Final Degree Project

Degree in Industrial Engineering Technologies

Functional and formal component design for an electric motorbike "Sound Module"

REPORT

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Summary

Nowadays, new technologies allow creating new advances in the society through the innovation or improvement of existent products.

This project intends to design a sound module that will be incorporated in an electric motorbike. As every motorbike has a different inside structure, the study will be carried out considering that the module's volume may be adapted depending on the motorbike.

The electric motorbike market is still in its development stage, and the studied topic in the project seems to be currently in research by many automotive enterprises, as the noise limit rulemakings in the city are a burning issue that has been already accomplished by 4-wheel vehicles.

The design and study aims to contribute in the decrease of accidents due to the lack of noise of this type of vehicles. This will be accomplished with a selection of elements that combined, will allow the citizens to discern the presence of the electric vehicle and act in consequence.

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1. Glossary

Alerting sound: An external sound emitted from a quiet vehicle whose aim is to warn about the presence of a moving vehicle nearby

Decibel (dB): The logarithmic scale, defined as ten times the logarithm of the ratio of a physical quantity to a standard reference value, used to express sound pressure measurements.

Electric vehicle (EV): Vehicle powered by battery system

External Sound Generation System: Audio system with external speakers, which provides warning, sounds, to the external environment of the vehicle in addition to the noise generated by the vehicle itself. Also called Audible vehicle system (AV-System or A VS)

Hertz (Hz): One cycle per second. It is the unit of measurement associated to frequency.

Hybrid electric vehicle (HEV): Type of electric vehicle that not only incorporates a battery and electric motor system, but also an internal combustion engine (ICE).

Hybrid vehicle (HV): Vehicle with an internal combustion engine and one of several possible alternate sources of propulsion, such as hydraulics or electric battery.

Impedance: The measure of the opposition that a circuit presents to a current when a voltage is applied

Loudspeaker: Electro-acoustic transducer used for the reproduction of a sound

Measuring Range: Maximum current (I_{PMAX}) or voltage (U_{PMAX}) that the sensor can measure with the Hall effect. It is given for specific operating conditions

Microcontroller: Control device, which incorporates a microprocessor

Miniaturization: Process of making something very small using modern technology

Motor vehicle: Vehicle powered by an internal combustion engine as its sole means of propulsion

Noise: Unwanted sound

NPRM: A notice of proposed rulemaking, is a public notice issued by law when one of the independent agencies of the United States Government wishes to add, remove, or change a rule or regulation as part of the rulemaking process

Organisation for Economic Cooperation and Development (OECD or OCDE): Intergovernmental economic organisation with 35 member countries, founded in 1961 to stimulate economic progress and world trade

Pitch Shifting: Sound recording technique in which the original pitch of a sound is raised or lowered

Plug-in hybrid electric vehicle (PHEV): Hybrid electric vehicle whose battery can be recharged by plugging it in to an external source of electric power as well by its on-board engine and generator

Sensor: Input device, being part of a bigger system, which provides input to a main control system, such as a processor or a microcontroller

Sound: Small, fast pressure variation in a fluid medium. In the case of tire/pavement noise, the medium is air

2. List of acronyms and abbreviations

AVAS: Acoustic Vehicle Alerting System

BRICS: The acronym for an association of five major emerging national economies: Brazil, Russia, India, China and South Africa.

dB: decibel

dB(A): decibel, A-weighted

EPA: U.S. Environmental Protection Agency

ERP: Enterprise resource planning

ESG: External Sound Generation

EV: Electric Vehicle

FMVSS: Federal Motor Vehicle Safety Standard

GHG: Greenhouse Gas

$GtCO_2e$: Equivalent CO_2 Giga tone.

GVWR: Gross vehicle weight rating

HEV: Hybrid Electric Vehicles

Hz: Hertz

ICE: Internal Combustion Engine

ISO: International Organization for Standardization

Km/h: Kilometres per hour

LASER: Light Amplification by Stimulated Emission of Radiation

L_{dn}: Day-Night Sound Level

L_{eq}: sound energy averaged over a 24-hour period

LIDAR: Light Imaging Detection And Ranging

LSV: Low speed vehicles

LTVS: Light trucks and vans

mph: miles per hour

NHTSA: National Highway Traffic Safety Administration

NPRM: Notice of Proposed Rulemaking

OECD or OCDE: Organisation for Economic Cooperation and Development.

PHEV: Plug-in hybrid electric vehicle.

PIR: Passive Infrared Sensor. Also known as "Pyroelectric" or "IR motion"

PSEA: Pedestrian Safety Enhancement Act

UNECE: United Nations Economic Commission for Europe

QRTV: Quiet Road Transport Vehicles

RADAR: Radio detection and ranging

3. Introduction

3.1 Motivation

On the last years the innovation of the electric motorbikes has rapidly evolved. Nevertheless, the still low implementation of this solution on the urban and interurban transport allows a tackle of solutions, which improve, or complement the ones achieved until now.

From the beginning, the automotive industry focused their attention at the drop of the combustion emissions, complemented by a more restrictive with time regulation, which have come to a decrease on the atmosphere of the particles release and the creation of cars becoming increasingly quieter.

Despite, ¿what happens with electric motorbikes? It is a recently new invention on the market with an imminent growth.

The meaning of the words *electric vehicle* is a motor vehicle with an electric motor as its sole mean of propulsion. One of the great advantages of the electric transport media is at the same time one of its greatest disadvantages: **the noise absence.**

Several studies predict a huge increase in electric motorcycles sales by 2025, also forecasting an approximately 1.5 million sales of this transport in the next half-decade.[1] Many widely known companies such as Yamaha, Kymko and Harley Davinson are currently investing on this field regarding the imminent growth on the electric segment. Moreover, the number of EV[2] Startups have notably risen for the last years and many signs trend to intensify it for the next year.

These are some of the reasons why it seemed very interesting to study this topic and think of something that could be useful for its development, knowing that in a recent future it will be deeply investigated and implemented.

[1] Study carried out by STATISTA. Link: https://www.statista.com/statistics/445004/worldwide-sales-of-electricity-powered-two-wheelers/

[2] EV: Electric Vehicles

3.2 Scope

With regard to combustion automobiles and the increasingly developed warning technologies, the human are every time more helped during the driving, avoiding possible collisions.

On the past years, a lot of debates have been followed in relation to electric vehicles. Some of them have been focused on the pedestrian and cyclist safety, while others on traffic noise reduction, as it contributes on the noise pollution as well as in people's health.

The automotive company Nissan was the first one introducing artificial sounds on its electric cars in 2011 with the presentation of the Nissan Leaf[3]. Since then, many electric warning sound systems have been developed in the electric cars world, based on the reproduction of a sound file similar to a combustion car, through speakers built into the vehicle.

The impacts of electric vehicles' market not only involve the transport sector but also they affect the electricity sector and environment. The batteries development, the creation of new charging infrastructures for Smart charging as well as the incorporation of new advanced modules into these vehicles are some of the aims of most automobile enterprises.

On the other hand, regarding CO_2 emissions, many municipalities and companies in Europe have already adopted planning strategies to improve their environmental conditions. These not only deal with air pollution problems, but also with a reduction of noise annoyance and improvement of the quality of life. [4]

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[3] Development of Nissan Approaching Vehicle Sound for Pedestrians. Link: http://www.autoguide.com/auto-news/2010/06/nissan-introduces-approaching-vehicle-sound-for-pedestrians-system-for-new-leaf-ev.html / https://www-esv.nhtsa.dot.Gov/Proceedings/22/files/22ESV-000097.pdf

[4] See ANNEX A

4. Goals

4.1 Target

The aim of this project is to design a sound module for an electric motorbike, which is intended to decrease the amount of accidents due to the lack of noise on this vehicle. It is a problem that not only involves the driver but the pedestrian.

On the one hand, the driver feels misinformation during the driving and they can easily fall asleep. On the other hand, in an increasingly distracted by technologies society, also it is presented as a security risk, as the electric or hybrid vehicles are more difficult to recognize and therefore the accident because of them are rising.

It will be selected, according to the market criteria, the most added or differential value achievement and will be developed following the industrial design project criteria.

Adapted to the existent conditions and aptitudes in our society, it will be designed with the intention of incorporation to any electric motorcycle, though some varieties may appear depending on the different models.

The main proposal is to improve the weak points of this transport media and contribute on its development and evolution motivation.

4.2 Limitations

This chapter of the project intends to describe some of the limitations that have been found while doing the research. The future confronts hybrid and electric vehicles as the only driving alternative, apart from the increasing autonomous driving. However, these low-emission vehicles are considered too quiet for the society[5]. It may seem a positive thing, as health and quality of life may be relatively affected by traffic noise, but it can also be dangerous, as the vehicle gives no audible warning to pedestrians.

Several studies have examined and compared electric and hybrid vehicle's accident data vs internal combustion engine vehicles, it has been found that the first ones are more likely to be

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[5] See ANNEX B

involved in collisions with pedestrians. In consequence during the previous years many regulations have appeared and are also yet to come.[6]

By consequence, the European Union highlighted that this type of vehicle should be equipped with acoustic vehicle alerting systems. This has come with a remarkable increase of noise on the roads across Europe.

First and foremost, it has to be said that currently nothing can be found in relation to the minimum sound requirements that would allow pedestrians to recognize an electric motorcycle. The CEPE/ONU nº41.04[7] rulemaking related to motorcycles homologation noise is not applicable to electric motorcycles.

Vehicle's noise or sound emissions are usually considered harmful to people and the environment. By consequence, many UN Regulations (Nos. 9, 41, 51, 63, 92, 117) set strict sound limits for vehicles of different categories, especially equipped with an internal combustion engine.

The NHTSA has recognized that it is early to apply minimum sonority standards for two-wheeled vehicles:

"Although the agency proposed in the NPRM[1] to include motorcycles in the final rule, we have decided not to apply the requirements of this final rule to electric motorcycles. As is the case with heavy hybrid and electric vehicles, we currently do not have enough information to determine whether the light vehicle acoustic requirements or the crossover speed in this final rule are appropriate for electric motorcycles."

Further research is planned on sound emitted by electric motorcycles to conclude acoustic requirements for these vehicles and on whether electric motorcycles require distinct specifications separate from four-wheeled vehicles.

Also the UN Regulation No. 138[8] on QRTV[9] makes only reference to electrified vehicles of M

[6] See ANNEX C

[7] See CEPE/ONU nº41.04. Link: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A42012X1114%2801%29

[8] See UN Regulation No. 138. Link: https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2017/R138r1e.pdf

and N categories, not applying to electric motorcycles. Its aim is to minimize the risk of the high number of cars' accidents. According to it, quiet cars should be equipped with an AVAS[10] to create artificial noise in the speed range from 0 to 20 km/h, given that above this speed the vehicle is audible.

In the Article 8 and Annex VIII of EU Regulation No 540/2014[11] the M- and N-category[12] vehicles AVAS requirements can be found, as well as its Delegated Regulation (EU) 2017/1576 [13].

Regarding the maximum sound level limits of combustion L-Category vehicles, they are in accordance with the requirements of EU No 168/2013 Regulation[14] and its corrigendum.[15] These are lower but similar to the M- and N-Category vehicles maximum sound level limits that can be found in the paragraph 6.2.2 of EU Regulation No 51.[16]

Therefore, here comes one of the important limits and assumptions of the project. Since no AVAS regulations for 2-wheel vehicles exist, the minimum and maximum values for these have been based in M- and N-category AVAS values.

On the other hand, among all the ISO standard specifications referring to electric motorcycles[17], it has to be mentioned that there is no noise level regulation regarding ISO standards as it is established by the correspondent municipal ordinances or acoustic applicable legislation.

All over the EU there are financial and non-financial policies, which aim promoting the EV

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[9] QRTV: Quiet Road Transport Vehicles

[10] AVAS: Acoustic Vehicle Alerting System

[11] Regulation No 540/2014. Link: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0540&from=EN

[12] Category M refers to 4-wheel vehicles carrying passengers. Category N refers to vehicles carrying Goods. Category L makes reference to 2- and 3-wheel vehicles and quadricycles.

[13] Delegated Regulation (EU) 2017/1576
Link: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1576&from=EN

[14] EU Regulation No 168/2013. Link: https://eur-lex.europa.eu/legal.content/EN/TXT/PDF/?uri=CELEX:32013R0168&from=EN

[15] EU Regulation No 168/2013 Corrigendum. Link: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0168R(04)&from=EN

[16] Link: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:42007X0530(02)

[17] See ANNEX D

market uptake, as well as R&D[18], and charging point developments.

A great progress has been made in meeting certain policy objectives, including efficiency and short-term greenhouse gas as well as noise reduction targets. But most of these policies are very recent, so it is likely to see some changes in especially the national and regional policies as they are constantly adapting to market developments.

Regarding acoustic vehicle alerting systems for not only 2- but also 4-wheel vehicles, is proposed for future research but not designed, that the sound is emitted just when necessary and in different manners, so that it would not be that harmful and acoustic pollution would notably decrease. For example, this could be achieved regarding the deserted and very populated zones in the city. The sound that may be reproduced in a zone where there are not so many citizens would not be of the same type or level as other zones with a lot of background noise and passer-by.

In addition, is suggested the incorporation of a speed measurement in the motorbike, so that the alert could vary on volume level depending on the driving speed. As is not coherent to emit the same sound level driving at a very low speed than at a higher speed.

Furthermore, the module could also be programed to emit different sound volume levels within different distances, from the motorbike and the individual. Someone staying at a 30 m distance would need a higher sound than someone who is at a 15 m distance.

In reference to the measurement range of the sensor, some studies have been considered related to motorbikes stopping distances. The project can be created in two directions. The first would be to create an alerting system, which is supposed to alert not only the pedestrian but also the driver (possible existence of two speakers). The driver has a time of reaction which influences in the stopping distance. Considering the total stopping distance with a certain margin to prevent the ran over, the measurement range would be very large arriving to distances approximately of 50 or 60 m; depending on different factors.

Regarding this huge distances, no sensors will detect a person in a reliable way as the best combination of optical sensing and processing is found in humans and animals and they are not able to do it.

[18] R&D: Research and Development. It refers to the work a business conducts toward the innovation, introduction and improvement of its products and procedures

The other direction would be to create a module that whose target is to alert the pedestrian who is located in certain distance, and he or she is the one who has to be attentive to the sound alert and avoid the accident, as the sound is directly going through them.

The LIDAR [19] systems, presented in more detail in the chapter 6.2 Alternative considered but still not analysed in detail, can reach very long distances with exactitude and are commonly used in automotive companies. Though for the project we are looking for something simple and cheap to install, and these can have very high prices in some solutions, the option is considered giving priority to the reliability offered by these sensors.

Last but not least, it has to be mentioned that from the beginning the project was been thought to have some future variations. Depending on the motorbike's model implementation the module may vary on its sizes, being adapted inside the electric motorbike. This is why no plans of the module have been made and a representation in volumes is given. Also the costs have been estimated considering that they may increase or decrease depending on the module's implementation and adjustments to the motorbike's model. It is not possible to foresee with exactitude how many hours will be necessary to create a module like this and make all the testing to ensure its reliability and utility.

[19] LIDAR: Light Imaging Detection And Ranging. Link: https://en.wikipedia.org/wiki/Lidar

5. Conflict to solve

Despite the desire of avoiding the acoustic pollution, is presented as necessary the existence of a signal or sound that one can easily perceive to avoid certain catastrophes. It would be interesting to create a sudden beep able to distract the driver and cause the following swerve or drift.

In the United States of America will be enforced in September 1st of 2019 a law where all four wheel vehicles, both hybrid and electric, weighing less than 4.5 tons must emit sounds that warn of their presence when circulating under 30 km/h. [20]

The NHTSA[21], the U.S. federal agency responsible for the road safety, filed as mandatory this law in order to prevent an estimation of 2400 pedestrian accidents per year. It has been the first official who has thought of establishing a regulation related to the necessary minimum sound emissions for electric vehicles.

The transportation secretary from NHTSA Anthony Foxx said in a statement:

" We all depend on our senses to alert us to possible danger. With more, quieter hybrid and electrical cars on the road, the ability for all pedestrians to hear as well as see the cars becomes an important factor of reducing the risk of possible crashes and improving safety".

Electric and hybrid cars have a 10% more chance to run over a pedestrian and it has been estimated that it could be reduced up to 50% the possibility of being on an accident.[22]

Given this recently established regulation it seems evident that similar measures in other continents like Europe will be imminent in the next few years.

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[20] Source extracted from the article written by Andrew J.Hawkins on November 2016. Link: https://www.theverge.com/2016/11/16/13651106/electric-car-noise-nhtsa-rule-blind-pedestrian-safety

[21] NHTSA: National Highway Traffic Safety Administration

Although there are in the automotive market car models that emit certain sounds at low speeds, this issue is yet to come in the world of electric motorbikes. These are an effective mean of transport and very efficient by the amount of space they consume.

