-floating chart

Almost **70%** of the drivers and Free-floating clients of between 18 and 25 years old have driven this car service under the effects of alcohol. This percentage is extremely high considering that almost **80% of this service´s user is of this age range**. Moreover, the survey also retrieved data of the users that have been in a Free-floating car where the driver (not them) was driving under the effects of alcohol. The results show that **79%** of the users have been in a Free-floating car where the driver was drunk.

After knowing these percentages, the survey asked the users to answer if they would stop using the Free-floating service if they had to take an alcohol test before each journey. This was the answer:

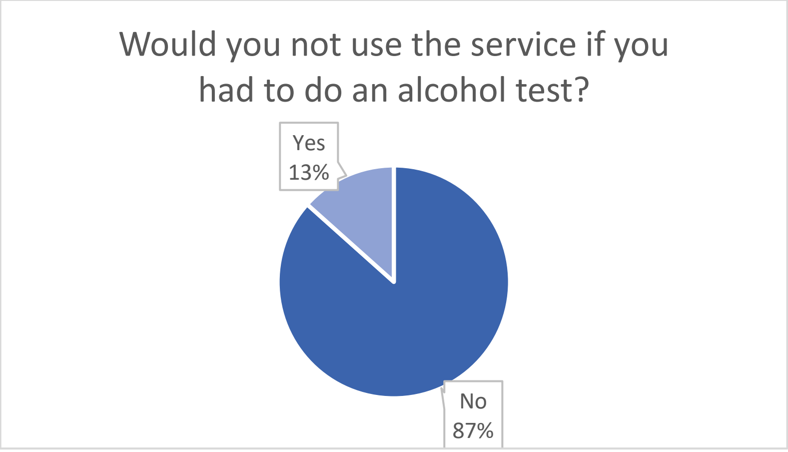


Diagram 16. Free-floating chart

This result helps to get a very interesting conclusion, the Free-floating market for people between 18-25 is extremely important, to the point where even if 70% of them drive under the influence of alcohol**, 87% would not quit renting this service**, having to give up alcohol instead. This data shows the massive positive impact that the Connected wheel could make in terms of driving and alcohol.

Moving onto the other two markets, Carsharing (Uber) and Taxi services, the focus of connected wheel in these markets is to add security to the client by testing the drivers before each journey. The results of the survey regarding these two markets where very similar. However, there is a very interesting difference between them, the fact that people feel safer in an Uber, for example, than in a Taxi. This conclusion is obtained through asking if they have had any **insecurity issues because they thought the driver was drunk.**

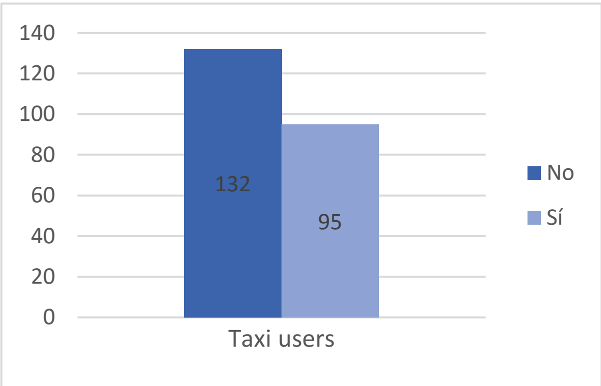


Diagram 17. Insecurity taxi

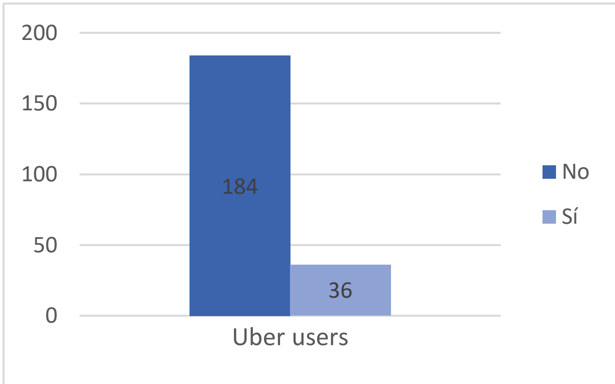


Diagram 18. Insecurity Uber

As it is shown above, the comparison between Uber users and Taxi users is considerable. The level of insecurity is clearly much higher in a Taxi than an Uber. The data on the graphs above are representing the whole sample, not differentiating by age.

After realising the insecurity issues due to the problem of the driver being under the influence of alcohol, the survey asked the users how much their level of security would increase if the connected wheel was incorporated in these services. In both sectors (Taxi and Carsharing), the result was very similar**: 10% would not care** in terms of security, **30%** would feel **more secure** and **70% would feel extremely secure**. This is an extremely relevant fact because it shows that almost **90% of Taxi or Carsharing companies' clients** will feel **safer** if they implemented the **Connected wheel** on their fleet of cars.

Finally, the quantitative analysis also wanted to know if the users thought that the incorporation of the **connected wheel** in the fleet of cars of a specific brand could make it **stand out** from the rest of the **competitors**.

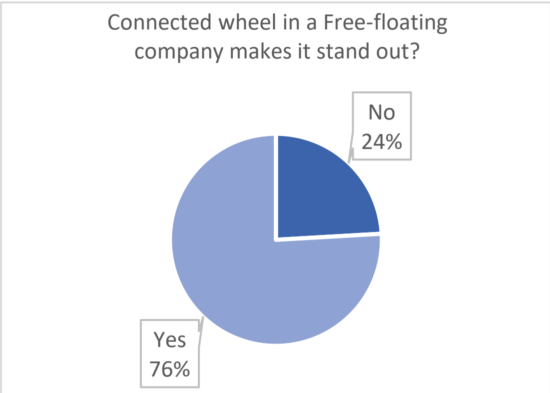


Diagram 20. Standout Free-floating

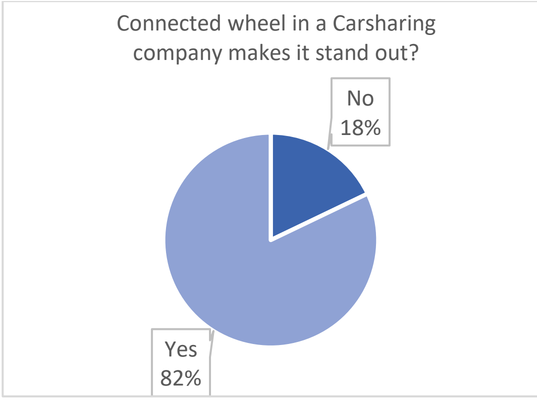


Diagram 19. Standout Carsharing

These two graphs show that most users of these two sectors (**76% for free-floating** and **82% for Carsharing**) appreciate the **value** that the **Connected wheel** can add to them and to the company up to the point where the company would stand out over the others if they implemented the connected wheel in their cars.

These results mean that the connected wheel not only helps stopping the disturbing **issue of alcohol and driving** in Spain, but it is also a product that will **add value to the companies** that implement it, making them stand out.