Two wheel vehicles are very different from cars in terms of layout and architecture. As there is less space in a motorcycle to install a speaker, some commenters have mentioned that the addition of an alert system to a motorcycle would be a technical challenge to integrate such a significant amount of hardware, and its weight would have a greater impact on the vehicle's range.

Cars have years of advantage in terms of electric mobility and sooner or later the requirements that these must follow will be applied to motorcycles, imposing a compulsory noise.

Although it may seem paradoxical as once the noise is eliminated after enough debates, new regulations has been implemented in order to reactivate it. Security is a necessary and sufficient condition, as this change will be accompanied by a reduction in pedestrian crashes.

6. Sound module options

Collisions with pedestrians and animals have nowadays an important role, and they are even more notable with electric/hybrid vehicles. Consequently multiple technologies, cameras, sensors, among others, have been developed for automobile safety. The motorbikes are left behind, as they are vehicles that have subsequently reached the market.

Living in an age of constantly evolving technology, in this project a study of the different options in the market related to the sound module implementation is carried out, as well as a comparative study of these. Finally being able to show a unique economical and efficient solution.

6.1 Development of alternatives

The following shows three basic directions of the creation of this project.

Firstly, it is presented bellow the option implemented in most cars to emit a continuous sound up to a speed limit. This speed is fixed taking into account the average speed while driving. The sound, which simulates the sound of a combustion car, will be always emitted according to the decibels allowed for the circulation in the city.

It is the automatic activation of an easily distinguishable sound by the driver and pedestrian, for the frontal and reverse displacement. A study from the Western Michigan University[23] carried out in 2008, suggested that hybrids and conventional vehicles are safe when travelling at higher speeds than approximately 30 km/h. At speeds up to this, known as cross-over speeds, factors such as the wind resistance or the tire noise would already be useful to alert, being not mandatory to make a sound at these situations. [24] Regarding motorbikes this speed should be well confirmed after research, as may differ from cars.

[23] Link: https://en.wikipedia.org/wiki/Electric_vehicle_warning_sounds#cite_note-UCRNews-13

[24] See Federal Register / Vol. 83, No. 38 / Monday, February 26, 2018 / Rules and Regulations. Background-Paragraph A. Notice of Proposed Rulemaking (page 4). Link: https://www.gpo.Gov/fdsys/pkg/FR-2018-02-26/pdf/2018-03721.pdf

It seems more appropriate to implement a system that does not constantly emit sound. It is intended to reduce the noise in the city to the maximum in order to create less acoustic pollution. Why to emit a sound if in a street there is no obstacle or pedestrian?

Regarding this issue is proposed the alternative of creating a button on which the driver could active or deactivate the sound. Nevertheless, the PSEA[25] mandates that the alert sound's activation should not depend on the driver and many people have mentioned their disappointment knowing that the driver could be permitted to turn off the sound, as it allows the drivers to deactivate this important safety feature and thereby endanger pedestrians, especially those who are blind. [26]

On the other hand it is suggested to implement a system where the sounds will work linked to specific situations, such as proximity of a zebra crossing, presence of a traffic light, proximity of a Hospital, etc. The sound would be activated by *geo-location*, a system included by a lot of transports and even modern technology apps linked to these.

It consists of the use of GPS and an inertial navigation system; a navigation aid system that uses accelerometers and rotational sensors to continuously calculate an estimation of the position, orientation and speed of the car's movement in a precise way.
Also when entering a high population density zone, it could have an automatic activation. The connectivity is based on the received geo and traffic information.

However, for the implementation of this idea very detailed maps or sensors, with an algorithm to detect the zebra steps among other spaces would be necessary, Google Maps could be a useful tool. This one reports all the intersections, however not of all the zebra crossings. Over time these are removed or added; consequently keeping the maps updated becomes a very expensive and laborious task.

In addition, the active evolution of automotive technology aims to deliver even greater safety benefits. A great number of today's new motor and electric vehicles have already implemented

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[25] PSEA: Pedestrian Safety Enhancement Act. Link: https://www.congress.Gov/111/plaws/publ373/PLAW-111publ373.pdf

[26] See Federal Register / Vol. 83, No. 38 / Monday, February 26, 2018 / Rules and Regulations. III. Petitions for Reconsideration Received by NHTSA – Paragraph D. Alteration of the OEM Alert Sound (page 5). Link: https://www.gpo.Gov/fdsys/pkg/FR-2018-02-26/pdf/2018-03721.pdf

technology that helps drivers avoid drifting into adjacent lanes or making unsafe lane changes among other things as well as being alerted about its surroundings.

These and other safety technologies use a combination of hardware and software to help vehicles identify certain safety risks so they can warn the driver to act to avoid a crash, showing and giving the driver a lot of information related to its surrounding. When it comes to the hardware, infinite sensors with the help of cameras can be found.

The most lately remarkable sensor packages could be the following: *Car Night Vision System*[27], and the newly appeared *Conti-Guard System*[28]. They are implemented in most of today's cars.

Car night vision is formed by a sensor that can reliably detect, and alert the driver of the presence of pedestrians, cyclists and figures beyond the scope of the car's own lights. Night vision systems use infrared sensor usually located on the grid, to search for hot objects on the road. The sensor is a video camera that captures the infrared spectrum just above the visible light. Finally sending the moving image to the inside vehicle screen.

This technology uses the best algorithms systems, on which infrared points detect the presence of an individual or movement on the road. Consequently the driver is alerted as well as the pedestrian or animal.

Their main advantage and difference with the already existent sensor systems is that the driver does not need to be consequently paying attention to the road approach manual change.

Though their cost has notably decreased in the past few years, an integrated night vision system for less tan 3000 has not been found. Its price is supposed to be lower in the recent future. Furthermore as they are very voluminous and because of their heavy weight, its use for a motorbike would be none.

The system of object recognition *Conti-Guard* aims to avoid mainly pedestrian or cyclist accidents. It is similar to the aforementioned night pedestrian recognition system.

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[27] Link: https://www.extremetech.com/extreme/193402-what-is-night-vision-how-does-it-work-and-do-i-really-need-it-in-my-next-car

[28] Link: https://www.continental-automotive.com/getattachment/6f44e687-dc28-436f-9800-4a362497bc45/divisionbrochure_en.pdf

It is for the moment an experimental system, which consists of two high-resolution cameras and it is placed in the upper part of the windshield, allowing having a stereographic vision to the microprocessor of the system.

The system is able to distinguish between pedestrians, cyclists, cars and other objects, not just measuring the distance to the person and predicting their trajectory but also verifying if this is crossed with the one from the car. It determines therefore if there is a risk of an accident, in order to take the preventive measures to avoid or reducing the consequences. The driver is warned and the vehicle's brakes could even be automatically actuated.

Many other technologies, which are unknown for the citizens, are already being studied and introduced to similar studies like this one. Autonomous driving stands for a new direction in mobility, with the creation of several systems that can work by themselves, detecting approaching figures and reacting in different situations. Google could be a Good example, to show how new advances pursue to recognize, track and avoid human beings. Its vehicles have sensors and software designed to detect pedestrians, cyclists, vehicles and a lot more, using technologies such as LIDAR, RADAR and complementary cameras, to ensure this kind of identifications within very long distances.

6.2 Alternative considered but still not analysed in detail

It is finally exposed the option of creating a kit that could be introduced in all electric motorbikes with its own specific characteristics. It would be an ESG[29] system, composed of a sensor, allowing the analysis of the obstacle, connected to a miniaturized acoustic box, whose rightly projected sound would have the capability of reproducing a sound alert assuming a certain distance, enough to avoid the accident.

There are many possibilities for the implementation of the system. For the project three blocks are mainly distinguished. By doing this block’s division, anytime it comes the need to make a change or modify any component, just a small modification would be done trying always to maintain the block’s interface in the same way.

[29] ESG: External Sound Generation

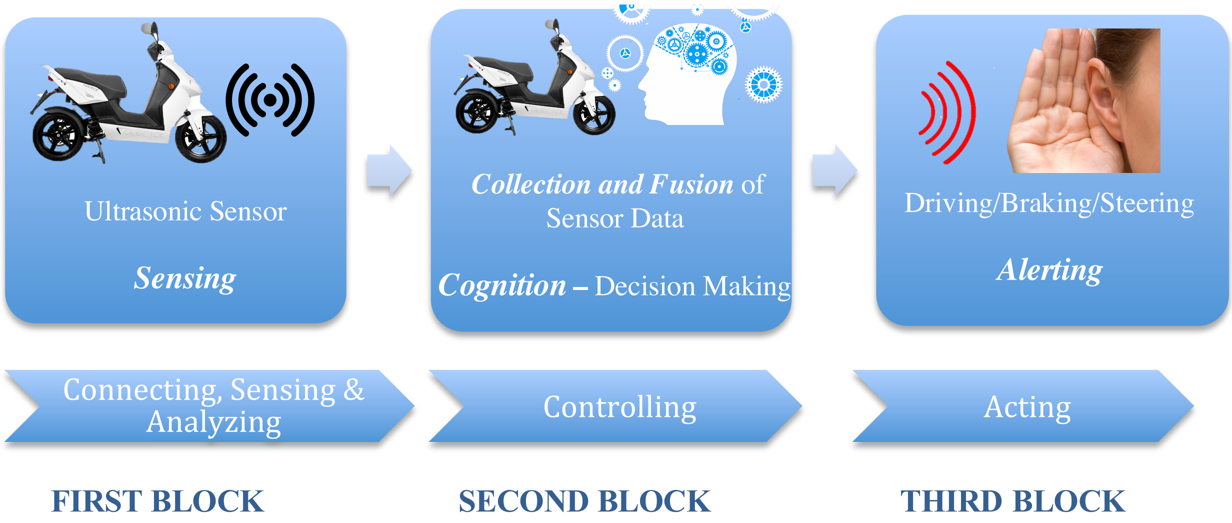

Figure 1: Basic characteristics of the three block structure [30]

Sensor Block

To detect pedestrians (and objects in general) automated vehicles use the following sensors: cameras, RADAR, and LIDAR.

The general **LASER**[31] sensors are in charge of scanning the environment. In this case its main objective is to calculate the distance from the car to the nearby objects. The information collected is usually combined with the obtained by integrated cameras in the vehicle. With this information a three-dimensional model of the environment is created. When opting for laser sensors is important to take into account that some of these may cause damage to the eyes of by-passers.

The **LIDAR**[32] are RADAR that emit radio waves, which bounce off the objects. It basically

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[30] Original figure from RENESAS Advanced Driver Assistance System (ADAS), adapted and personalized by the author

[31] LASER: Light Amplification by Stimulated Emission of Radiation

[32] Link: https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff

consists of a beam-emitting focus of infrared laser beams[33], which are not seen; as well as an infrared receiving lens capable of seeing those laser beams. In the intended conditions of use, they are not dangerous for the eyes.
These sensors are able to scan the vehicle's surrounding in all directions, as well as determine the position of the objects that are up to long distances, such as 120 meters, with a lot of accuracy to generate a precise three-dimensional map.

In this way the LIDAR processor obtains a cloud of points from the environment. The computer processes a 3D image in real time with it, which is permanently updated and in which objects are moved. The most important thing about this points cloud is that for each point its precise position in the space can be known as well as the distance to it.

It is possible to foresee the situations that will occur, for example the movement of other vehicles or pedestrians whose trajectory will cross the vehicle's one or to determine if there is danger of impact.

As an advantage it can rapidly obtain and deliver an amount of information as well as entering into vegetation or the road surface. Nevertheless its costs are normally very high and their size is pretty big.

As for **PIR** [34] these are intelligent sensors that allow to sense motion. It is almost always used to detect whether a human has moved in or out of the sensors range. Their main advantages are that they are small, inexpensive, low power, easy to use and they don't wear out. For that reason they are commonly found in appliances and gadgets used in homes or businesses.

In reference to infrared array sensors, it is interesting to mention the Panasonic Grid-Eye sensor, which is based on a matrix detector. It acts as a low-resolution thermal chamber; therefore it is ideal for detecting the presence of a mobile or stationary body. It is in charge of evaluating, by means of a main system based on a microprocessor, the thermal image. With this sensor the human silhouette or a traffic light could be detected.

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[33] See explanation of *Radar Beams emission* in the link: https://en.wikipedia.org/wiki/Radar#Beam_path_and_range

[34] PIR: passive infrared sensor. Link: https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor?view=all

Another good option would be to use simple **RADAR**[35]. It is currently one of the most popular technologies for obstacle detection in vehicles, corresponding to the relative positioning sensor. They are capable of detecting small movements, distinguishing between objects that are approaching and moving away, some functions that the aforementioned sensors could not achieve. RADAR sensor's principle of operation is very similar to the PIR. It is based on movement, but they have the disadvantage of not being able to detect motionless objects. Consequently if a pedestrian would stay still in a pedestrian crossing, it would not detect it.

It would be an interesting but more expensive idea, to complement the RADAR with a camera. By doing this not only distances and speeds between objects would be detected with these, but also object shapes would be clearly recognized with the cameras.

Control Block

A MP3-player, a mobile phone, a microwave, a washing machine, the ABS[36] brake system or a GPS positioning system among others; are all electronic devices that have something in common: they use a microcontroller as the central process unit.

The microcontroller has a very important role in every electronic design of integrated designs. They would receive the signal from the sensor and act on a sound or light output that would alert the pedestrian.

It is an integrated circuit, which includes the basic blocks to form an embedded system or a smaller scale PC. In other words, the microcontroller is a chip inside which we find a CPU, memory, clock, communication ports and outlying modules of I/O.

[35] RADAR: Radio detection and ranging. Link: https://en.wikipedia.org/wiki/Radar

[36] ABS: Anti-Lock Braking System

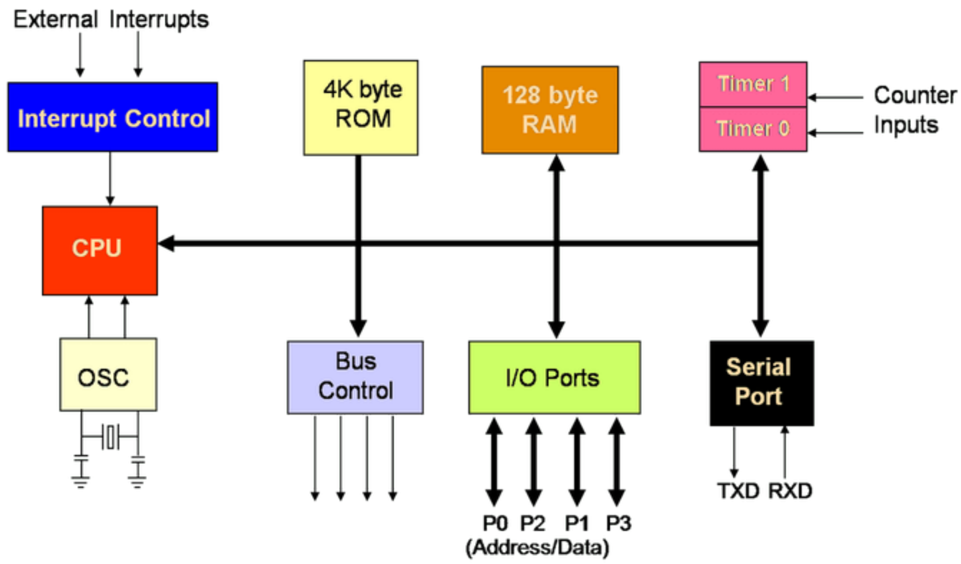

Figure 2: Block diagram of a microcontroller [37]

Each of these intern blocs performs a specific function providing a better control of the system. The CPU is a small and lower power microprocessor that monitors and controls all operations that are performed in the microcontroller. Its function is to read program written in the memory, which stores the program that has to be run, and do the executed task. Looking at the intended application design, the MCU/CPU will be very useful to run the actual person detection algorithms.

A microcontroller has several development characteristics as the language programming, the IDE[38] to write programs, how the internal memory is programmed or the external hardware needed to make this recording. It is these characteristics that make the difference at the time of the correct choice of a type of microcontroller.

The PIC and the AVR are microcontrollers, with very similar characteristics from the point of view of general structure. However new designers and even nowadays learning centres, during the last past years prefer AVR use.

[37]Link: http://editsworld.com/8051-microcontroller-architecture-block-diagram/#Block_Diagram_of_8051_Microcontroller

[38] IDE: Integrated Development Environment. Software application that provides comprehensive facilities to computer programmers for software development

The main differences reside in the integration of the system, in elements like the programming language, IDE, interfaces for the programming, internal clock, power voltage, power or its cost.

Both families have peripherals such as digital ports, ADC or PWM.

The PIC is a family PIC is a family of 8-bit microcontrollers manufactured by the American company MICROCHIP. For storage DL Firmware have a RISC CPU and FLASH memory.

Whereas the AVR is a family of microcontrollers manufactured by the Norwegian company ATMEL. They also consist of 8 bits, a RISC CPU, and their program memory is also implemented in FLASH.