CONCLUSSIONS

The objectives of this market research were to **investigate the situation of alcohol and driving** in Spain to get to know the impacts that the connected wheel could make, study the different **possible competitors** and find out **the impact that our product could cause** on the specific markets that it is focusing on.

In terms of the situation of driving under the influence and all its consequences, the **web research** helped to acknowledge the gravity of the situation here in Spain, with some very drastic facts. Knowing the actual state of this national issue makes the Connected wheel a product that is very necessary to in order to fix the situation.

The **benchmark** focused on analysing the competitors so that the Connected wheel could learn from their mistakes and virtues. However, the resolution is that the market that the connected wheel wants to enter is a completely **new market**, with very low entry barriers for some aspects and high ones for others. This uncertainty due to the undiscovered market, made obligatory the development of a **quantitative analysis**.

The **quantitative analysis** shows very convincing results, not only about the situation of driving and alcohol but also about the impact that the connected wheel could have. In conclusion, the analysis puts the connected wheel as a product that can help society in terms of alcohol and can also help companies make better profits.

Business Model

After carrying out different researches regarding the market that the Connected Wheel is going to enter, it is ought to focus on the specifics of the business model regarding the first 5 years of the Start-up´s life. In this section there will be a **Lean Canvas Business plan** to get an overview idea of the different aspects and goals of the company, followed by a **Financial plan** and a **Pricing Model** that shows the course of action of the potential start-up in its **5 first years** of life.

A crucial point in the birth of a Start-up is the obtainment of economic resources from **investors**. That is why the business model will include sales projections, costs, required initial investments and other specifics so that the investors know the value of the project and the path that the company intends to follow.

LEAN CANVAS BUSINESS PLAN

The Lean Canvas Business plan is a one-page diagram that shows the relevant aspects of a business model. It is extremely efficient to pitch investors in the first steps of a start-up. The Canvas diagram focuses on the following aspects:

1. **Problem**: The problem that the company has been built to overcome.
2. **Solution**: The main solutions that the product or services of the company has to the problems mentioned.
3. **Value Proposition**: the main aspects of why the company will stand out between its competitors.
4. **Unfair Advantage:** the advantage of the company over the rest of the market.
5. **Customer Segments:** targets of sales of the solutions offered by the company.
6. **Existing alternatives**: Different solutions to the needs and problems that the company satisfies (i.e. competitors).
7. **Key Metrics:** crucial activities and impacts that your product can make.
8. **High-Level Concept:** an overall idea of what the company offers.
9. **Channels:** the path to the potential customers.
10. **Early Adopters:** a description of what the company´s ideal customers would be.
11. **Cost Structure:** List of the most important costs incurred in the company´s activities.
12. **Revenue Structure:** sources of revenue of the company.

These aspects are crucial to understand the Lean Canvas Business model. The following diagram shows the Canvas Business model of the Connected Wheel, made using *the Neo Chronos Limited template* (Chronos).

Lean Canvas

Designed for:	Designed by:	Date:	Version:
Connected Wheel	Alberto Mejia	21/07/2020	1.0

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer Segments
The serious problem of driving under the influence of alcohol and the consecuences this matter provokes Insecurity issues in the Taxi and Uber services due to drivers under the influence of alcohol	Reduce Alcoholism while driving with the alcoholometer Connected Wheel to add security to traffic	Versatile device that ensures alcohol-free driving Revolutionary device fully incorporated in the car Connected product so that data can be monitorised and controlled in near-real time	Inexistance of a product like the Connected Wheel in the market Added value of a industry 4.0 Connected product	Free-floating companies to ensure the integrity of their fleet of cars Carsharing and Taxi services to add security to their users
CReExisting Alternatives	**Key Metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
The issue of driving under the effects of alcohol is only taken care of by irregular controls made by the police, beeing unable to secure clean drivers on the streets. There is no product on the market that offers solutions either	Social impact of the connected Wheel Consciousness over the issue of driving under the influence in Spain	**Constant alcohol control with drive block if test is positive**	Sales representatives that target companies that could require the implementation of the Connected Wheel in their services	Companies with big fleet of cars that offer services in which the connected wheel is a need.

Cost Structure	Revenue Structure
Production costs: Warehouse, suppliers, materials… Distribution costs Staff salaries and office costs	Big scale Contracts IoT service fees Other optional services such as installation and monitoring of devices

The diagram shows a very general scope of the company´s goals and bases, so that investors have a clear idea about what the main focuses, assets and setbacks the company might have. To be more precise on the company´s economic potential, more detailed information is required.

PRICING MODEL

It is key to have a successful method of revenue to obtain maximum profitability out of the products of a company, therefore, a pricing model is one of the most crucial aspects of the Business model. This pricing model will consist of different methods of monetizing the Connected wheel **depending on the customer**, the **services offered**, and the **number of devices** in each order.

However, in order to set a price which is optimal for the Connected Wheel, it is necessary to study the **costs of the production** of the given product. Given a first impression of what the product could cost by creating the first prototype, and the improvements needed to be a highly functional al quality product, the costs will round up to **200€**. This assumption is based on first year suppliers and small orders, meaning that the costs should get optimised as the company sells more products.

The next step is to set the different fees and services into a pricing structure. The Connected Wheel is going to have 3 bases of income: **Devices, IoT services** and **Optional services**.

In terms of devices, the prices per devices might vary depending on the size of the order, meaning that a bigger order will imply less price per device. This way, there will be 3 segments:

1. **Small accounts**: these group of clients are the ones which will not order more than 100 devices. It will consist on small and medium business that have a small fleet of cars to implement the Connected Wheel. The fee per device will be **500€**.
2. **Medium accounts**: This segment will include bigger clients, normally at a regional level, with a maximum of 1000 devices. The fee per device will be **400€.**
3. **Big Accounts**: These customers will be ordering more than 1,000 devices to integrate in their fleet. The profile of these type of clients will be top of the market international players. The fee for this segment will be **300€** per alcoholometer.

These are the base fees for each segment of the company´s target customers, however, there are other services necessary to obtain the full experience of the connected wheel**. IoT services** will be required for the implementation of the Connected wheel. The usage of the **IoT platform** where the data from the devices will be **managed and stored** can be **hosted internally** (by the client) or can be **offered by the company**. If the client suggests hosting the platform under their software structure and atmosphere, the fee will be **5,000 € per year.** The positive part about this offer is that if they want to host the platform their selves, the company will have much less costs in terms of infrastructure, creating a bigger margin (the customer will have their own platform costs). However, if the client prefers to not host the cloud infrastructure, they fee will be charged **50€ per device and per year.** This second option is rather useful for small accounts.

Finally, there is a third income path for the Connected wheel which is **optional**. These Optional services are: **Installation and Monitoring.**

Installation is the process of setting up the device on the car so that it is ready for its use. This service will probably be free for new clients during the launch and early phases of the company, but then it will be optional to install it independently. It is important to highlight that for **big accounts**; this service will be **free of charge**. For the rest of segments, the fee will be 20€/ device installation.