Output block

Electric vehicle alert sounds are designed to alert pedestrians of the presence of electric drive vehicles such as hybrid electric vehicles, HEVs[39], PHEVs[40], and all EVs travelling at low speeds.

In some cases is the driver who triggers these, as is the case of having a horn; but they should be automatic according to the law. Varying from being an artificial beep or a light sign, to reproducing engine sounds or imitating tires moving over gravel.

The output block would be responsible for warning the pedestrian of the presence of the motorcycle through a loudspeaker or a high-powered buzzer. It could also be implemented the action with a luminaire or any other type of device.

For the loudspeaker warning, it is crucial to create a detection-based trigger and send the signal to the loud speaker.

[39] HEVs: Hybrid Electric Vehicles

[40] PHEV: Plug-in hybrid electric vehicle

7. Best solution technical description

The sound module system would be a ready to use kit, which pretends to incorporate the necessary interface and tools, including a sustainable and environmental awareness. It is a simplification of automotive software. It is based on a sensor, a microcontroller and a loudspeaker, which are customized for high performance and low power consumption.

In order to do a good design it is always important to identify the main and most important criteria of each component of the project. Different criteria are found regarding each part of the block's division.

It will be important too, to pay attention to the durability issues regarding the parts and their positioning on the motorbike.

7.1 Sensor Block

Figure 3: Basic transducer structure[41]

When detecting approaching vehicles, the first crucial task in the recognition process is to gather the available surrounding information. It depends on the person's capability, experience and learned competence to react when any vehicle is coming to them.

By using a sensor system, will be possible to locate the direction of the signal source, its small space and low power will be profitable, and mainly the data can be collected at on location, not requiring network communication nor maintenance.

[41] Original figure from Nikhil Kanakamedala, Instrumentation undergraduate at MIT of India, adapted and personalized by the author. Link: https://www.quora.com/What-is-the-difference-between-a-transducer-and-a-sensor

In order to determine the right sensor for an application, there are some specifications[42] that should be considered, but regarding the measurement uncertainty the following three are the most important characteristics to bear in mind[43]:

- Accuracy - How close the reading is to the true distance.
- Resolution - The smallest reading or change in readings that can be reported.
- Precision - The smallest reading that can be taken repeatedly and reliably.

The information is provided at the output, either as digital or analog signals, depending on the sensor type:

- Displacement Sensors
- Proximity Sensors
- Motion Sensors

For this project a displacement sensor is needed in order to detect the pedestrian/figure at a specific distance. They are collectively known as displacement sensors, analogical output sensors, linear sensors or distance sensors. These devices allow determining, while having the simplicity of the sensor integration, more than the presence or absence of an object.

In addition, they are based in different technologies, providing a digital or analog in tension or current output signal, proportional to the distance between the sensor and the object of interest.

Considering this, initially three main types distance sensors were differed and regarded as a good choice:

- Inductive: Based on impedance changes due to the influence of an exterior object measured by a signal of continuous current or alternating current.
- Optical: Encoders, laser, IR, etc.

[42] Link: http://www.electronicdesign.com/components/consider-all-factors-when-selecting-proper-inductive-proximity-sensor

[43] Link: https://meettechniek.info/measurement/accuracy.html

- Ultrasonic: They measure the time between the emission from an ultrasonic impulse and the received eco.

Inductive sensors are widely used to measure position, speed, displacement, vibration, and other process variables, especially in harsh environments. Nevertheless they have such a complex signal conditioning increases the space, cost and power consumption.

As for optical sensors, materials and colours affect their detection. In addition, they have a lower detecting range compared to ultrasonic sensors, 1000 mm vs. 10 m, as well as measuring range. Though having a high accuracy and a fast response speed, they are susceptible to interference from environmental effects, and they can be expensive.

When it comes the time to choose a type of sensor, it totally depends on its application. Infrared (IR) sensors are used to detect presence through the heat of the body; therefore they could be an interesting option. However, the inability to use them in sunlight due to interference or outdoors; makes it difficult to pick them. If reliability is an important factor, ultrasonic sensors are more reliable than IR sensors.

After this short study, an ultrasonic sensor was firstly chosen. They are reliable, providing information on an absolute position of a target or moving object. They can be used in dark environments and are not affected by colour or transparency of objects and they are economical.

Nonetheless, for the project these types of sensor are useless, not only because they do not have an enough reliable measuring range, but also because of the movement they will be exposed to. It happens the same regarding PIR sensors. Though some 50 or 70 m ultrasonic sensors can be rarely found, the most commonly used ultrasonic sensors have sensing capability up to 4 metres, as up to this distance (approximation) they become unstable and unable to accomplish their function. [44] Also it should be said that these can be a useful tool to detect an object, but is difficult to detect a person, as a person would be rightly detected up to 2 or 3 m, considering that the sensor is not moving.

[44] According to sensor enterprises' email replies mentioning that they just had effective maximum measurement range from ultrasonic sensors around 4, 5 and 6 m; and the following corroborating links: https://www.quora.com/What-is-the-maximum-range-of-an-ultrasonic-sensor / https://www.sensorsmag.com/components/choosing-ultrasonic-sensor-for-proximity-or-distance-measurement-part-1-acoustic

The ideal sensor for the project would be LASER, RADAR or LIDAR as they are able to detect objects in their line of sight. These are the ones currently used in automotive companies.

Many well-known companies such as Tesla and Google use laser detectors to let their automobiles see other vehicles, pedestrians, and obstacles on the road when driving.

After contacting various sensor enterprises and having different advice, the suggested tool to be used for the project was the LIDAR. They may be not that affordable like many other detection system alternatives, however their efficiency is enough to justify their use.

Both RADAR and LIDAR have similar working principles using different wave sources. While LIDAR have specific lasers and optics for receiving and transmission, the RADAR emit radio signals by using an antenna. [45]

When the detection distance has more importance than the appearance of the road figure, the RADAR is more convenient.

While driving is important to recognize whether an element is a pedestrian, a car, or a light post; this recognition will allow the system to whether reproduce or not the sound in the road. A device with a light-based working basis, like the LIDAR is a good option to achieve this aim.

As LIDAR are very used in the obstacle detection field, they were considered as a good option. After contacting several enterprises some sensors of this type with relatively affordable prices where found. Regarding that the measurement is a short/medium range, this would decrease the price.

It is thought that future autonomous cars will rely on laser scanner information to get information from surrounding obstacles.[46]

When regarding laser sensors is important to see the type of class they belong to. These are classified for safety purposes depending on their potential for causing human injuries. For the project only Class I lasers are taken into consideration. This type of laser is eye-safe under all

[45] Comparative study between LIDAR and RADAR. Link: http://www.archer-soft.com/en/blog/lidar-vs-radar-comparison-which-system-better-automotive

[46] Link: https://www.ncbi.nlm.nih.Gov/pmc/articles/PMC5335929/

operating conditions.[47]

Once the type of sensor is chosen some criteria regarding its functionality has to be taken into consideration.

Regarding the purpose of the sensor passive and active sensors can be differed. The LIDAR are active sensors. This type of sensors need a 'source of excitation' provided by an external circuit to be activated, whereas for the passive these are not necessary.

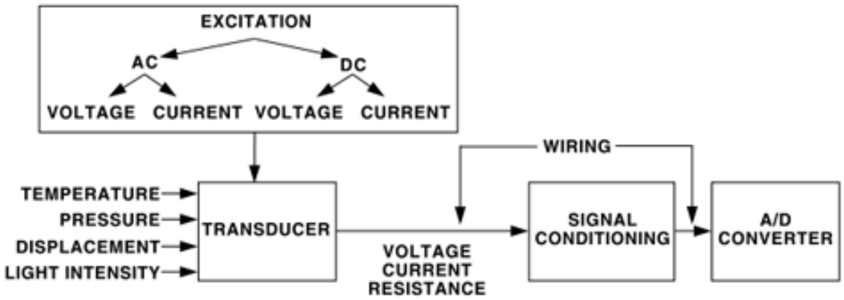

Figure 4: Typical transducer-based data acquisition system[48]

Regarding the output, AC (Alternating Current) or DC (Direct Current) sources can be used to make the excitation possible. The majority of electronic devices are operated with DC power supply. Direct current, unlike alternating current, is easier to harness, providing a regular and consistent voltage.

Earlier in motorcycles the brakes or the lights among other things used to be engine dependant, but now it is all set up straight from the battery. This justifies the need of developing as time goes by stronger battery models. Normally the battery of the motorbike, which is used for supply, provides DC. DC represents the electrical energy coming to any electronic part of the motorbike. It is all connected directly to the battery, as it is the main source of power, allowing a constant and steady flow of electricity.

[47] Link: http://www.lasersafetyfacts.com/laserclasses.html

[48] Link: http://www.analog.com/en/analog-dialogue/articles/transducer-sensor-excitation-and-measurement-techniques.html

Active sensors can be excited using a controlled current or voltage depending on the designer's choice. In a noisy industrial environment, it is always more advisable the current excitation, as it is more immune to interference.

For the project a voltage excitation is chosen. DC voltage is an analog signal that gives excellent resolution. It does not need a lot of energy and is very easy to connect. Therefore a low power operation will provide very short to long-range detection and ranging in a compacted form.

To avoid compatibility issues with the battery of the motorcycle, it is crucial to find a voltage that matches our system. Usually, 12V is the operating voltage electronic devices.

The sensor frequency has to be fast enough in order to avoid objects getting too close before detection.

The temperature range is also a very important aspect to take into account. Regarding that it will work in an environment with not extreme temperatures, its operational temperature should stay within a range from 0º to 50º degrees Celsius.

Last but not least, the maximum and minimum distance values that can be measured by a sensor are called the measurement range, also known as the dynamic range or span. It is always advisable to work on the optimum range instead of one of both extreme values in order to avoid any accident.

Sensing systems are designed to perform over a specified range, which is usually specified on its technical sheet. The measuring range would be directly related with the output, obtaining a more or less accurate reading and optimum lifetime. All signals out of this range may be unintelligible and cause irreversible damage to the sensor.

To know exactly the minimum distance on which the sound should be emitted to prevent an accident, it is necessary to make a study of the needed distance to stop the motorbike. It is important to note that the most important factor to bear in mind is not the braking distance, but as already said, the stopping distance, which is formed by two components: Braking distance + Reaction distance.

The braking distance refers to the distance a vehicle will travel from the point when the breaks are totally applied to the complete stop of the vehicle. It depends on different aspects for example the brake efficiency, the tire type/condition, the load, the driver's braking skills or the motorcycle type or structure among others. Nevertheless, it is mainly affected by two factors: the original speed of the vehicle and the drag, which is the amount of friction between the tires and the road surface.

Braking distances may also vary with speed and the road condition (gravel, lumpy, dry, wet or asphalt cover). According to Spain city circulation regulations, the maximum allowed speed is about 50 km per hour (30 mph).[49] As there are many types of motorbikes and all have different break down distances, an average should be calculated.

The other component is the reaction distance, which is the distance the vehicle travels during the reaction time. It depends on the reaction time (seconds) and speed (m per second).

Reaction Distance = Reaction Time x Speed

The reaction time is the time it takes you to react to a hazard and it involves the following steps:

Detection → Hazard recognition → Decision making → Reaction

The following table shows a study of distances and times that have been estimated mathematically, carried out by LIIKENNETURVA, the Finnish Road Safety Council. The distances have been rounded up to the nearest meter. One-second reaction time has been used as basis for calculation while calculating distances and times.

		ROAD SURFACE		
URBAN AREA SPEED		**DRY**	**WET**	**OPTIMAL**
40 Km/h	Reaction Distance	11 m	11 m	11 m
	Braking Distance	9 m	18 m	6 m

[49] The maximum allowed speed in town might vary depending on the country. See ANNEX E

	Stopping Distance	**20 m**	**29 m**	**17 m**
50 Km/h	Reaction Distance	14 m	14 m	14
	Braking Distance	14 m	28 m	10
	Stopping Distance	**28 m**	**41 m**	**24 m**
60 Km/h	Reaction Distance	17 m	17 m	17 m
	Braking Distance	20 m	40 m	14 m
	Stopping Distance	**37 m**	**56 m**	**31 m**

Figure 5: Motorcycle stopping Distances in different conditions[50]

In the previous study the average retardation factor has been set at 7 m/s² for dry road surface and 3.5 m/s² for wet road surface. As for the optimal condition, the best achievable situation, an average retardation factor of 10 m/s² has been set.

It has also been considered the following study carried out by the UK Department of Transport in 2007, which verifies the stopping distances presented above:

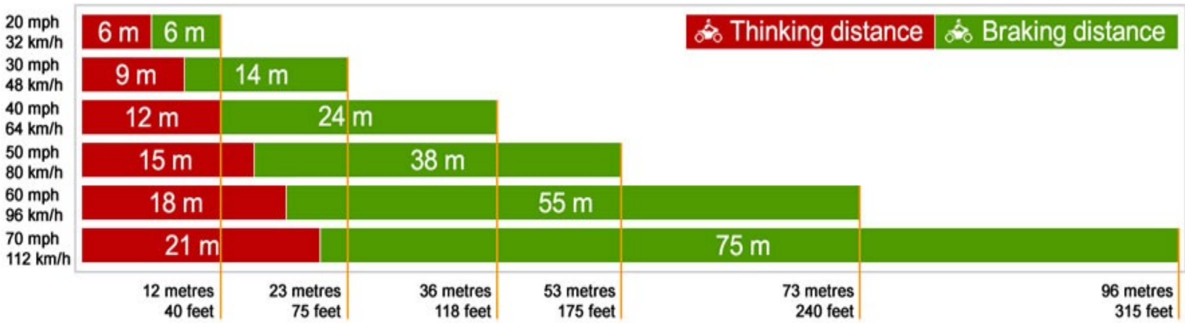

Figure 6: Motorcycle stopping Distances[51]

[50] Link: http://extrat.liikenneturva.fi/pysahtymismatka-moottoripyora/en/

[51] Link: https://www.Gov.uk/Government/publications/the-highway-code-typical-stopping-distances

These distances may have fluctuations depending on the type/model of the vehicle, road and environment conditions and some other factors.

Regarding the high measure range, a long-range distance sensor is needed. It is important to take the more restrictive measure, consequently the maximum allowed speed in the city will be chosen. When referring to the road surface, the wet condition is considered with a retardation factor of 3.5 m/s^2 as mentioned before. Considering the described results and taking into account that is important to leave after the stop of the vehicle a minimum distance between the motorcycle and the object, an approximation, that may be studied in deep detail is done with the following calculus:

$$\text{Warning sensor distance} - \text{Stopping distance} = \text{Final margin}$$

Considering a speed limit of 50 km/h[52] with the most unfavourable stopping distance of 41 m, and a final margin of approximately 2 meters, the alerting sensor measurement range would be around 50 m. This would be the maximum distance referring to a situation where the pedestrian has not moved when the sound was reproduced. For the project a maximum measurement distance of 20 m is chosen, considering that this one, though it should be studied in more detail, would be enough to emit a sound leading to the obstacle's reaction and consequent movement after hearing the sound.

7.2 Control Block

Most electronic devices have a microcontroller inside. Microcontrollers are optimized for control of the input and output of a device. They require less power than other processors and they are easier to connect with the physical world through input circuits (sensors) and output circuits (actuators).

The sensor of the project has to be connected to a control board and this one should be as simple as possible, as we are not working with a complex design. Its very important its compatibility regarding other parts in order to have a correct functionality.

When talking about compatibility it is referred to the following aspects:

[52] Speed limit within Spain towns. See ANNEX E

- ✓ Same voltage operation
- ✓ Having the correct interface
- ✓ Being programmable with the used tools and the existing codes

Consequently the power supply is supposed to be standardized to 12V. It is assumed that no compatibility issues will appear, as it is a pretty simple system.

The clock frequency has not a lot of importance, for the measurement frequency is greatly lower, causing most of the latencies in the system.

The Arduino Nano, Raspberry Pi, Teensy 3.5 could be some control board examples of use.

7.3 Output Block

When it comes to the sound that has to be emitted in order to allow the pedestrian or animal to discern the vehicle presence, is necessary to know and study the more suitable type of sign.

On the one hand is proposed after regarding some comments from René Weinandy, the head of Noise Abatement in Transport for the German Environment Agency; that non-acoustic sign is emitted, otherwise a light would be necessary to alert the obstacle in front of the electric motorbike.

René Weinandy was impressed to know that the European Union had drafted regulations to equip electric vehicles with speakers that continuously emit a sound at low-speeds

"Our goal is to scientifically assess acoustic vehicle alerting systems, as well as to develop a non acoustic alternative".[53]

On the other side, emitting a sound would be the common thing to study. Always having an opened mind among alternatives that have not been considered in a public way until today, like Weinandy referred as: "*Less harmful alternatives haven't been systematically sought or explored. Clearly, there must be better alternatives.*"

The vehicle-emitted sound is referred with the term **alert sound.**

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[53]Source from a public release in December 5th 2017, WASHINGTON, D.C. Link: https://www.eurekalert.org/pub_releases/2017-12/asoa-hha112917.php

Firstly, it is crucial to pay attention to four main parameters, which will help knowing if a computer is Going to have a Good sound, even without having heard it previously.