Monitoring services are meant to give customers a better customer experience by managing their devices and handing **weekly and monthly reports** on all their devices data and status. This way the customer will have all the data required with no effort or knowledge on IoT. Moreover, the client can suggest changes and real-time data whenever it is desired. This fee will be charged 100€ per device and per year. This service is ideal for Small and medium accounts with no infrastructure resources nor IoT workforce.

Given this pricing system, the following table shows a complete view of the different income strategies and opportunities for each account profile, so that the pricing overview can be understood perfectly:

Client Profile	Device Fee	IoT platform Hostage control	IoT platform managed by customer	Installation	Monitoring
Small accounts (<100)	500€/device	50€/device/year	5000€/year	20€/device	100€/device/year
Medium Accounts (<1000)	400€/device	50€/device/year	5000€/year	20€/device	100€/device/year
Big Accounts (+1000)	300€/device	50€/device/year	5000€/year	0€/device	100€/device/year

Diagram 21. Pricing table

The previous table shows an overview of the pricing model developed. However, it is important to show some real examples to fully understand the possibilities of this model. the next table will show real revenue data examples of each of the customer profiles:

Client Profile	Device Fee	IoT platform Hostage control	IoT platform managed by customer	Installation	Monitoring	TOTAL
Small accounts (100)	50,000€	5,000€/year	NO	2,000€	10,000€	**67,000€**
Medium Accounts (1000)	400,000€	NO	5,000€/year	20,000€	NO	**425,000€**
Big Accounts (2000)	600,000€	NO	5,000€/year	0€	NO	**605,000€**

Diagram 22. Pricing Example

The pricing proposed is an ideal schematic of how to monetize the Connected wheel, but these strategies might be **flexible** as the company grows and adapts to changes in the market. Obviously, at the start, there might not be many big accounts contracts, but these **small**

accounts that refer to small businesses, might grow and therefore, their account will grow as well.

FINANCIAL PLAN

This section will be evaluating the financial **growth** of the Connected Wheel company in terms of both the **Balance sheet** and **the Income statement**. More precisely, it will be a 5-year projection (first year is not counted as a prediction) of the finances of the start-up, so that investors can get a good idea of what the company can become in that period of time if the objectives are achieved.

To start with the Income statement, it is required to set some **growth ratios** throughout the 5-year forecast regarding **Revenue**, **Costs of Goods Sold** (COGS) as a percentage of the raw sales and Operating Expenses also as a percentage of raw sales. The following table shows the percentage values for these variable forecasts:

	2020	2021	2022	2023	2024	2025
Revenue Growth	0%	100%	80%	40%	30%	30%
COGS (% sales)	120%	90%	50%	50%	40%	15%
Total Operating Expenses (% sales)	20%	10%	10%	10%	10%	10%

Diagram 23. Growth forecast

The **revenue growth** will grow quickly the first two years with a 100% and a 80% in 2021 and 2022 respectively and settling more timid growths in the following years as the company gets bigger and achieves a greater market share.

The **Costs of Good sold**, which would stand for **Production and Distribution**, will be higher the first years (120%) and, as the company grows in different aspects (specially Revenue), the processes involving Production and Distribution will be **optimised to increase margins** and therefore, profits.

The **Total Operating Expenses** represent indirect costs such as Rent and Marketing campaigns amongst other. These costs are **constant** throughout the whole 5-year prediction with the exception of a bigger investment the first year as the product will be in the launch phase.

These growth rates have been implemented in a 5-year Income Statement of the Connected Wheel company, showing values of the different incomes and profits after costs. Here is the Income statement 5-year forecast based on the growth and cost percentages explained above:

	2020	2021	2022	2023	2024	2025
Revenue	€ 250.000,00	€ 500.000,00	€ 900.000,00	€ 1.260.000,00	€ 1.638.000,00	€ 2.129.400,00
Cost of Good Sold	€ 105.000,00	€ 200.000,00	€ 297.000,00	€ 378.000,00	€ 327.600,00	€ 319.410,00
Gross Profit	€ 145.000,00	€ 300.000,00	€ 603.000,00	€ 882.000,00	€ 1.310.400,00	€ 1.809.990,00
Operating Expenses						
Marketing expenses	€ 50.000,00	€ 50.000,00	€ 90.000,00	€ 126.000,00	€ 163.800,00	€ 212.940,00
Rent & Distribution	€ 50.000,00	€ 50.000,00	€ 90.000,00	€ 126.000,00	€ 163.800,00	€ 212.940,00
Wages and Salaries	€ 50.000,00	€ 50.000,00	€ 90.000,00	€ 126.000,00	€ 163.800,00	€ 212.940,00
Total Operating Expenses	€ 150.000,00	€ 50.000,00	€ 90.000,00	€ 126.000,00	€ 163.800,00	€ 212.940,00
EBITDA	**-€ 5.000,00**	**€ 250.000,00**	**€ 513.000,00**	**€ 756.000,00**	**€ 1.146.600,00**	**€ 1.597.050,00**
Taxes	€ -	€ 62.500,00	€ 384.750,00	€ 567.000,00	€ 859.950,00	€ 1.197.787,50
NET INCOME	**-€ 5.000,00**	**€ 187.500,00**	**€ 128.250,00**	**€ 189.000,00**	**€ 286.650,00**	**€ 399.262,50**

Diagram 24.Income Statement

As shown, the Income statement shows good numbers when following the growth forecasts mentioned earlier. Starting by obtaining a **negative revenue** the first year is the starting point because of the period of prototype development and business strategy implementations. From there we would be obtaining revenues of just under 2 million euros in 5 years, reaching a **EBITDA** (Earnings Before Interests, Depreciation and Amortization) of **1,6 million euros**, a good result for investors. Moreover, the company would have a negative net income the first year but will be reaching breakeven point very quickly to start receiving net profits of around half a million by the fifth year.

Another Financial requirement for investors to decide whether to invest or not in a company is by looking into the Company´s **balance sheet**. As the Connected Wheel is a new company, a balance sheet has been carried out taking into consideration the **initial capital** required and the different **assets and liabilities** throughout the first year of the company, to set the starting point and resources needed to build a profitable company. Due to the instability of a start-up at its early stages, the realisation of a **balance sheet forecast** would be very **imprecise**, and although it might show the correct assumptions for results, most of the other values would be extremely difficult to predict. The income statement can be forecasted with more security; however, the balance sheet serves as an initial idea of the **accountable resources** that the company will require and the **liabilities** that it might encounter:

ACTIVE		PASIVE	
ASSETS		**LIABILITIES**	
Short Term Assets		**Short Term Liabilites**	
Inventory	- €	Suppliers	€ 100.000,00
Short Term Client	100.000,00 €	Short Term Loan	- €
Cash &Equivalent	€ 280.000,00	Total ST Liabilities	100.000,00 €
Total ST Assets	380.000,00 €		
		Long Term Liabilities	
Long Term Assets		Long Term Loan	€ 50.000,00
Software Patents	1.500,00 €	Total LT Liabilities	€ 50.000,00
PPE	15.000,00 €		
Total LT Assets	16.500,00 €		
		TOTAL LIABILITIES	150.000,00 €
TOTAL ASSETS	**396.500,00 €**		
		EQUITY	
		Common Stock	250.000,00 €
		Retained Earnings	- 3.500,00 €
		Accumulated Income	- €
		TOTAL EQUITY	246.500,00 €
		EQUITY + LIABILITIES	**396.500,00 €**

Diagram 25. Balance table

As we can see, the balance sheet allows to acknowledge all the assets, equities, results and liabilities that the company will face at its birth. These values have been obtained based on opinions of what the initial common stock should be, the credits that are going to be required and the different resources needed (PPEs, Patents…). The most relevant data to study from this is the **first common stock** needed, which would be an initial investment of **250,000€** and the **retained earnings** from the same year, an estimated **negative 3,500€,** a very similar forecast than the one made with the **income statement**.

CONNECTED WHEEL NET PRESENT VALUE

Given the predictions calculated in the previous sections, we can calculate a Net Present Value of what the company is worth if those given targets where to be achieved. This tool is very useful for investors to know an actual quantity of what the company is worth today with the future forecasting.

To complete a NPV there are various methods, like the DCF (Discounted Cash Flow analysis) or the EBITDA valuation method. Given that the company is new and has no years of business and earnings, the DCF evaluation would be much more inaccurate than the other method.

To calculate the NPV using EBITDA (Earnings before Taxes, Depreciation and Amortization) we need the EBITDA values forecasted earlier for each year forecasted. A 5-year forecast is a good time range to calculate the today´s worth of the company. Another value that we need is the discount rate, which symbolizes the return rate of a given investment. It is also an identifier of the risk of a business operation. The discount rates for a start-up stand around 15-20% due to the high risk that the start-up has to achieve its goals. A higher discount rate will mean a higher risk for the start-up to meet its expectations, though the return is higher. Given this, the **discount rate** for this analysis will be of a **18%**.

These are the data that we are going to use to calculate the NPV and the formula that will be applied to calculate it (2020 does not count as a forecast):

	2021	**2021**	**2022**	**2023**	**2024**	**2025**
EBITDA	-200,000€	- €	360,000€	504,000€	819,000€	1,597,050€
Discount Rate	18%	18%	18%	18%	18%	18%

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Figure 30 (Kenton, 2020):

The ***R*** represents the **EBITDA** in this case, ***t*** is the year predicted (2020 is t=1, 2021 is t=2…) and ***i*** is the **discount rate** (0,18). Proceeding with the calculations the NPV value of the company as of 2020 would be: **1,259,163 Euros**. This would mean that an initial investment of 250,000€ is worth **1,26 million euros today** if the results proposed go as expected, with a relatively low return rate, therefore a very slim risk. This result is coherent given the slim initial investment required of 250,000€ and it is a good value so that the investors can see the value of return to the money that they will be investing on.

CONCLUSIONS

This project concludes on a very positive note, having learned the bases of IoT and putting them to practice when developing the Connected Wheel. The Connected wheel first prototype is a fully functional device, which uses IoT technology to be connected to the cloud. However, this section of the report will contain not only the successes and positive aspects of the project, but also the struggles and inconveniences of such prototype.

Starting with the Hardware, the one thing that stands out for its lack of precision is the MQ-3 alcohol sensor. This analogue sensor is extremely inaccurate, and it is a very difficult task to calibrate properly so that the result given for the level of alcohol is in milligrams of alcohol per litre of blood. The sensor takes several minutes to warmup and stabilise, and it stabilises in different levels each time it gets activated. That is one of the main setbacks encounter during this project.

Another setback found along the way is the fact that the Arduino Mega, needed to fit all the ports required for the display, leds and other, is not prepared for IoT projects. And this because it does not include a WIFI module incorporated, so the need of an external WIFI module made the connection to the cloud much harder. The connection to the cloud had to be made via de WIFI module, so the Arduino Mega had to communicate via Serial port with the WIFI module. That communication is extremely unreliable because it does not send the appropriate data and there are usually some *garbage* data sent instead. This hardware election made the IoT incorporation a struggle. But in the end, it works, and the final result is a solid first prototype, not ready to commercialise, but it is a good head start.

The software involved in the project was an easier task due to the easy to implement mqtt protocol. With the use of pre-arranged libraries, the software developed for the prototype was easy to implement. Apart from the serial communication codes, which is clearly the most difficult aspect of the prototype to manage, the rest of was accessible, and ended up being a reliable and efficient prototype. The most unknown technology for me at the starting point of the project was the MQTT communication protocol, and it turned out to be accessible and easy to understand and implement, which was a pleasant surprise.

In terms of the business aspect of the project, it was extremely rewarding getting to know the Carsharing market, its different branches and how the Connected wheel could be successful on that sector.

Moreover, the market research came out a complete success, with a considerable amount of people surveyed and that made it possible to obtain pretty impressive conclusions on how clients of the different target sectors think about the project, being these results extremely positive. And the research also served to acknowledge the gravity of the situation that Spain lives regarding the number of accidents due to alcohol while driving. This market research was a great way to get to know the value of the product in question and the impact that it could create on the streets.

The forecasting made was also an interesting tool for me to understand the risks that a company might have, the assets it need to be able to form itself properly and the possible growth that it can have, especially in its first years in business. In addition, calculations such as the EBITDA and the NPV also came out really useful to understand what investors are focused on when it comes to numbers and returns required. They do not only need to like the idea and the project, but they also need to believe on the forecasts and numbers presented, which seemed reasonably accurate.