1. The output power
2. The frequency range
3. Its sound system
4. The impedance

The output power makes reference to the loudspeaker Watts's emission. It would be totally related to the sound pressure in decibels, in other words, the volume.

It is crucial that the emitted sound is heard by the passer-by without having other interferences. The sound level is measured in decibels (dB). A small increase on decibels represents a great increase of sound energy. Technically, an increase of 3 dB represents a double on the sound energy, and an increase of 10 dB represents an increase of ten times.

The human hearing perceives 10 dB as the double of noise or sonority, and it is difficult for it to distinguish sounds less than 3 dB. The sound level of a normal conversation is around 60 dB. [54]

The U.S. EPA[55] determined that the maximum sound level that will protect against hearing damage would be a sound average of 70 dB over a 24h day.

The following table shows EPA's sound levels for an alone human hearing:

EFFECT	LEVEL	AREA
Hearing Loss	L_{eq}[56] ≤ 70 dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use

[54] See more at the link: http://www.sengpielaudio.com/calculator-levelchange.htm

[55] EPA: Environmental Protection Agency

[56] L_{eq} represents the sound energy averaged over a 24-hour period. L_{dn} represents the L_{eq} with a 10 dB penalty for sounds occurring between 10 pm and 7 am.

ETSEIB

	$L_{eq} \leq 55$ dB	Outdoor areas where people spend limited amounts of time e.g. playgrounds
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{eq} \leq 45$ dB	Other indoor areas with human activities e.g. schools

Figure 7: Information on Levels of Environmental Noise Requisites to Protect Public Health and Welfare with an adequate Margin of Safety[57]

In addition to this, some regulations related to the equipment of electric vehicles with acoustic vehicle alerting systems are already being introduced into laws both in the U.S. and Europe. When it comes to L-category vehicles, no acoustic vehicle alerting system AVAS requirements exist. This is why the study of the minimum and maximum dB, is based on the following regulations, which apply to electrified vehicles of categories M and N which can be driven without an internal combustion engine operating referring to their audibility.

Noise level should not exceed certain values to protect public health and welfare. Despite regulations may vary between countries or local laws, according to the European Union's directive UNECE R138, the implementation of an AVAS in a four-wheel vehicle should not emit a total sound level of more than 75 dB in the forward driving direction, which is presented in the paragraph 6.2.7 of the Regulation No. 138 last updated on November 2017.

When referring to their minimum sound limits of 4-wheel electric vehicles are shown in the following figure:

[57]Source: EPA/ONAC 550/9-74-004- SUMMARY, March 1974 Link: https://nepis.epa.Gov/Exe/ZyNET.exe/20012HG5.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1976+Thru+1980&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C76thru80%5CTxt%5C00000008%5C20012HG5.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

Frequency in Hz		*Constant Speed Test paragraph 3.3.2. (10 km/h)*	*Constant Speed Test paragraph 3.3.2. (20 km/h)*	*Reversing Test paragraph 3.3.3.*
Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*
Overall		50	56	47
1/3rd Octave Bands	160	45	50	
	200	44	49	
	250	43	48	
	315	44	49	
	400	45	50	
	500	45	50	
	630	46	51	
	800	46	51	
	1,000	46	51	
	1,250	46	51	
	1,600	44	49	
	2,000	42	47	
	2,500	39	44	
	3,150	36	41	
	4,000	34	39	
	5,000	31	36	

Figure 8: Minimum Sound Level Requirements in dB (A)[58]

In conclusion, is important to find a light-weight sound speaker, of a small size, but at the same time this one should reproduce between 15 and 20 Watts in order to achieve a high enough volume, as it has to be heart in exterior places. Regarding the minimum and maximum sound requirements for hybrid and electric vehicles, it would be required to establish a minimum sound of 30 arriving to a limit of 75 dB. These would be the maximum and minimum number of dB that we are looking for the speaker range, but they will be regulated according to the future law. It is important to find a loudspeaker with a minimum and maximum dB range higher than these values, so that it can be rightly adjusted.

[58] Source: Paragraph 6.2.8. of the Regulation No. 138. Link:
http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2017/R138r1e.pdf
An extended and last updated version can be found here: https://www.law.cornell.edu/cfr/text/49/571.141

Regarding the frequency range, the audible spectral or the human perceptible sounds are from 20 Hz to 20.000 Hz. The bigger the frequency range is, the clearer sound will be heart. A sound below 20 Hz, known as infrasound, or above 20 kHz known as ultrasound (further than the sound), is out of the audible human range. There is considerable variation in the hearing range between individuals depending on their hearing ability.[59]

The main components of an alerting sound should be in the hearing sensitive range. The ear's sensitivity varies significantly depending on the frequency. [60]

The sound generated should be loud enough to get people's attention. However, always taking into consideration that it should not create annoyance to the passer-by nor being so low that aged pedestrians would miss them. It is a well-known fact that as people get older, they lose higher frequencies.

The masking effect of background noise should also have to be taken into consideration. The background noise, usually from traffic, creates a masking of the sound from a nearby vehicle. In the suburb and urban environment the masking from the traffic is in general higher. The masking effect cannot be predicted and it is frequency dependant and in general is less in frequency ranges where the background noise levels are low.

All the noises are generally composed of pressure variations of different frequencies too. It is important to bear these in mind.

As for the sound system, every system is based on a determinate number of channels. Each of these is the one in charge of the sound reproduction.

A projected sound is crucial, so that it can be heart by the driver and by the external person. Speakers with an amplifier or high power speakers, which can be used without an amplifier, are needed.

As for the impedance, the lower it is, the better sound would be emitted.

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[59] Link: http://www.simonheather.co.uk/pages/articles/science_hearing.pdf

[60] See ANNEX F

It is important too, to pay attention to the structure of the loudspeaker that will be used and its compatibility with the microcontroller.

Among all the speakers in the market, it would be advisable to use full-range loudspeaker. These emit a wide range of frequencies audible by the human ear, within the limits imposed by the physical characteristics of the design itself.

This type of loudspeaker is used in all kinds of applications; they are widely used and can be found in many sound systems, like public address systems (PA systems), televisions, radios, intercoms (an electrical device allowing one-way or two-way communication), computer speakers as well as high fidelity hi-Fi systems.

The main advantage offered by full-range loudspeakers is the high sound coherence and the lack of interference, as well as their good response at not only low but high frequencies. Their use is highly recommended to avoid unwanted interactions in multiple speaker systems caused by non-matching speaker location or crossover problems.

The limited frequency range and sometimes having to incorporate big and expensive acoustic boxes are some of their principal disadvantages. However as a highly power is not needed in this project, the size and economical drawback will not be a problem.

A speaker or a screen is usually formed by one or more loudspeakers located in a normally wood enclosure, though it can be manufactured from various materials. In our case it is important to find a resistant material enclosure, which improves the quality sound.

Regarding the material of the loudspeaker, it can be differed mainly to types ferrite and neodymium.

Conventional loudspeakers are built with iron ferrite magnets that provide good performance, but are heavier and more voluminous than neodymium loudspeakers. Depending on its function is recommended one type of material or other. Regarding the comparative study shown in ANNEX G.

Neodymium is the ideal material for limited and small spaces as well as for lightweight products, in other words, for miniaturization.

One of the first proposals regarding sound speakers was the use of a Bluetooth, a wireless speaker.

It can be thought that the connection might be easily lost, but by the time technologies are developing better systems. All modern cars have Bluetooth to connect mobile phones, and generally they do not lose their connection. It may depend on the quality of the speaker so it is worth choosing a Good Bluetooth speaker.

When using Bluetooth there would be no compatibility problems between different phones[61], as new iPhones and new pixels no longer have 3.5 mm plug. They also use different types of cable between them (Lightning vs USB C vs Micro-USB).

In order to avoid the lost of some sounds, it is important to find a wireless speaker capable of emitting a great range of the audible spectral in order to finally have a clearer sound.

Some electric scooters are geo-located and connected by 3G, Bluetooth and GPS. In consequence it would be interesting to consider a Bluetooth speaker model, having a USB output or Micro-USB to load it easily by connecting it to your computer or to the network and to be able to be less than 3.5 hours later. No interference appears and it is an easy, solid and safe tool to use.

Another advantage could be not requiring a clear line of sight between the synchronized devices. When it comes to the electrical system there would be no compatibility complications in the connection, as no wiring or lines are required.

Regarding its costs, they would totally decrease, as the speaker price is much cheaper than the elaboration and maintenance of an electrical system.

The use of a Bluetooth speaker requires little energy and long-range batteries with short recharge times can be found. Some models incorporate batteries that allow up to 10/18 hours of music playback with a single load. It has to be mentioned that our device will not be playing music all the time; therefore its autonomy will be greater.

On the other hand, like many other devices, some disadvantages can be found. Sometimes the transfer rate can be slow (up to 1 Mbps[62]) compared to other wireless systems (up to 4 Mbps). Although technologies have notably been developed and new and better Bluetooth devices have

[61] Link: https://sennheiserusa.happyfox.com/kb/article/85-what-effects-bluetooth-compatibility-and-connectivity-with-a-standard-device-ie-cell-phone/

[62] Mbps: Megabit per second

appeared, the connection can be sometimes easily lost, letting other technologies being safer.

Finally, it should be said that a remarkable drawback having this type of multimedia devices is presenting the need to be constantly aware of recharging their battery. To avoid this situation, great reproduction autonomy is needed.

Wire connections are more reliable and practical in some way. The other option would be to use a small and compacted device, also known as Tweeter. These small loudspeakers are specifically built to reproduce high frequencies, from 2000 Hz to 20000 Hz.

Type of tone

Noise is an overlooked environmental issue. Vehicles, railways and airports operating within or near cities contribute in the noise pollution increase, which can cause negative health and economic impacts. If an alert sound is emitted is important to be attentive on the tone that should be emitted, and different alternatives could be considered.

While doing the study of the project, the two following questions are presented: ¿Does a pedestrian just need to know about the danger he/she is in? ¿Or the important is to know about the vehicle's presence and its current operating condition?

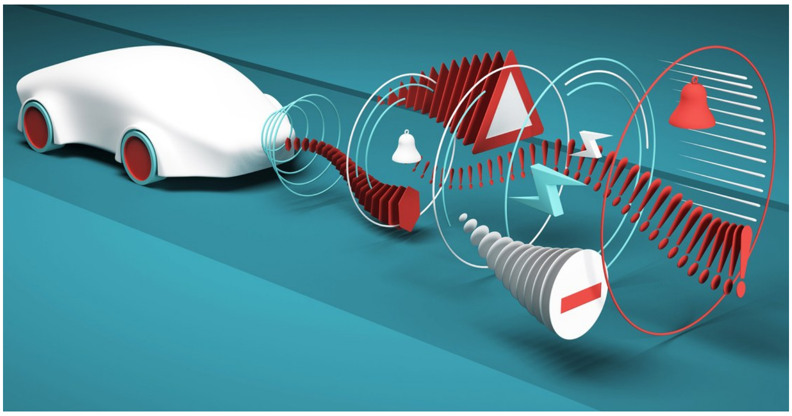

Figure 9: Representation of an EV emitting diverse acoustic signs[63]

Consequently, it is thought and proposed to create a sound module, which vary its sound frequency depending on the driving speed. By doing this this not only the pedestrian is allowed

[63] Source from an article published in 2017 by Elisabeth Stinson. Link: https://www.wired.com/2017/04/evs-dangerously-quiet-heres-sound-like/

to know about the possibility of danger, but also has information about the speed, position, distance or the direction of moving of the quiet vehicle.

In relation to the aforementioned and consequent to the PSEA, the NHTSA published the NPRM [64] the 14th of January 2013 to create a new FMVSS[65] setting minimum sound level requirements for low-speed operation of hybrid and electric light vehicles.[66] Minimum sound requirements for hybrid and electric vehicles are specified in the document.

The agency originally proposed to require pitch shifting, meaning that as HV/EVs increased or decreased in speed, from stationary up to the cut-off of 30 km/h. Therefore, the frequency of the sound produced by the HV/EV had to vary up or down with speed by 1% per km/h to finally allow pedestrians to detect vehicle acceleration and deceleration.

In response to some manufacturers comments as well as other assessments, it has been finally decided just to require that the four-wheel vehicle emitted-sound might increase or decrease in volume by a specified amount[67], regarding the vehicle's speed increase and decrease, being sufficient to allow a pedestrian to detect a nearby EV or HV operating at different scenes.

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[64] NPRM: Notice of Proposed Rulemaking

[65] FMVS: Federal motor vehicle safety standard. Link: https://www.mercatus.org/system/files/Preliminary_Regulatory_Impact_Analysis_Minimum_Sound_Requirements_for_Hybrid_and_Electric_Vehicles_FMVSS_141_0.pdf

[66] See Federal Register / Vol. 83, No. 38 / Monday, February 26, 2018 / Rules and Regulations. Background-Paragraph A. Notice of Proposed Rulemaking (page 4). Link: https://www.gpo.Gov/fdsys/pkg/FR-2018-02-26/pdf/2018-03721.pdf

[67] See sample of increasing sound audio test for acoustic vehicle alerting system from UNECE. Link https://www.eurekalert.org/multimedia/pub/157218.php

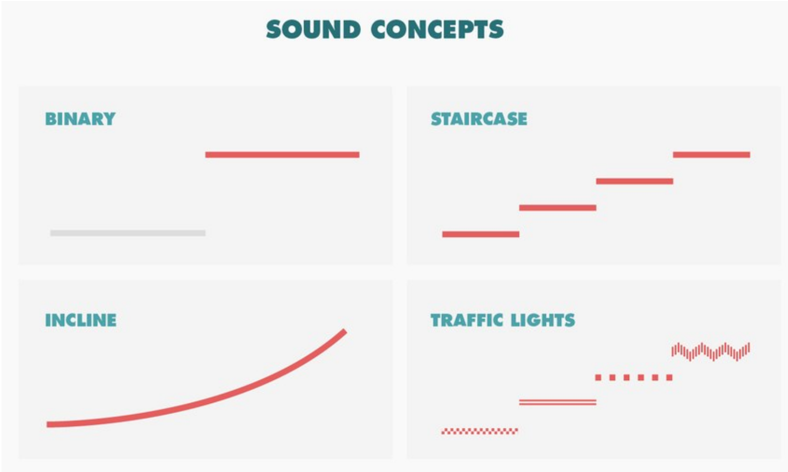

Figure 10: Representation of different sound concepts [68]

On the other hand, it is believed that the first hybrid and electric vehicles to make a mandatory noise will now be model year 2020 vehicles. Nevertheless, it is not certain that all of them emit the same noise as the National Highway Traffic Safety Administration from the USA is considering allowing cars to offer different sounds that a driver could select from. The NHTSA mentioned that restricted sound variation between different makes, models, and trim levels could be made.

Currently, manufacturers are allowed to provide four-wheel vehicles with one or more alert sounds that comply at the time of manufacture with the safety standard. These different sounds denote different operating scenarios. In addition, each vehicle of the same make and model must emit the same alert sound and it is prohibited to provide anyone, other than them or dealers, with a device designed to disable, alter, replace or modify the alert sound or set of sounds emitted from the vehicle.

As the already mentioned by the NHTSA, it would be very interesting to consider the driver's own noise choosing. It could be a manually operated noisemaker, a button on the steering wheel triggering a recording of the driver's choice. Experiments could be carried out to see which sounds are more effective, clearer and satisfactory for the human. One way to go could be to preserve the typical sound of electric engine. Also, the addition of specific tones to create

[68] Source from an article published in 2017 by Elisabeth Stinson. Link: https://www.wired.com/2017/04/evs-dangerously-quiet-heres-sound-like/

harmonies and consonance together with existing noise components could also be an intended development target. In addition to it, another development direction could be the creation of a totally new sound. Over all these the driver should always be able to recognize the technology and drive concept.

In conclusion, the implementation of the sound system could be compared to the phone sound/tone selection of some electric devices, such as phones or tablets. One could chose from a variety of sounds, not only in relation to combustion engine vehicles but other symphonies. These sounds could be configured and adjusted via an App, by for example a Bluetooth connection, connecting automatically every time the driver was closet o the motorbike. Finally, these could increase up to a maximum permitted regarding the regulation limits.

Further study should be done in order to exactly know those limits. The relevant challenge is to optimize the signals for maximum pedestrian and cyclist safety with minimal environmental noise and annoyance.