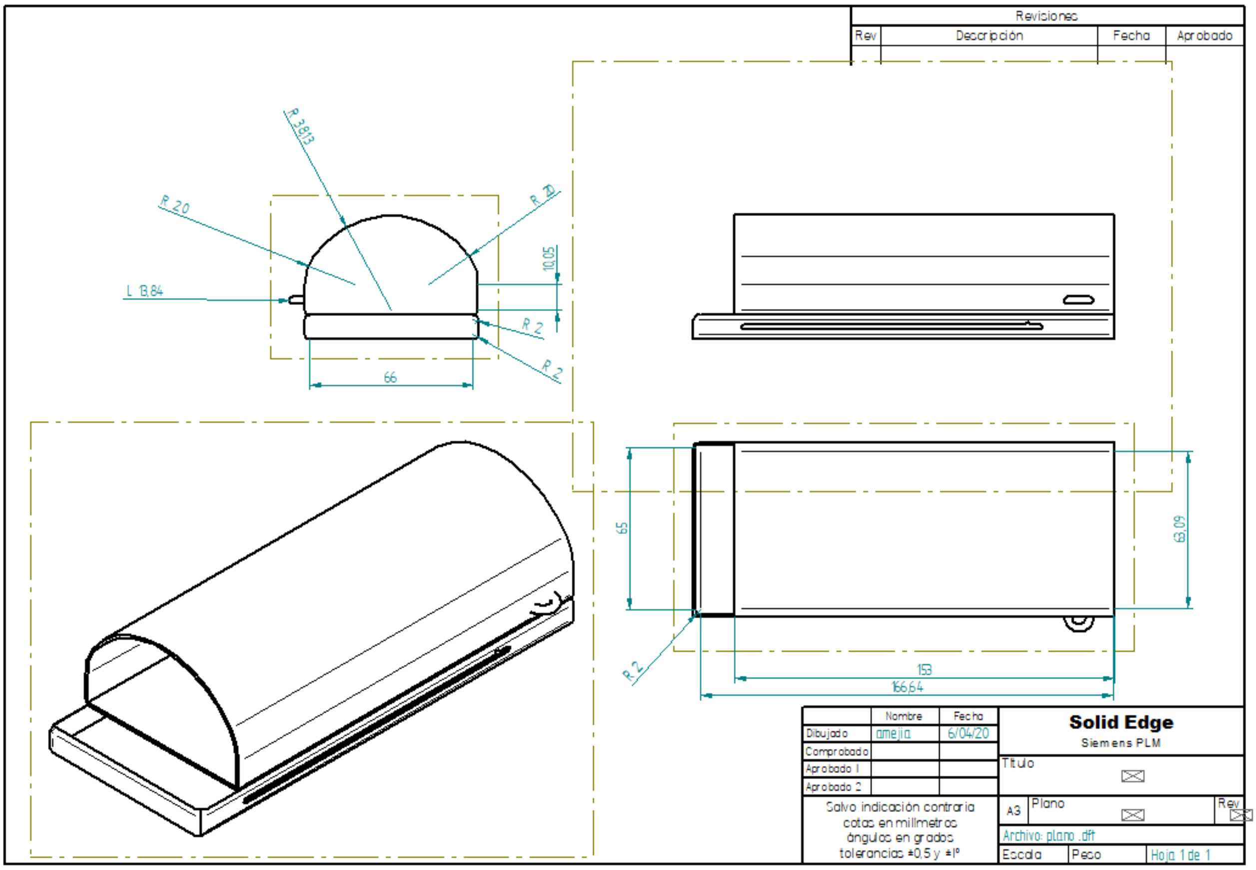
Finally, the project as a whole has made me enter a new technology with a very bright future ahead, IoT, where I have learnt a great deal of things regarding its functions, its assets, its methodologies and its possibilities. But more generally, the project has taught me how to not only focus on one thing but to bear in mind every aspect, both technological and financial, which go together and need to be on the same page in order to create a successful start-up.

ANNEXES

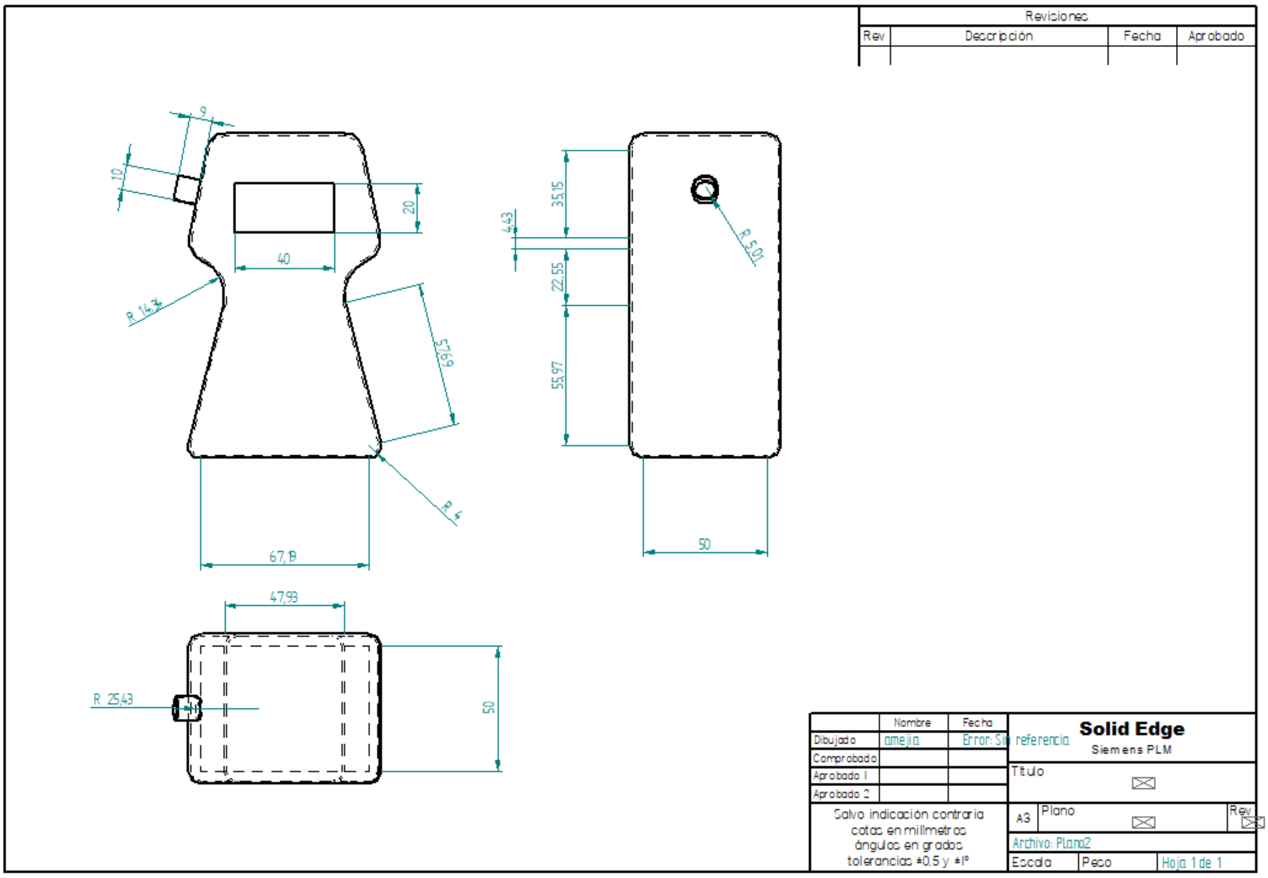
ANNEX 1: DESIGN BLUEPRINTS

This annex shows the drawing plans of the designs for the support and case of the alcoholometer:

1. Support:



2. Case:


Revisiones
Rev
Descripción
Fecha
Aprobado
9
10
20
40
R 14,3
69,25
R 4
67,19
35,15
4,3
22,55
55,97
R 5,01
50
47,93
R 25,43
50
Nombre
Fecha
Dibujado
amejia
Error: Sin referencia
Comprobado
Aprobado 1
Aprobado 2
Solid Edge
Siemens PLM
Título
Salvo indicación contraria
cotas en millmetros
ángulos en grados
tolerancias ±0,5 y ±1°
A3
Plano
Rev
Archivo: Plano2
Escala
Peso
Hoja 1 de 1

Annex 2: List of Materials

This is all the materials used in the construction of the prototype, including where they were obtained from and their corresponding datasheets. There might be some materials bought as a package from one purchase. In that case, the link to shop will be the same, but there will be specific datasheets for each material.

MATERIAL	QUANTITY	BRAND	LINK TO SHOP	DATASHEET
ARDUINO MEGA 2560	1	ELEGOO	Amazon	Link
MQ-3 (alcohol sensor)	1	TT2	Amazon	Link
YF-S201 (Caudal Meter)	1	TIENDATEC	TIENDATEC	Link
USB CABLE	1	ELEGOO	Amazon	-
CABLES (male and female)	35	ELEGOO	Amazon	-
LEDS	2	ELEGOO	Amazon	-
BREADBOARD	1	ELEGOO	Amazon	-
ESP-8266 (WIFI module)	1	AZ DELIVERY	Amazon	Link
ESP-8266 ADAPTER (for breadboard)	1	AZ DELIVERY	Amazon	-
POTENTIOMETER 10K	1	ELEGOO	Amazon	-
RESISTORS (10K,300 ohms)	3	ELEGOO	Amazon	-
BUTTON	1	ELEGOO	Amazon	-
RECHARGEABLE BATTERY	1	ZNTER	HobbyKing	Link
BATTERY TO POWER ADAPTER	1	ELEGOO	Amazon	-

Annex 3: Coding

In this annex you will find the exact coding of the program installed in the Prototype (Protype Construction/Firmware). The first code will be the main code uploaded onto the Arduino Mega, and the following ones are the different functions called from the main. The last code is the one uploaded to the WIFI module to send data through MQTT:

Main:

```
//#include <ESP8266WiFi.h>
#include <EEPROM.h>
#include <LiquidCrystal.h>

const int ledPIN_G = 12;
const int ledPIN_R= 11;
const int DISP= 2;
const int PINTERR_1= 10;
const int D_sensor=24;
const int A_sensor= A0;
int caudalimeter = 3;
LiquidCrystal lcd(52,53,50,51,49,48);
int turnon;
float testresult;
int warmval;
volatile int blow;


int f_interrupt();
void display_1(int y,float x);
float alc_test ();
int warmup();
void CaudalimeterM();
float getQ ();

void setup() {
  // put your setup code here, to run once:

  Serial.begin(9600);    //iniciar puerto serie
  pinMode(ledPIN_G , OUTPUT);
  pinMode(DISP , OUTPUT);
  pinMode(ledPIN_R , OUTPUT);
  pinMode(PINTERR_1 , INPUT);
  pinMode(D_sensor , OUTPUT);
  pinMode(A_sensor , INPUT);
  lcd.begin(16,2);
  pinMode(caudalimeter, INPUT);
  //attachInterrupt(digitalPinToInterrupt (caudalimeter),CaudalimeterM,RISING);

}
void loop() {

    turnon=f_interrupt();
    while(turnon==1){
       digitalWrite(D_sensor, HIGH);
       digitalWrite(ledPIN_R , HIGH);
       display_1(1,0);
       warmval=warmup();//CHARGING ALCOHOLOMETER
       digitalWrite(ledPIN_R , LOW);
       display_1(2,0);
       blow=0;
       while (blow==0){
        blow=getQ();
      //stop measuring because user has started to blow
      }
       testresult=alc_test();
       display_1(3,0);

       if (testresult<=(warmval)){
```

```
        testresult=0,00;
        digitalWrite(ledPIN_G , HIGH);
        display_1(4,testresult);
        delay (3000);
       }else if (testresult>(warmval)){
        testresult=(testresult-warmval)/100;
        digitalWrite(ledPIN_R , HIGH);
        display_1(5,0);
        delay(3000);

       }
      turnon=0;    //turn off automatically when everything is finished
      digitalWrite(ledPIN_G , LOW);
      digitalWrite(ledPIN_R , LOW);
      digitalWrite(D_sensor, LOW);
      delay (500);

   }
 display_1(10,0);
  }
```

F_interrupt:

```
int f_interrupt(){

  int count;
   count=0;
   if (digitalRead(PINTERR_1)==HIGH){
    count=1;

}
return count;
}
```

Display:

```
void display_1(int y,float x){
  if (y==1){
      digitalWrite(DISP , HIGH);
      lcd.setCursor(0,0);
      lcd.print(" Hello,wait for");
      lcd.setCursor(0,1);
      lcd.print("    warm-up");
      }else if (y==2){
      digitalWrite(DISP , HIGH);
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Ready: Now blow");
      lcd.setCursor(0,1);
      lcd.print("strongly for 8 s");
      delay(3000);
  }else if (y==3){
      lcd.clear();
      lcd.print("  Waiting for ");
      lcd.setCursor(0,1);
      lcd.print("    Results ");
      delay(4000);
  }else if (y==4){
      digitalWrite(DISP , HIGH);


       lcd.clear();


      lcd.setCursor(0,0);
```

```
      lcd.print("Test result:");
      lcd.print(testresult);
      lcd.setCursor(0,1);
      lcd.print("  PASS: drive!");
      delay(3000);
      }else if (y==5){
    digitalWrite(DISP , HIGH);
     lcd.setCursor(0,0);
      lcd.print("Test result:");
      lcd.print(testresult);
      lcd.setCursor(0,1);
      lcd.print(" FAIL: try again");
      delay(3000);
  }else if(y==10){
    lcd.clear();
    digitalWrite(DISP , LOW);
  }
}
```

Warmup:

```
int warmup(){
  int i=0;
  int warm=0;
  int warm2=0;
  int avg=0;
  while(i<20){
    Serial.print(analogRead(A_sensor));
    Serial.print("\n");
    warm2=analogRead(A_sensor);
    avg=(warm+warm2)/2;
    warm=warm2;
    if(avg==warm){
      i++;
          }
    delay(1000);
  }
return warm;
 }
```

Alc_test:

```
float alc_test (){
 float result=0;
  int i=0;
  for (i=0;i<16;i++){
    Serial.print(analogRead(A_sensor));
    Serial.print("\n");
    if (result< analogRead(A_sensor)){
      result=analogRead(A_sensor);
    }
    delay(500);
      }
  return result;
}
```

GetQ:

```
float getQ(){
 attachInterrupt(digitalPinToInterrupt(3), CaudalimeterM, RISING);
   interrupts();
   delay(100);
```

```
    return blow;
  }
```

CountQ:

```
void CaudalimeterM (){
   blow++;
}
```

SERIAL:

```
void serial(float y){
  String Testresult;
  int z;

   Testresult=String(testresult);
  Serial.println(Testresult);

  delay(500);
  }
```

MQTT CONNECTION (WIFI module):

The skeleton of this code has been obtained from platformio.org (Lapoint, 2020):