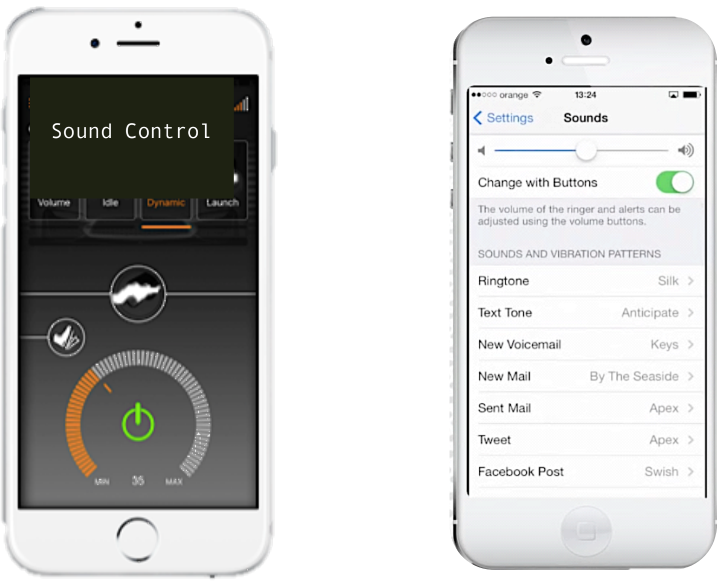

Figure 11: Simulation of alert tone choosing Smartphone application

8. Design

8.1 Components [69]

After doing an extensive research and comparison with the found options to implement the module and contacting several enterprises, three component shave been chosen.

- **SENSOR** SOLUTION: **TF02 LIDAR**[70]

DESIGN REQUIREMENTS AND CRITERIA	SOLUTION
Voltage range	4.5 V to 6 V
Operating voltage	5 V (≥1A)
Weight	52 g
Measurement frequency	100 Hz
Measurement sector	0,4 to 22 m
Operating temperature	-10 to +60 ° C
Storage temperature	-20 to +80 ° C

[69] See remarkable studied options in ANNEX H

[70] See TF02 LIDAR Data Sheet in ANNEX I

Compatibility	Yes
Price	99,00 €/product

Table 1: Characteristics of **TF02 LIDAR** Sensor

Note that the sensor has been chosen bearing in mind that it has to be well stabilized and should respond to certain characteristics. Though vibrations and other motion may appear, these will not impact its signal

- **MICROCONTROLLER** SOLUTION: **UNO-Arduino** [71]

DESIGN REQUIREMENTS AND CRITERIA	SOLUTION
Processor	ATmega328P
Simplicity	Yes
Weight	25 g
Voltage range	7-12V
Operating voltage	1.8 - 5.5V
Clock Speed	16 MHz
Flash Memory	32 KB

[71] See UNO-Arduino Overview, Data Specificaations and documentation in the link: https://store.arduino.cc/arduino-uno-rev3 . See Arduino UNO Data Sheet and ATmega328P processor Data Sheet in ANNEX J

Operating temperature	-40 to + 85° C
Storage temperature	-65°C to +150°C
Compatibility	Yes
Price	19,95 €/product

Table 2: Characteristics of UNO-ATmega328P Microcontroller

- **LOUDSPEAKER** SOLUTION: **SBS12M1PC**[72]

DESIGN REQUIREMENTS AND CRITERIA	SOLUTION
Weight	32 g
Decibels	95 to 105 dB
Frequency	150 to 4000 Hz
Voltage	9 V to 12 V
Flash Memory	32 KB
Operating temperature	-30 to +65° C
Storage temperature	-40° to +85° C
Compatibility	Yes
Price	18,61 €/product

Table 3: Characteristics of SBS12M1PC Loudspeaker

[72] See SBS12M1PC Data Sheet in ANNEX K

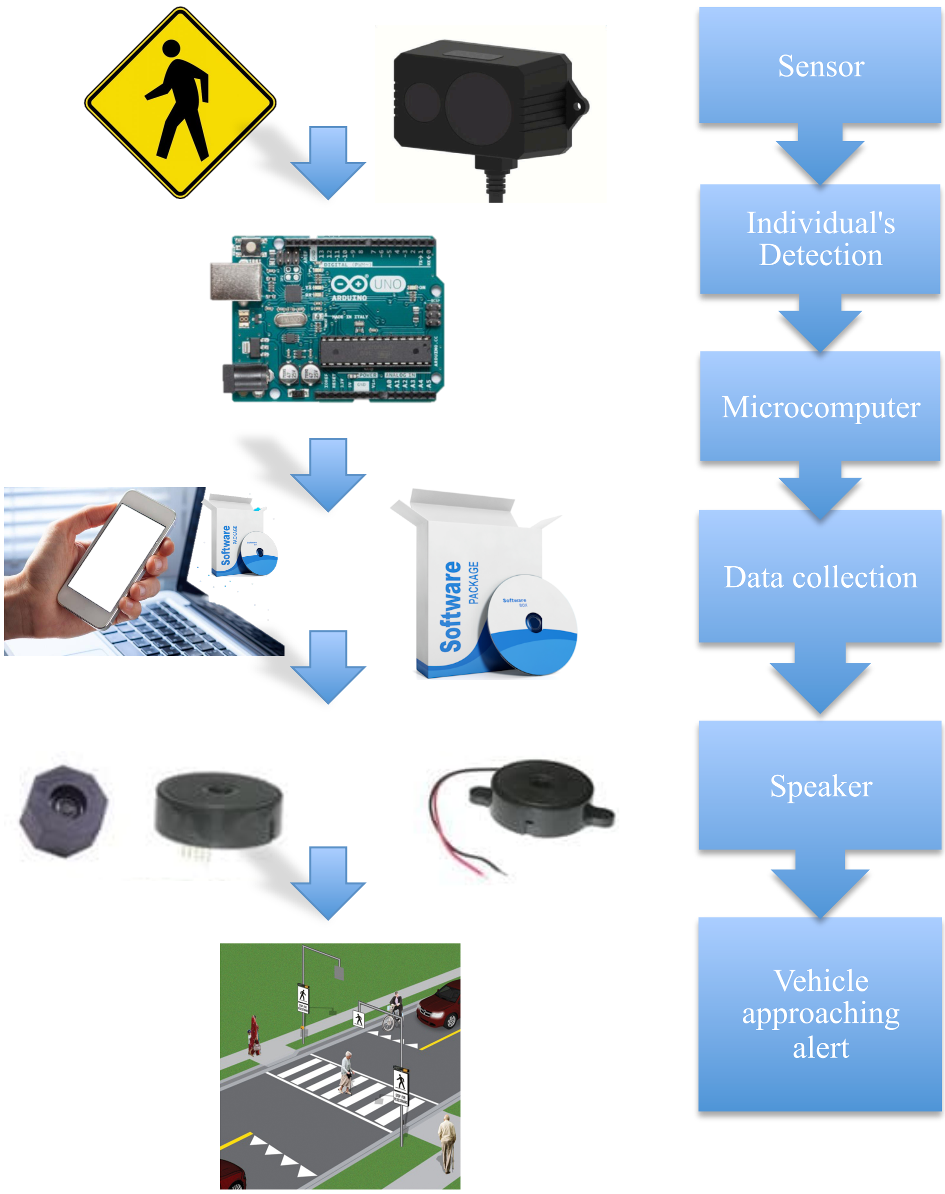

Figure 12: Working process diagram block of the sound module

- THE BOX

The design is presented as a small box of certain dimensions, which includes the necessary components to create the connection of the module. The dimensions are variable depending on the motorbike model of implementation as it has to fit in a correct manner.

In the box front there is a resistant plastic piece that has to make contact with the inside of the motorbike's fairing, in order to avoid vibrations that can appear during the driving. It has an aluminium in order to avoid any unwanted detachment of the components on its inside. It is attached to the box thanks to the existence of two small screws.

The chosen material for the box construction is aluminium. It is a lightweight material, which is used in automotive applications, and very resistant to corrosion. Also it is recyclable, has a good formability and also a low cost.

The box will have a metallic support that will give resistance to the structure, avoiding extreme movements, and allowing the union and good hold inside the motorbike. Throw a clamp the box is connected to the steering column.

It can be seen in **Figure 13** that some holes are extruded to give way to the ventilation output of the box and avoid possible overheating of the CPU. The microcontroller and loudspeaker are anchored inside the box. The loudspeaker is proposed to be anchored in a way that can make it more easy to project the sound and make its hearing clearer.

The sensor will be situated outside the box, as it is important that it has a clear view of the motorbike's front. Its connection to the other components will be done with wires that may cross the box with special holes. Depending on the company it will be located on the most preferable place of the motorbike. Its dimensions are small; therefore it will not be difficult to introduce it on the fairing of the motorbike, where a frontal view is well achieved.

COMPONENT	WEIGHT	DIMENSIONS
Sensor	52 g	62 x 46 x 26 mm
Microcontroller	25 g	68.6 x 53.4 mm
Loudspeaker	32 g	Ø : 44.45 mm Width: 15.00 mm
Box	5,4 kg*	Variable in volume
Total weight	5,509 kg	-

Table 4: Weight and geometry of the sound module components

* It is considered that an aluminium sheet of 2000x1000 mm and a thickness of 1 mm, whose weight is of 5,40 kg is enough to build the whole box, variations on the final weight may appear.

SolidWork design

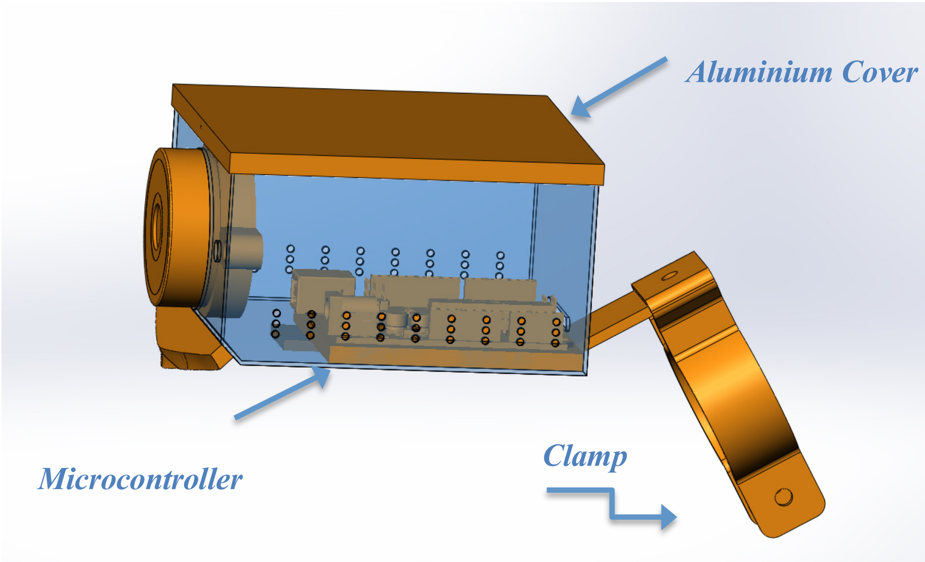

Figure 13: Design of the sound module, which includes the loudspeaker and microcontroller on its inside. It is represented with a support that makes the connection to the clamp

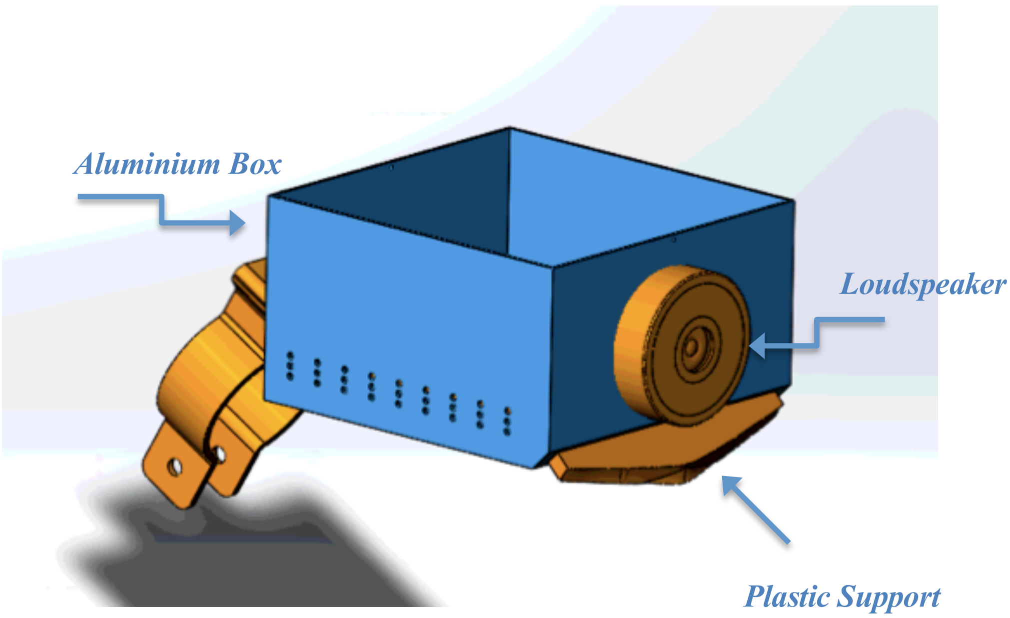

Figure 14: Alternative view of the sound module

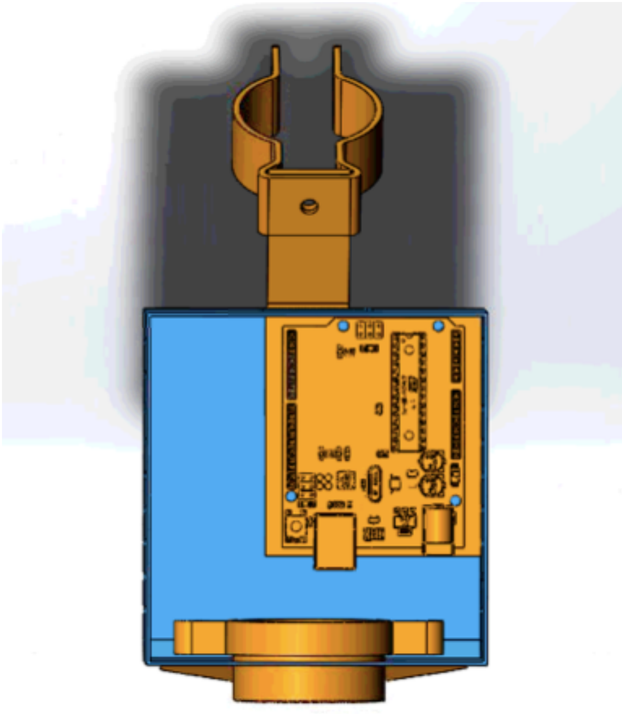

Figure 15: Upper view of the sound module

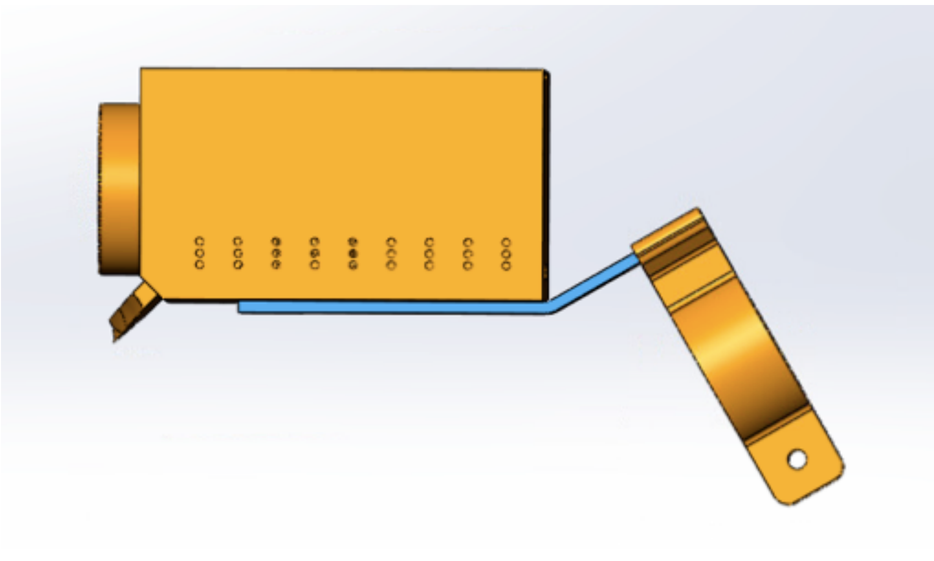

Figure 16: Right profile of the metallic support

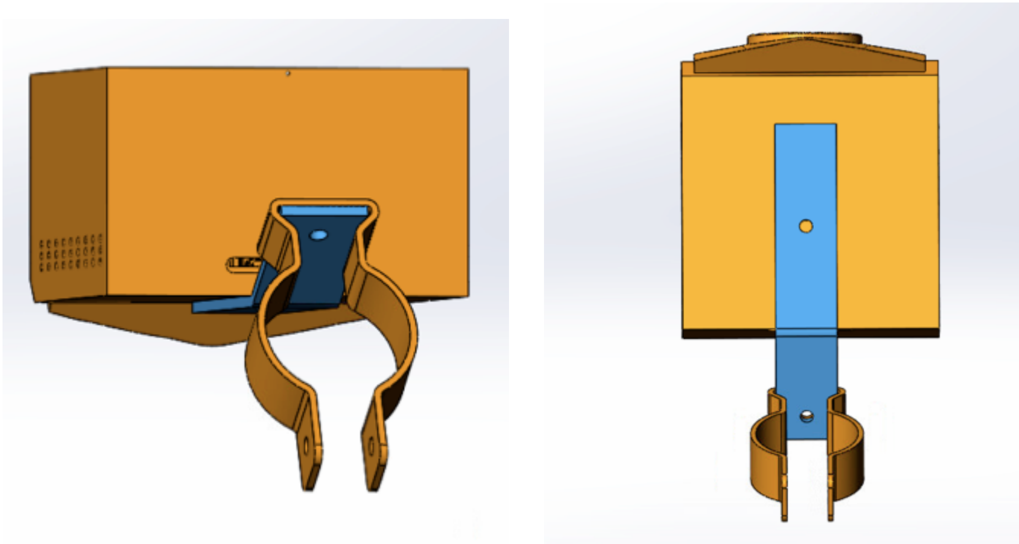

Figure 17: Different views of the metallic support where the two holes to introduce the anchoring screws are shown