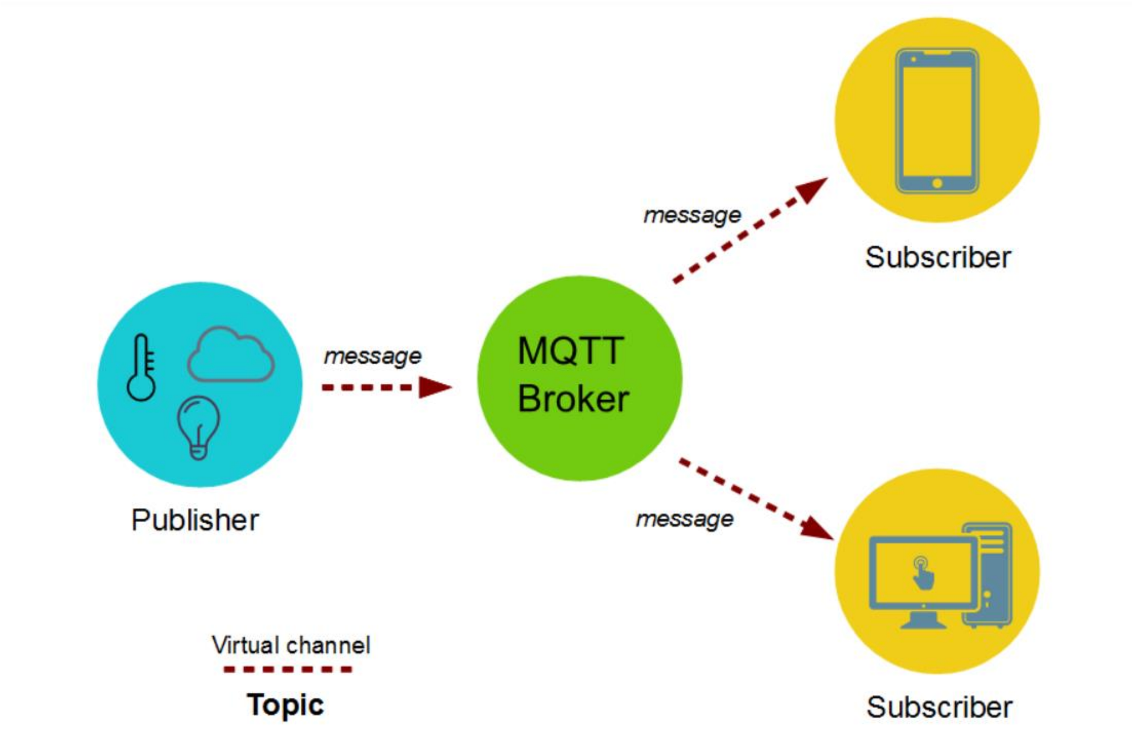
```
#include "EspMQTTClient.h"
String Testresult;
#include <ArduinoJson.h>
EspMQTTClient client(
  "Personal Hotspot",
  "WIFICONNECTION",
  "mqtt.eclipse.org",  // MQTT Broker
  "ConnectedWheel_1",     // Client name that uniquely identify your device
  1883              // The MQTT port, default to 1883.
);

void setup()
{
Serial.begin(9600);
  // Optionnal functionnalities of EspMQTTClient :
  client.enableDebuggingMessages(); // Enable debugging messages sent to serial output
  client.enableHTTPWebUpdater(); // Enable the web updater. User and password default to
values of MQTTUsername and MQTTPassword. These can be overrited with
enableHTTPWebUpdater("user", "password").
  client.enableLastWillMessage("TestClient/lastwill", "I am going offline");  // You can
activate the retain flag by setting the third parameter to true
}

// This function is called once everything is connected (Wifi and MQTT)

void onConnectionEstablished()
{
  // Subscribe to "mytopic" and display received message to Serial
  client.subscribe("Alcoholtest", [](const String & payload) {
    Serial.println(payload);
  });

  // Subscribe to "mytopic" and display received message to Serial
  client.subscribe("Alcoholtest", [](const String & topic, const String & payload) {
    Serial.println(topic + ": " + payload);
  });

  // Publish a message to "mytopic/test"
  client.publish("Alcoholtest", "This is a message");
  delay(500);
```

```
}

void loop()
{
  client.loop();
  String message ;

  int n;

 if (Serial.available() > 0) {
message= Serial.readString();

  client.publish("Alcoholtest", message);


}
}
```

ANNEX 4: MQTT PROTOCOL

MQTT stands for **Message Queuing Telemetry Transport**, and it is the most used communication protocols in IoT projects (Sheeld, 2018). It is based on a publish/subscribe operation exchange data between the different clients of a server. It is the most commonly used protocol due to its **lightweight aspect**, being able to implement it easily in data transmission projects and it is based on a **messaging technique** with **low power usage** and **real time data transfer.**

Like other protocols, MQTT makes the communication possible due to a server and its clients. However, the server is called the broker and it is in charge of receiving data from client which is publishing and sending it where it is supposed to, like to another client which is subscribed.



MQTT methodology explanation (Sheeld, 2018)

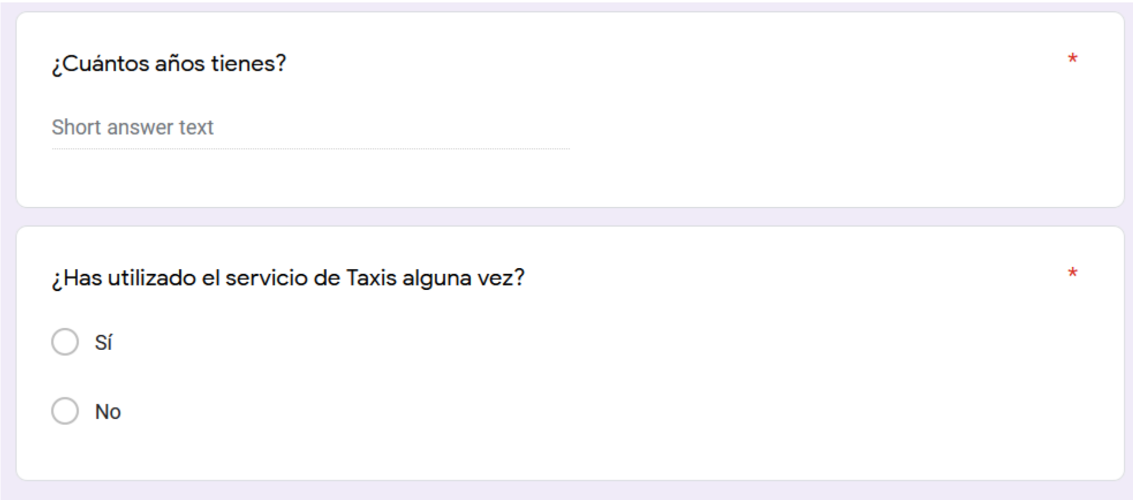
This diagram explains the methodology that this protocol follows, with a **publisher** sending a **message** to a **broker**, and the broker sending it to all the **subscribers**. The broker knows where to deliver the messages because a message is sent through a virtual channel called **Topic**. You can be a client and subscribe to a topic to receive the information sent through that channel or you can publish on that topic to send a message. To enter this communication, you first need to create a **client**, so that you can publish or subscribe to exchange information.

To relate this explanation with the Connected wheel, the server in this case is *mqtt eclipse*, the client is *ConnectedWheel_1* and the topic where the alcohol test result gets sent through is *Alcoholtest*.

This is why MQTT is the most **efficient protocol** of communication along IoT projects **over other** protocols such as **HTTP** because this last one is stateless and carries more overheads per transmission than MQTT. In addition, it has a lower throughput than MQTT meaning that the quantity of messages in a period of time is much lower (Spofford, 2019).

ANNEX 5. Online Survey

This annex shows the different questions of the survey conducted to develop a quantitative analysis on the impacts of the connected wheel on the target markets. Depending on the answer of a user, the survey redirected him to different questions. This is why there are different sections on the survey. The survey has been carried out using Google Forms (Google). Here are all of the questions of the online survey:

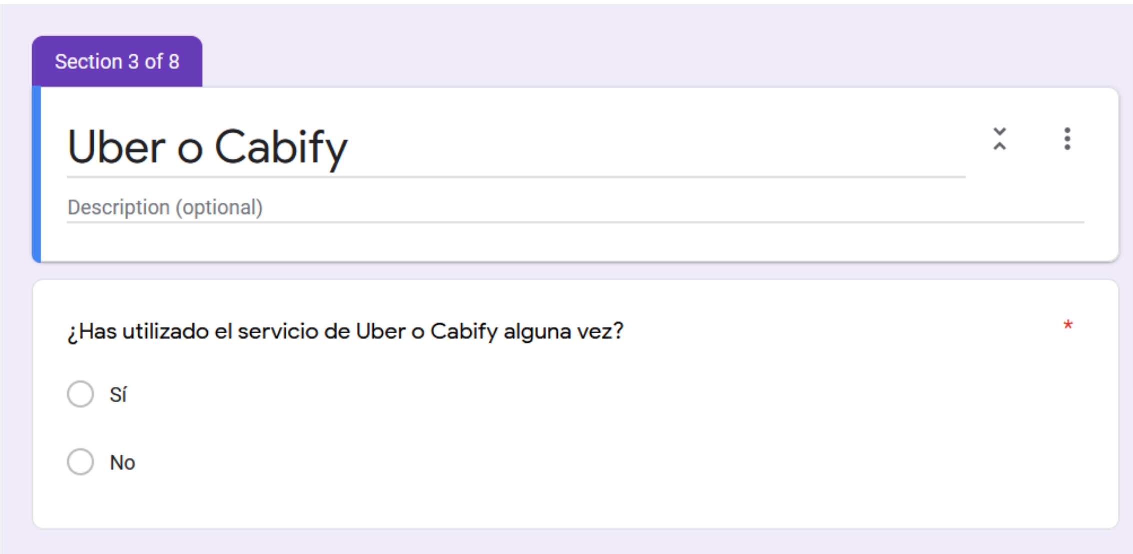


¿Cuántos años tienes? *

Short answer text

¿Has utilizado el servicio de Taxis alguna vez? *

- Sí
- No



Section 3 of 8

Uber o Cabify

Description (optional)

¿Has utilizado el servicio de Uber o Cabify alguna vez? *

- Sí
- No

Section 4 of 8

Zity, Wible, Emov, Car2Go...

Description (optional)

¿Has utilizado el servicio de coche compartido (Zity, Wible,Emov, Car2go...) alguna vez? *

Puede seleccionar más de una.

- ◯ Sí
- ◯ No

¿Alguna vez se ha sentido inseguro en un taxi por sospecha de que el conductor iba bajo los efectos del alcohol? *

- ◯ Sí
- ◯ No

¿Cómo de seguro/a te sentirías si el taxista tuviese que hacer un control de alcoholemia antes de su trayecto? (1: No me afectaría, 2: me sentiría seguro, 3: me sentiría muy seguro) *

1	2	3
◯	◯	◯

A la hora de pedir un taxi, ¿estaría dispuesto a esperar más tiempo por un taxi con verificación de test de alcoholemia (Connected Wheel) que por uno convencional? *

- ◯ Si, en cualquier caso
- ◯ Solo si el tiempo de espera es menor a 15 minutos
- ◯ No, cogería el primer taxi que viese

¿Alguna vez se ha sentido inseguro en un Uber o Cabify por sospecha de que el conductor iba bajo los efectos del alcohol? *

- Sí
- No

¿Cómo de seguro/a te sentirías si el conductor tuviese que hacer un control de alcoholemia antes de su trayecto? (1: No me afectaría, 2: me sentiría seguro, 3: me sentiría muy seguro) *

1 2 3

A la hora de pedir un coche, ¿estaría dispuesto a esperar más tiempo por un taxi con verificación de test de alcoholemia (Connected Wheel) que por uno convencional? *

- Si, en cualquier caso
- Solo si el tiempo de espera es menor a 15 minutos
- No, cogería el primer taxi que viese

Como consumidor de este servicio, cree que la marca que incorpore el Connected Wheel (control de alcoholemia a conductores) se convertiría en una marca preferente frente a las que no lo lleven incorporado? *

- Sí
- No

De manera totalmente sincera y anónima, ¿ha conducido alguna vez bajo los efectos del alcohol? *

- Sí
- No

Si asi es, alguna vez ha sido en alguno de los coches compartidos (Zity, Wible, Emov, Car2go): *

- Sí
- No
- No he cogido nunca ningún vehículo bajo los efectos del alcohol

¿Alguna vez has ido en un coche compartido donde el conductor iba bajo los efectos del acohol? *

- Sí
- No

Si fuese obligatoria la realización de un test de alcoholemia (Connected wheel) antes de utilizar un coche compartido,¿dejaria de utilizar este servicio? (El test no tarda más de 1 minuto en realizarse) *

- Sí
- No

Como consumidor de este servicio, cree que la marca que incorpore el Connected Wheel (control de alcoholemia a conductores) se convertiria en una marca preferente frente a las que no lo lleven incorporado? *

- Sí
- No

ANNEX 6: SUSTAINABLE DEVELOPMENT GOALS

Following **the United Nations Sustainable Development Goals**, the Connected wheel as any other company in the world should follow their values and objectives to enhance a better world for everyone.

The connected wheel could make a great impact on the third of the UN goals, **Health & Wellness**, due to the labour that the alcoholometer could do in terms of **reducing the number of accidents** in the streets due to drunk drivers. This device will add extra security to the citizens as they know that the traffic is alcohol free, therefore the level of wellness of the citizens would rise.

In terms of sustainability, the connected wheel is completely sustainable due to its **low power** consumption, however, it could improve on the **mouthpieces**, by creating some **recycled** or non-contaminating ones to help the environment every one of us live in. this actions would be achieving several UN goals such as **Action for the Environment** and **Sustainable Cities.**

Moreover, the introduction of an alcoholometer in a car could not only prevent the issue of driving and alcohol of today, but it can also serve as **education** for the youth so that they grow in an **alcohol-free environment**.

These are some of the measures that the Connected wheel will focus on in order to work together with the rest of the World, and if everyone adds their little help, we can achieve the goals for a better World.

***UN** SUSTAINABLE DEVELOPMENT GOALS (HZ)*

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