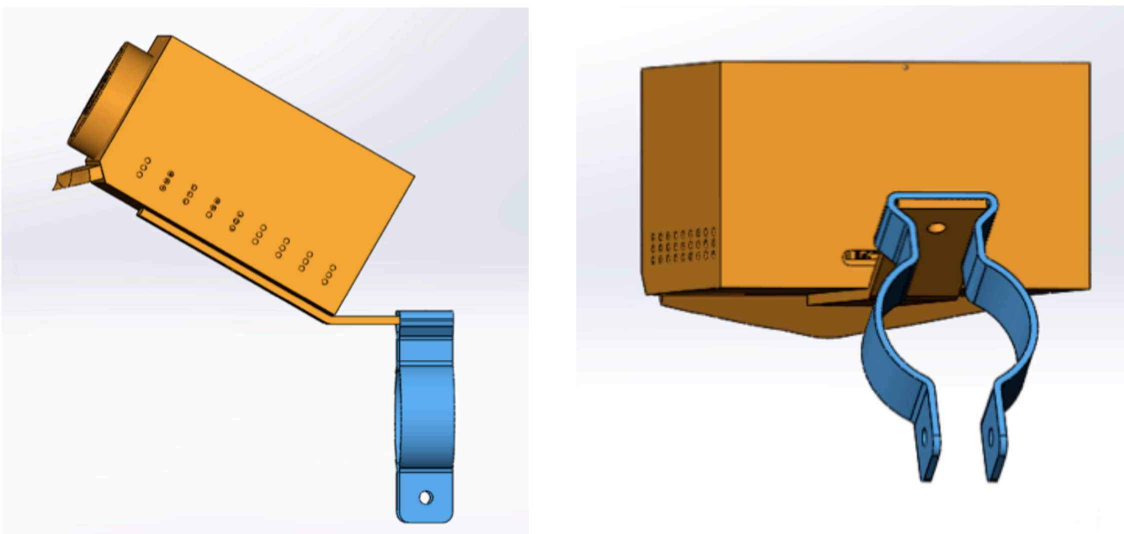

Figure 18: Different views of the clamp, used for the anchor of the box with the motorbike

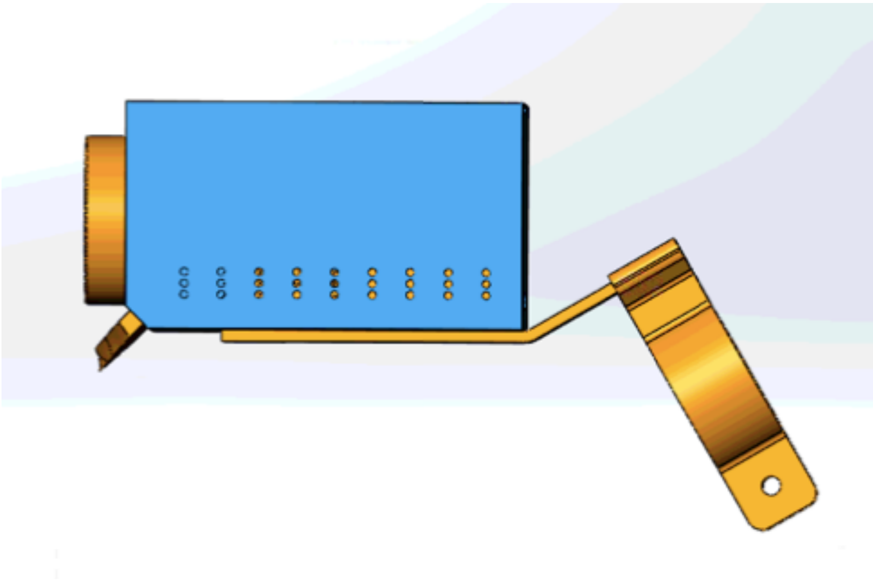

Figure 19: Right profile of the aluminium box

Figure 20: Back profile of the box with an overture that allows the wires crossing of the box. Note that the measures of this overture vary depending on the wires' thickness

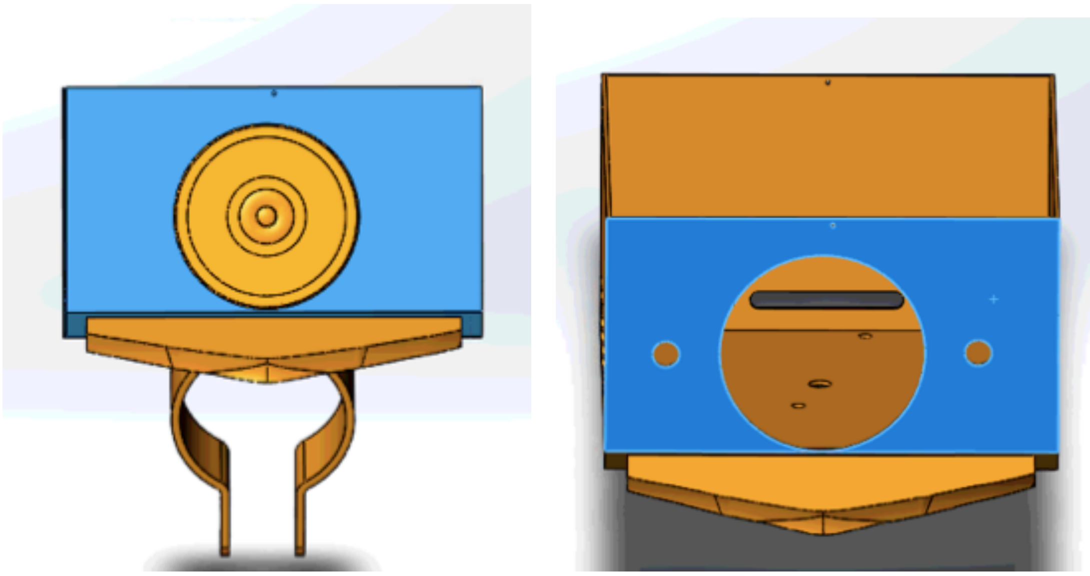

Figure 21: Frontal view of the sound module where the loudspeaker location is shown. The perforation to introduce it comes with two other holes to make its right anchoring.

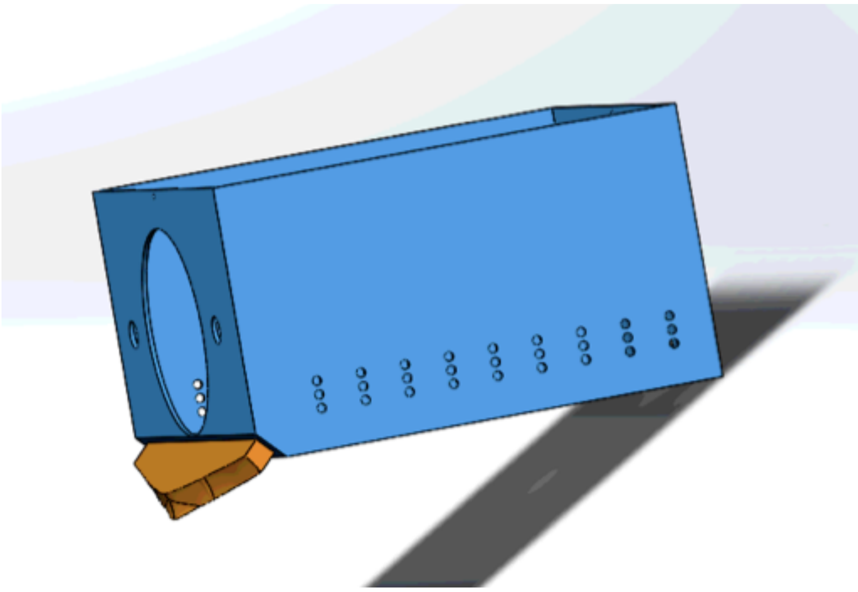

Figure 22: In brown can be differed the plastic structure that ensures a good support. In blue the ventilation outputs and the holes for the location of the loudspeaker can be differed

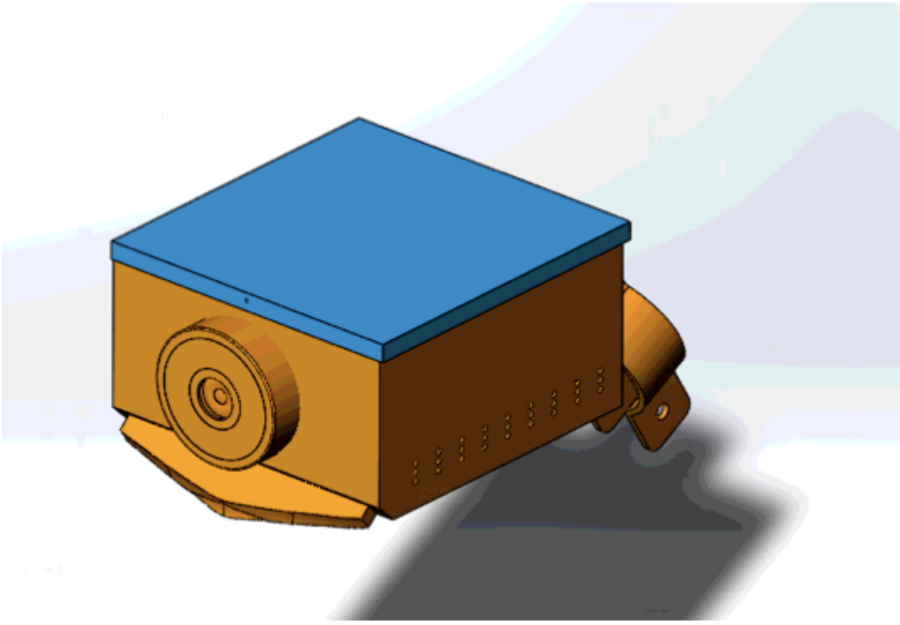

Figure 23: View of the aluminium box with the cover

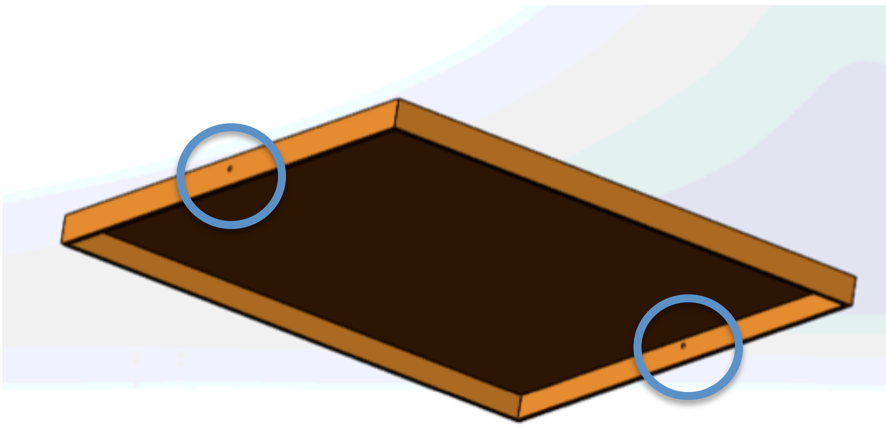

Figure 24: Aluminium cover upper view. Note that two small holes can be differed, so that the anchor with the box can be possible

8.2 Sensor-Microcontroller-Audio connection

While processing data, every part of the module should be well verified to ensure its reliability in the motorcycle and in consequence achieve the aim.

The module will need a DC / DC converter from 12 V to 5 V for the sensor and microcontroller, to allow their good working. The microcontroller should be well wired[73] to the sensor a well as the loudspeaker. To make all the wiring connections, a study of the schematics of each component should be accurately done, this one is included in the electronic engineer working hours. In the ANNEX J the Arduino UNO schematics can be regarded.

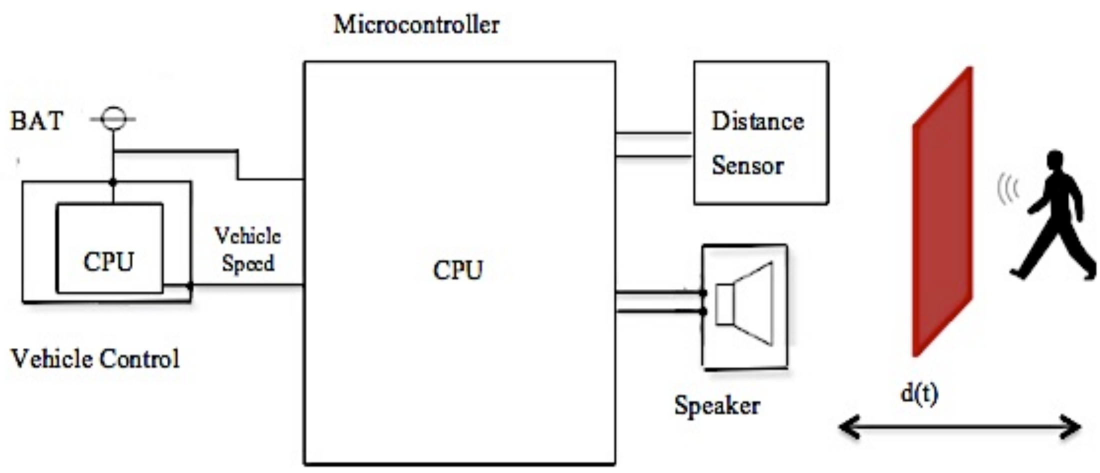

Figure 25: Inside view of the sound module

8.3 Programming of the Software

The Arduino UNO is a microcontroller board based on the ATmega328P. This control board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. [74] To enable the sensor and microcontroller connectivity, an introductory manual of how to

[73] Illustration link that shows how to wire the LIDAR sensor the microcontroller
Link: https://www.14core.com/wiring-the-lidar-light-detection-and-ranging-sensor-with-micro-controller/

[74] Continue reading more information in the link: https://store.arduino.cc/arduino-uno-rev3

create connections between the microcontroller UNO Arduino board and the TF02 LIDAR sensor can be found in ANNEX L.

As the code to make the sensor connection is already given, just an amplification of it will be needed, introducing certain algorithms to give power to the loudspeaker and following procedures.

Many objects and obstacles would be detected in a 22 m distance, and the radial to analyse would be huge. In order to achieve a goal like this, as the environment is also constantly changing and moving, powerful software should be created to carefully map what the system is measuring the whole time, however it is, after expert advice, simpler than it seems.

9. Development time - Sound module incorporation in a scooter

After designing a sound system capable of emitting a noise avoiding possible accidents, which can be implanted on any electric motorbike, it has come the decision to implement it as an example to the model from the German company GOVECS.

Thomas Grubel and Nicholas Holdcraft founded GOVECS GmbH in 2009, with the aim of offering pioneering solutions of electric mobility. As a leading manufacturer of electric scooters in Europe, GOVECS is a well-known German company, which uses only materials and components of the highest quality for the production of e-scooters. Its motorbikes are produced in Breslau/Wroclaw, Poland.

One of the strongest forces in the entire e-market is urban and suburban area. Consequently, GOVECS main markets can be found in Spain, France and Germany, due to the continuous expanding of sharing programmes in those local regions.

GOVECS considers that with these electric motorbikes business everyone is someway completely electrified - *"Irgendwie sind wir hier alle komplett elektrifiziert."*

As GOVECS is one of today's companies, which is already developing the solutions for the future, it is very interesting to set to the practice the sound module to one of their models.

The chosen model is the one used by Cooltra, a Catalan company created in 2006. It is nowadays the referring enterprise and leader in *motosharing*[75] service in Barcelona and Madrid.

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[75] Motosharing/ Carsharing are both services that have recently reached the market. By these anybody who is a user of these services app's, would be able, normally through a monthly rental system or for a short time in a day, to rent one of the fuel/electric vehicles.

Characteristics of the scooter[76]

Cooltra has received around 3000 Scooters from GOVECS since 2012. This company first purchase was of the Go! S3.4 model. With the new state of the art BMZ batteries[77], the model S3.6 replaced these models. Although Cooltra has still a few Go! S3.6 the German company no longer produces these.

Nowadays most Cooltra scooters on the market are Go! S1.5 models. These are used for the sharing and last year around 1500 units were sold.

Both S3.6 and S1.5 are very similar models and their whole system works very similar, the main difference resides in the motor power and wire harness.

The study of the sound module implementation has taken Go! S3.4 as the example design, however all GOVECS Go! S models have almost the same inside structure and space.

Figure 26: GOVECS GO! S Scooter example[78]

[76] To know more characteristics of the scooter see ANNEX N

[78] BMZ GmbH is a leader in Europe as a system provider and specialist for intelligent battery solutions, well known for its rapid lithium-ion battery developments and growth.

[79] Photos from GOVECS Enterprise Link: http://www.Govecs.de/en/products/Go-s-series/

9.1 Implementation in the scooter

Generally GOVECS electric scooters of the Go! S[79] models have a wide space inside their front structure; this is why is proposed that the sound module inside the cabin of the motorbike. It is shown in Figure 27:

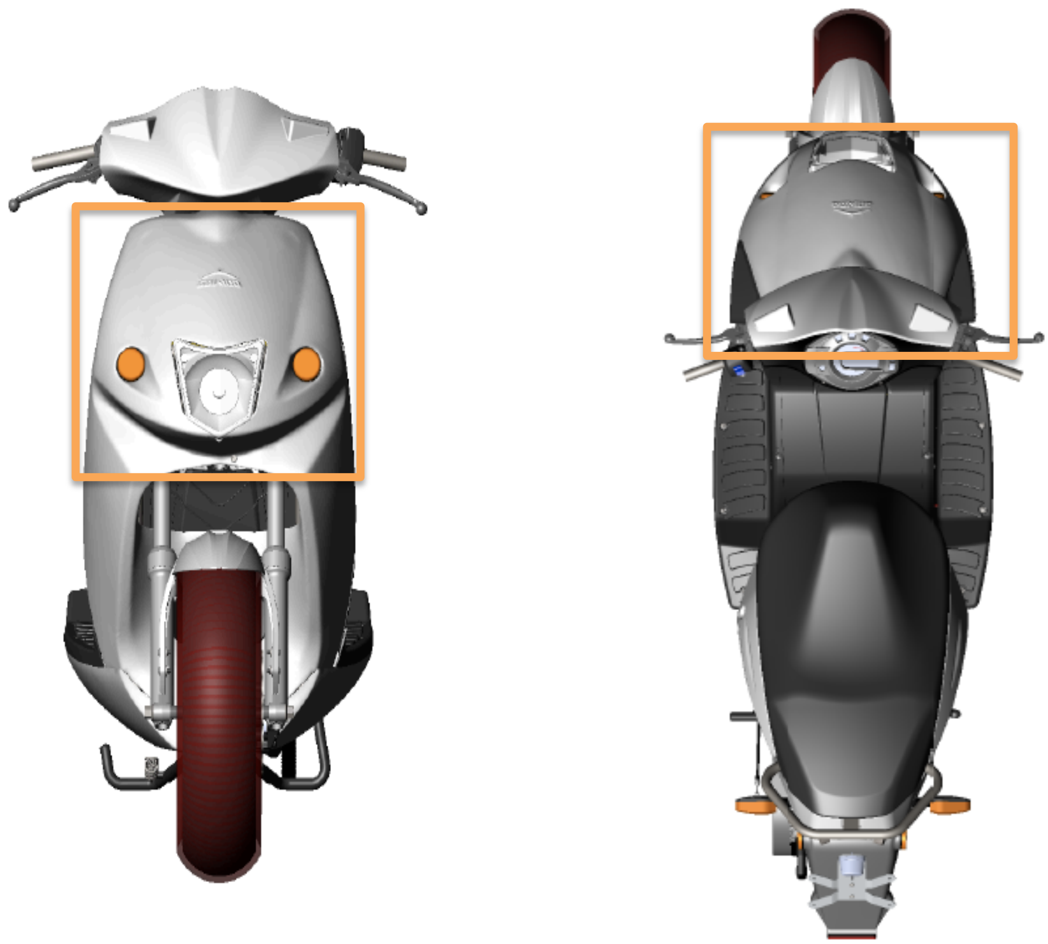

Figure 27: GOVECS Go! S1.4 model with the sound module location marked with an orange square

[79] See GOVECS GO! S series in link:
http://Govecs.de/fileadmin/user_upload/20160524_GOVECS_S_Serie_Flyer_English.pdf

In addition, if the aim is not only to alert the pedestrian but the driver too, it could be considered to introduce another speaker or the same speaker itself in the panel control of the motorbike, by doing this the driver would listen the alert sound better. It is shown in Figure 28:

Figure 28: GOVECS motorbike's control panel

<u>SolidWork design of the module implemented to GOVECS electric motorbike</u>

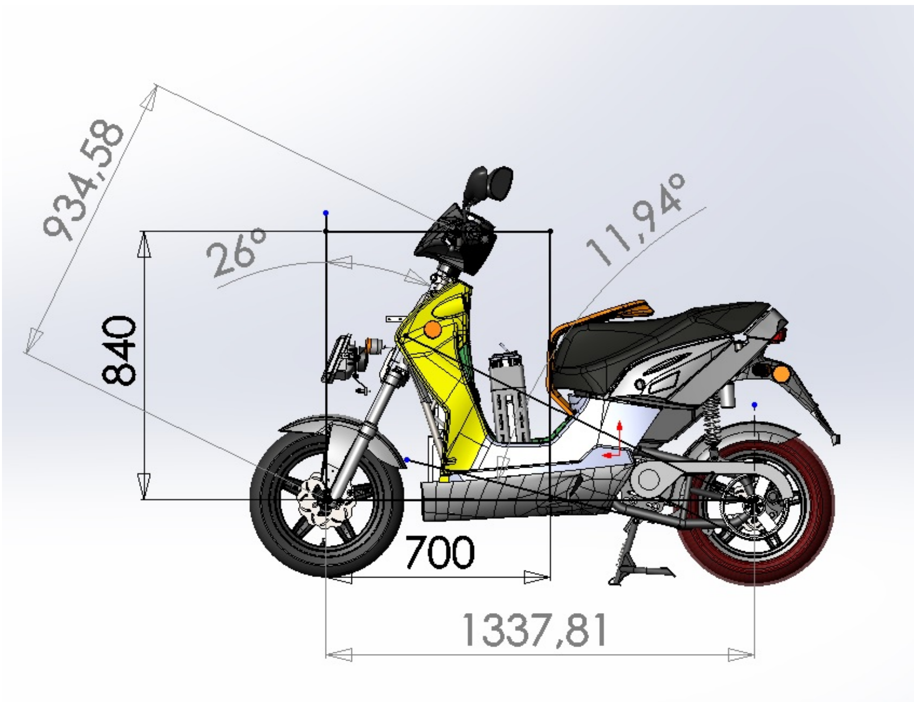

Figure 29: GOVECS motorbike main distances for the design

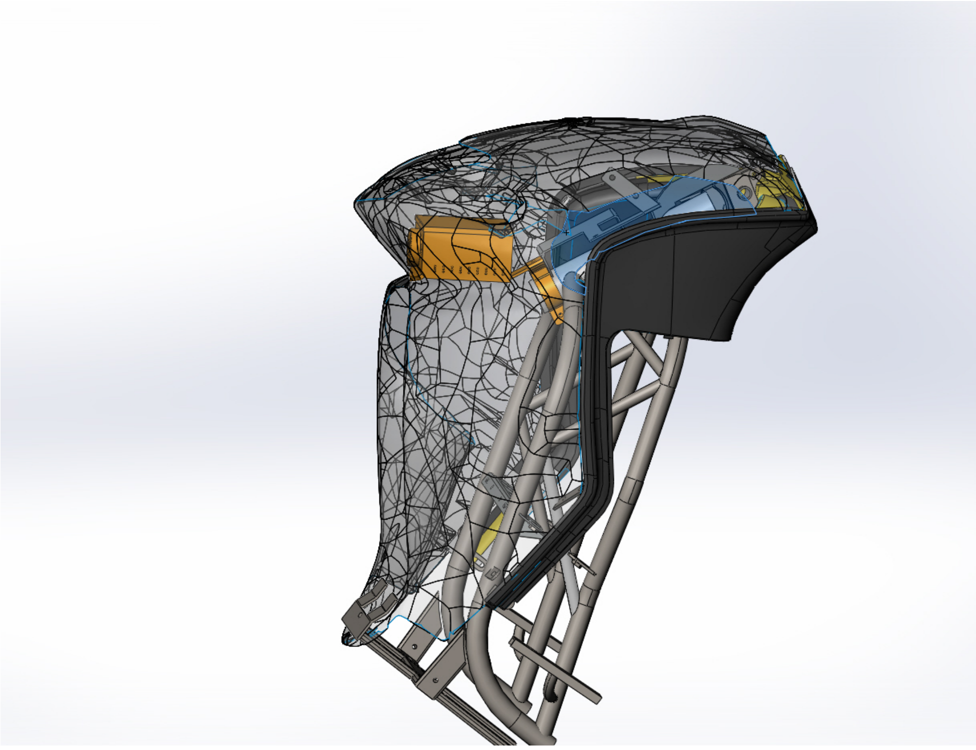

Figure 30: Left profile of electric GOVECS motorbike showing the inside location of the sound module

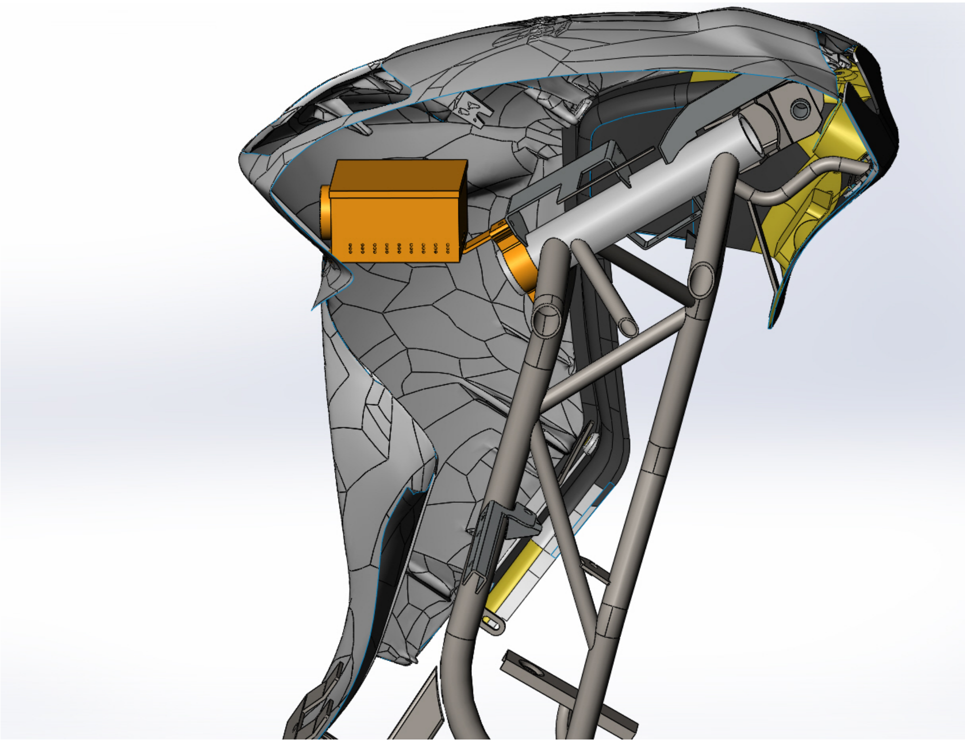

Figure 31: Left profile of GOVECS electric motorbike external structure with sound module on its inside

10. Economical study

10.1 Operations

It is considered that this study and design are part of an engineering project, which would be presented as an innovative an interesting idea to consider for an automotive company.

To make possible this project, an engineer needs to follow some steps and spend time making research in order to achieve the goal.

First of all an overview of the current status of the electric motorbikes in the market has to be taken into consideration. As mentioned no sound module systems for this transport exist, so new and alternative ideas have to be thought to make a final good design.

Also is important to foresee the limits of the project in relation to the time and the material available. Is crucial to know how to synthetize and optimize the tools and finally see what are the relevant aspects to focus on.

A market study should be done to see what are the useful options for the creation of the module. At first some options may be considered that finally will not be profitable, and the same happens with other firstly not regarded but after study and investigation becoming the chosen option.

Once the project is planned and a first draft is done, it comes the time to contact with the available enterprises in the market and experts in the field. Not only is noteworthy to listen for a professional advice from the engineering, but also to have a view of the experts from the different sectors that also are involved in the project development, such as mechanical and electronic engineers or software programmers, and listen to their recommendations.

The first view of the project will change during its development and is important to be opened to those changes and move on to new ideas.

Working in the electric motorbike field in order to design a product that can bring new ideas to the automotive sector, it comes the time to establish a connection with them and see what they thing about the idea of creating a sound module for an electric motorbike. One has to study where the issue starts and where it finishes. Knowing where the electric motorbikes are designed and produced, where the headquarters are located and how these motorbikes are transported and provided to different countries, and with which aim. Establishing relation with all the members of this chain is fundamental.

All the mentioned activities take a lot of time but with patience good results finally appear. The project cost has to be estimated at the end. Some of the prices have been estimated in a high way, so that if they vary is for a fewer expense.

10.2 GOVECS enterprise producer

GOVECS's company state of the art production plant is located at the centre of Europe, in Wroclaw, Poland. [80] It covers a surface of 4000 square metres. The production line is 36 metres long and provides enough room for the parallel assembly of up to nine scooters. Having a fully automated assembly line installed in 2013, every 15 minutes an electric scooter rolls off the production line working to full capacity.

The work ergonomics of the production line guarantees GOVECS is VCA[81] certified throughout the applied production processes. Not only ensures a totally safe work environment but also takes into account the many manual work steps providing optimal accessibility.

The production is controlled by an ERP[82] computer system with a just-in-time delivery method of the components. The FIFO warehousing method safeguards smooth operation of inventories.

Classical OEM[83] products are produced in Wroclaw as well, where also the entire value creation chain of vehicle construction and vehicle development, ranging from R&D and prototyping to the final serial production or homologation takes place.

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[80] See ANNEX M

[81] VCA is the designated UK Approval Authority and Technical Service for type approval to all automotive European Community (EC) Directives and the equivalent United Nations Economic Community for Europe (ECE) Regulations.

[82] ERP: Enterprise resource planning is the integrated management of core business processes.

[83] OEM stands for Original Equipment Manufacturer. Meaning that a company that is a subcontractor to a vehicle manufacturer made the product.

Electric vehicles are constantly evolving, introducing new changes, therefore it is good to innovate and go for new project. One of the main restrictions of these vehicles is their high cost, specially the cost of the batteries as well as the vehicle evolution, regarding the vehicle and battery lifetime.

The final price of a vehicle includes many factors, from its design to the arrival at the delivery place.

Some of GOVECS motorbikes' intern processes are shown in Table 5:

Packaging Costs	100, 00 €
Assembly Costs	300,00 €
Transportation costs from Wroclaw, Poland to other countries in Europe	150,00 € /scooter
Transportation costs from Wroclaw, Poland to Barcelona	40 and 50 € /scooter

Table 5: Overview of some relevant costs to develop a new product in GOVECS enterprise

Table 6 shows a comparison of the three models that have been used by Cooltra, for Go! S3.4 and Go! S3.4 the market price is given. As for Go! S 1.5 its base price is shown.

Go! S3.4	5.990,00 € - incl. VAT
Go! S3.6	5.990,00 € - incl. VAT + 500,00 € - extra
Go! S 1.5	4.990,00 € (Base price)

Table 6: Price of the GOVECS models used by the motosharing enterprise Cooltra: Go! S3.4, Go! S3.6, Go! S 1.5

11. Budget

The budget for the design and construction of the sound module is based on its components, the spent hours as an engineer for the project, the software among other factors. These are synthetized in the following tables:

Concept	Number of units	€/unit	Price [€]
Project Engineer	400 hours	50 €/h	20.000,00
Software development + **Wiring design**	20 hours	50 €/h	1.000,00
System implementation	15 hours	50 €/h	750,00
Testing	25 hours	50 €/h	1.250,00
TOTAL	460 hours	-	23.000,00

Table 7: Total costs regarding the spent hours in the project as an industrial engineer and elaboration of the sound module

Note that the software programming time and implementation has been estimated after contacting an electronic engineer. The testing hours may differ depending on the possible complications of the project. An upward number of hours has been considered, this is why the total price, regarding the spent hours may vary, as it also depends on the engineer expertise in the field

Concept	Unit price	100 Units	500 Units	1000 Units
Sensor	83,20 €/unit **Total:** 83,20 €	70 €/unit **Total:** 7.000,00 €	64 € /unit **Total:** 32.000,00 €	58 € /unit **Total:** 58.000,00 €
Microcontroller	19,94 €/unit **Total:** 19,94 €	19,94 €/unit **Total:** 1.994,00 €	19,94 €/unit **Total:** 9.970,00 €	19,94 €/unit **Total:** 19.940,00 €
Loudspeaker	18,61 €/unit **Total:** 18,61,00 €	14,24 €/unit **Total:** 1.424,00 €	14,24 €/unit **Total:** 7.120,00 €	14,24 €/unit **Total:** 14.240,00 €
TOTAL	121,75 €	10418,00 €	49090,00 €	92180,00 €

Table 8: Total price to retailer in regard to module components for 1, 100, 500 and 1000 units. Prices with VAT[84] not included

The prices of each component may differ depending on the provider. In the project a research has been carried out among all market options, finally choosing the most economical ones. Also has to be mentioned that new offers with regard to the components purchase could be negotiated depending on the size of purchase, apart from the ones shown in the table.

Referring to the construction of the as it is more expensive, it is advisable in order to decrease its price, not to do a mechanized of its whole.

By buying an aluminium sheet of 2000 x 1000 it will be enough to build the box and its cover. The components of the module can be anchored with screws; some examples are given in Table 9-

Regarding the cutting of the aluminium sheet, it can be done with the water cutting technique, giving more quality and precision to the cuts, as well as being an affordable technique.

[84] VAT: Value Added Tax

The following table represents the box breakdown with examples of some providers of its components:

Concept		Provider	Number of units	Price [€]
Material: Aluminium Sheet 6082 (5,40 kg / unit of 2000x1000 1mm) Note: Minimum purchase price: 350 €		Alu-Stock[85]	1 unit	44,20
Water cutting		Aquatall[86]	1 box mechanized	100, 00
Screws	**Screw M1** [87] 1 Lot: 200 units	Tormetal	2 units	0,0478
	Screw M3 [88]		4 units	0,0457
	Screw M5 [89]		1 unit	0,0563

[85] Link: http://www.alu-stock.es/es/aluminio-industria/productos-laminados/chapas-aleaciones-comerciales/chapas-aluminio-en-aw-6082/

[86] Link: http://aquatall.es

[87] Used to make the aluminium cover and box anchoring. Link: http://webcatalog.tormetal.com/es/product/d963-m-3-x-8-laton-id-319420

[88] Used for the anchoring of he microcontroller board with the box and metallic support. Link: http://webcatalog.tormetal.com/es/product/d963-m-3-x-8-laton-id-319420

[89] Used to make anchor of the metallic support with the superior part of the clamp. Link: http://webcatalog.tormetal.com/es/product/d963-m-5-x-8-laton-id-284469

	Screw M5[90]		1 unit	0,0798
	M6 Screw[91]		2 units	0,0798
	M5 Through-bolt [92]		1 unit	0,5251
Construction of the box		Mechanical Workshop (45,00 €/hour)	1 hour	45,00
Plastic support		3D printing estimation	1 unit	20,00
Clamp[93]		Electrica 108	1 unit	5,44
Metallic support		Mechanical Workshop	1 unit	30,00
TOTAL [€]		-	-	245,4745

Table 9: Total cost of one box construction. The screws are sold in lots of 200 units each.

[90] Used to anchor the metallic support with the aluminium box. Link: http://webcatalog.tormetal.com/es/product/d963-m-5-x-12-laton-id-346701

[91] Used to anchor the loudspeaker with the box. Link: http://webcatalog.tormetal.com/es/search?keywords=901159&type=0

[92] Used to make the inferior union of the clamp. Link: http://webcatalog.tormetal.com/es/product/d7977-5-x-40-st-id-296486

[93] Example of clamp for the project. Same price for one and multiple units. Link: https://www.maschendraht-online.de/zaunzubehoer/strebenschellen/strebenschelle-edelstahl::1076.html

The chosen providers may differ depending on the like of the company. The prices shown in the table have been estimated after contacting the given as example providers.

Regarding the conversion DC/DC from 12 V to 5 V for the sensor and microcontroller, any converter allowing this would be suitable (without an USB input/output). For the project is chosen the one shown in Table 10:

Concept	Provider	Input	Output	Units	Price [€]
DC/DC Converter[94]	Amazon	8-23 V DC	5 V DC	1 unit	3,39

Table 10: Relevant characteristics of the 12 V – 5 V DC/DC converter

Concept		1 Unit	100 Units	500 Units	1000 Units
Aluminium Sheet 6082		44,20	4420	22.100	44.200
Water cutting[95]		100	10.000	50.000	100.000
Screws	**Screw M1**	0,0478	4,78	23,90	47,80

[94] After establishing contact with Amazon, is known that the price of the converter will not change depending on the ordered quantity. Link: https://www.amazon.com/Converter-Regulator-Power-CPT-UL-1-Cable/dp/B07CQWCT8L/ref=sr_1_3?ie=UTF8&qid=1529402971&sr=8-3&keywords=12+V+–+5+V++DC%2FDC+converter+CPT

[95] Price given after contacting enterprise with expertise in the field. Link: http://www.perndorfer.at/produkte/wss-2d/wss-portal.html?k=2575&agid=18323560217&kw=pwater%20cutting&creativeid=258608488988&pos=1t1&gclid=CjwKCAjw06LZBRBNEiwA2vgMVZ99BWNN8pUobCtAhPHzGKMVOcyIiw-1FiGQV572aQ-ZN-O3mbbR2BoCSt0QAvD_BwE

	Screw M3	0,0457	4,57	22,85	45,70
	Screw M5	0,0563	5,63	28,15	56,30
	Screw M5	0,0798	7,98	39,90	79,80
	M6 Screw	0,0798	7,98	39,90	79,80
	M5 Through-bolt	0,5251	52,51	262,55	525,10
Construction of the box[96]		45,00	4500,00	22.500	45.000
Plastic Support		20,00	20,00	20,00	20,00
Clamp		5,44	544,00	2720,00	5440,00
Metallic support		30,00	30,00	30,00	30,00
12 V – 5 V DC/DC converter		3,39	339,00	1.695,00	3.390,00
TOTAL [€]		248,8645	19.936,45	99.482,25	198.914,50

Table 11: Summary of the costs for 1, 100, 500 and 1000 units without taking into consideration the three main components: Sensor- Microcontroller and Loudspeaker

[96] Making reference to the price of construction by one worker. Automation will be cheaper, faster and more advisable for a great production.

The metallic and plastic supports' prices have been regarded after contacting to mechanical workshops. It is proposed to create the plastic support with a 3D printer, adapting the figure to the motorbike's structure.

Finally, to see the total cost of the module its necessary to join the costs of producing a module box and the costs of the three components purchase. By doing this it will be possible to see if its viable to start working for the development and creation of a project like the described.

Concept	1 Unit	100 Units	500 Units	1000 Units
Sensor + Microcontroller + Loudspeaker	121,75 €	10.418,00 €	49.090,00 €	92.180,00 €
Rest of the module	248,8645	19.936,45	99.482,25	198.914,50
TOTAL	**370,61 €**	**30.354,45 €**	**148.572,25 €**	**291.094,50 €**

Table 12: Final required amount for the construction of the sound module for 1, 100, 500 and 1000 units

12. Project continuity

It is highly expected that hybrid and electric vehicles will gain importance in the near future. Electric motors will eventually replace combustion engines. The remaining question is how long it will take to achieve these new goals.

The aim of the project is to describe and design a sound module system. However due to the lack of time and resources it has not been created. In the early future other alternatives to the module may appear, as mentioned electric motorbikes are still to improve and develop sound systems, the ones have been just introduced for the moment in four-wheel vehicles.

The given sensor, microcontroller and speaker are, after a deep research, three chosen options to consider which respond to the good working of the sound module. Other alternatives may appear that also could be useful. In addition all the elements that compose module in the project are given as a reference, to have an estimation of how much would it cost to elaborate a module like this.

After doing a kind of project like the studied, where safety is involved many hours of testing should be taken into consideration, an average of 25 hours of testing of the software have been given, however once it is introduced in the motorbike, it should be well regarded and confirm its good functionality. The cost of the sound module may increase after continuous trial period.

Moreover, having nowadays your own vehicle is the most usual thing, because of the amenity and availability. However not everyone can afford it. The social habits and new tendencies are changing.

The public transport is the alternative but sometimes it comes with long time traffic jams and stressful trips. Regarding the aim of our society which is decreasing the high pollution indexes in the big cities, a new tendency has came into the market that presents electric motorbikes as the solution: **The Motosharing**

The motosharing has revolutionized the mobility market in the big cities. The concept of "sharing" comes with a change in the citizens' mind. It is a new way to move around the city, changing the usual routine.

As already mentioned at the chapter 9 Development time - Sound module incorporation in a scooter, Cooltra is nowadays a very well known enterprise in motosharing service. The enterprise started in March 2016 a circulation plan of 1000 electric scooters from the aforementioned German company GOVECS, with an initial investment of 4,5 million euros.

This motosharing service has already been implemented in other European cities such as Lisbon, Madrid, Milan and Rome.

The user of the service has its one app, where a total connection to the motorbike is found. Given that the app centralizes all the operations, the suggestion regarding future development would be to use it for sound tone control. Modifying the sound to emit depending on the liking of the consumer.

The motorbike also incorporates a geo-location service, which could be useful for further developments of the sound module. E.g. while using a Bluetooth speaker, it would allow to know exactly where the motorbike is located in order to change/recharge the speaker.

Regarding the Bluetooth speaker mentioned connection, if technology evolves in a way that improves their working manner it would be very interesting to use them, regarding costs, maintenance as well as the possible compatibility issues.

Considering that the motorbike driver should be connected to its motorbike, it would be interesting that he/she knew at all time the battery status of not only the motorbike but also the loudspeaker.

Also it should be said that many other companies are currently working on the vehicle-driver connectivity. The following figure shows GOVECS as an example of these companies, who is innovating and working for future solutions, and Bluetooth connectivity with all smartphones.

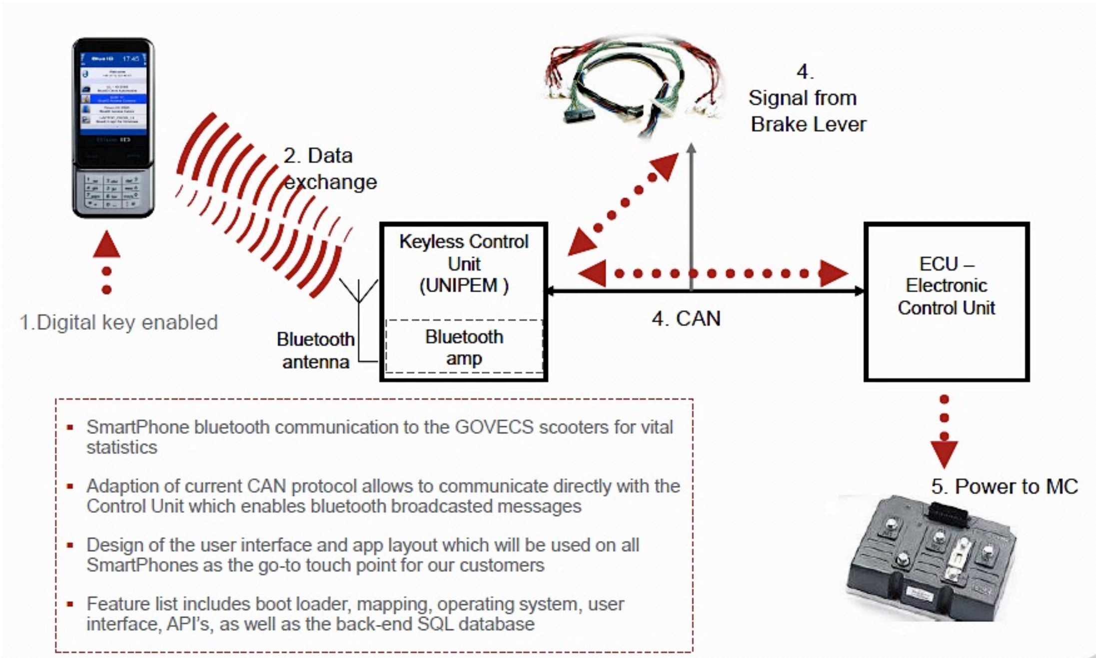

Figure 32: Representation of GOVECS Smartphone's Bluetooth connectivity [97]

In addition to this, some of the limitations that have been found while doing the project , exposed in chapter 4.2, could be regarded and considered for future development. These are interesting ideas that due to the lack of time have not been more intensively studied, but could give rise to greater developments.

[97] Figure from a GOVECS Management Presentation. Link: http://www.Govecs.es/sites/default/files/gv_04_2014.pdf

13. Conclusions

Having a personal interest in the electric vehicles field, has allowed me to easily work and make deep research to do the project.

Once the project has been finished is important to see if its aim has been achieved: To equip electric motorbikes with 'AVAS' to create artificial sound for the purpose of road safety. In order to make it possible, a combination of elements has been found after wide research.

The basis of the product design has been well described following these steps:

1. Study of different alternatives: They have been well described and compared, bearing in mind the material, properties, structure among other factors.
2. Optimal alternative election
3. Design of the project: Making real and visual the described device.
4. Example of implementation to a motorcycle

Different criteria and variables, regarding each component, have been taken into consideration. In addition, by using the acquired knowledge of the last few years of university, this project has helped to understand and consolidate more how a design project works, as well as the opportunity to use some of the learnt tools to make the design possible. The project has permitted to work with subjects such as electronics, materials, design or economical issues without finding relevant complications, being more involved in the manufacture world.

The noise pollution issue is a burning debate and after the car recent regulation imposed by the USA, it seems imminent that a similar rule to 4-wheel vehicles appears for electric motorbikes.

Due to the electrification of vehicles, acoustic engineers are already facing a revolution in the field of vehicle acoustics[98]. After continuous development and optimization of the conventional combustion engine, new drive concepts are constantly arising causing completely new acoustical conflicts and requiring new approaches and engineering solutions.

Although acoustical design for electric 2-wheel vehicles is still unclear, it seems that vehicle acoustics, sound design and NVH[99] will become even more crucial for all kind of vehicles.

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[98] Link: https://www.researchgate.net/publication/301439478_Future_Acoustics_of_Electric-Vehicle

[99] NVH: Noise, Vibration and Harshness. It is an industry term that stands for the search for the source of a noise, shake, or vibration, and it refers to the entire range of vibration perception, from hearing to feeling.

As already mentioned in the project, it comes the need to see in the recent future new regulations regarding electric motorbikes, consequently these conclusions may differ regarding that an exhaust study should be done taking them into consideration.

Also, to meet the new challenges in the field of acoustic comfort, advanced analyses must be developed in order to adequately determine and make measurable the sound sensitivity phenomena.

After studying the sound module it seems interesting to see if is viable to introduce the new idea.
GOVECS has approximately an investment cost budget for a new product development from 4.5 to 7 million euros. Considering from two to two and a half years to completely develop a new product. The investment costs of this company take everything into consideration; from all the processes to build a new motorbike to the introduction of some changes and advances. These costs may vary in other companies such as BMW motorcycles, where it takes from four to five years to develop a product with an investment around years 30 to 50 million euros.

The estimation of inversion for a module like the described has is of 370,61 €. It fulfils all the components costs and incorporation in the electric motorbike.

If the price is compared with some of the costs that GOVECS enterprise spends in the motorbike's construction and delivery process, shown in Table 5 of chapter 10, it is seen that they are similar to these; baring in mind that this is an hypothetical price that has been calculated upwards, as it is better to have a high budget and see its consequent savings.

If the kit is introduced into a fleet of 1000 motorbikes, would have a price of 291.094,50 €; decreasing the cost per unit (291,0945 €/unit), as it seems obvious that the price of a unit should not be the same as a serial production of it.

Taking as example S1 .5 model base price, which is 4.990,00 €, the total module price represents a 7,43 %. Apparently, would be possible to install a sound module similar to the characterized and contribute to the electric world's improvements.

By doing this project, somebody is able to see the great number of options that a company has to foresee to design a module like the described. Though many structures are already created as a package for some companies, a simple solution with the necessary tools can be easily designed, bearing always in mind the criteria and required considerations in order to follow the existing law and environment restrictions.

The result of this study could be the start of the commercialization of a product. It gives an idea to the big companies to innovate in their two-wheel vehicles, seeing further than the current basic designs.

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