Report

Bicycle Probe

Author(s):

- Juho Ruusunen
- Kaan Isik
- Logan Smith
- Mélissa Boularas
- Zuzanna Szmytke

Acknowledgement

Glossary

Abbreviation	Description
COP	Conference of Parties
EPAC	Electronically Power Assisted Cycles
EPS	European Project Semester
ERSO	European Road Safety Observatory
ISEP	Instituto Superior de Engenharia do Porto
SDGs	Sustainable Development Goals
USB	Universal Serial Bus

1 Introduction

In this paper we will document the process of creating a bicycle probe device meant to measure the polution of the air and present user with the data from other users, along with ensuring their safety. In this chapter we included a general presentation of our team, goals and motivations, along with basic outline of our work methodology.

1.1 Presentation

The group consists of six members: Zuzanna from Poland, Kaan from Belgium, Julia from Germany, Juho from Finland, Logan from Scotland and Melissa from France. The different backgrounds give a wide spectrum of resources. All members have experience working in teams to create new products or versions of existing products, nevertheless, the different educations focus on different aspects, e.g. the level of engineering, design, marketing, economy, and creativity. Furthermore, the various backgrounds provide the individual with a new view or level of programs, methods, and priorities within the focus areas. All those information are gathered in the **Table 1**.

Table 1: Team members

	Zuzanna Szmytke	Kaan Isik	Julia Szembek	Juho Ruusunen	Logan Smith	Melissa Boularas
Country	Poland	Belgium	Germany	Finland	Scotland	France
Studies	Computer Science	Product Design	Interactive Media Systems	Mechanical Engineering	Electrical Power Engineering	Environmental Engineering
University	Lodz University of Technology	Univeristy of Antwerp	Augsburg University of Applied Sciences	Tampere University of Applied Sciences	Glasgow Caledonian University	Unilasalle

1.2 Motivation

Our team will focus on the 3D modeling of a bicycle probe. This probe, named GOairLight will ensure the cyclist the safety he needs to ride from a point A to B, and in the meanwhile, get information about air quality. As we are all aware about the air quality issues, especially in big cities, this is a good opportunity for all of us to work on that issue. The project was chosen because all of the team members can participate with their knowledge from different backgrounds (see **Table 1**). The project realization was in english, meaning that we have to talk, to write and the understand english. This is an opportunity for us to improve our english.

1.3 Problem

Nowadays we see a rise in the ecological awareness of people. We are more than ever conscious of the health problems caused by air pollution (see also Introduction below). We want to be more and more informed about our immediate environment. However, currently, the most popular means of measuring air pollution is by stationary probes placed in certain parts of the city. Pollution maps created this way are insufficiently accurate. GOairLight can be a solution to have a real-time data collection regarding air pollution in cities. Even though cycling accidents are decreasing over the years, accidents related with cycles still occur, meaning that safety isn't 100 % ensured.

1.4 Objectives

The 2 main goals of GOairLight is to ensure the safety of the cycist with an all-included device equiped with a front, sustainable energy provided light. This same device get information about the air quality in the cyclist's environment. GOairLight aims in helping the bicycle community on finding better - less polluted routes. We want the rider to be more conscious about his lifestyle.

1.5 Requirements

Functional requirements

- The prototype has to be a device that transforms a bicycle into a smart mobile probe
- A 3D modeling must be done to imitate the real-life conditions when using GOairLight

Limitations

- Maximum budget of 100.00 €
- Low-cost hardware solutions
- Open-source software

Technical requirements

The probe must comply with the following european directives:

- 2006/42/CE 2006-05-1705-05-1717 [https://ec.europa.eu/growth/sectors/mechanical-engineering/machinery]
- 2004/108/EC 2004-12-15 [https://ec.europa.eu/growth/sectors/electrical-engineering/emc-directive]
- 2014/35/EU 2016-04-20 [https://ec.europa.eu/growth/sectors/electrical-engineering/lvd-directive]
- 2014/53/EU 2014-04-16 [https://ec.europa.eu/growth/sectors/electrical-engineering/red-directive_en]
- ROHS EU Directives [https://ec.europa.eu/environment/waste/rohs_eee/legis_en.htm]

1.6 Functional Tests

Since our product is partly meant to provide safety for the user, all of its components must work correctly. In order to ensure that, we decided on conducting several tests of both components and the software, as depicted in **Table2**

Table 2: Functional tests

Element	Purpose	Testing
Led light/lasers / turn signal button	Increasing the visibility of the user	Provide processor with test code for turning on all the lights and testing buttons
Arduino board	Make sure the control unit of the product is functional	Test code example
Sensors	Make sure the components are working	Test code example
Dynamo	To provide electricity to a device	Power a test diode
Accumulator	Make sure the energy is stored	Check if the device works when not provided with energy from dynamo
Application	Make sure the application is clear, legible and connects to the probe	Test the included functionalities and possible scenarios of use
Cloud	Make sure the data is transferred to cloud	Read data in the cloud
Bluetooth	Check if Bluetooth connection is working	Test the connection between device and application, send dummy data

1.7 Project Planning

In our project we use the Scrum methodology **[1]**. The main idea behind it is to break down work into single tasks that are then completed in a given time frame, called sprint. Sprint can last anywhere from a week to a month, however we chose to use a one week interval. The general expectations for the project and tasks to be completed are placed in the product backlog. Then tasks for each sprint are derived from those general ideas and placed in the sprint backlog. As the sprint progresses they are moved to an "in progress" section and finally the "done" section. Those tasks and workload division are established at the first meeting of each cycle. During the sprint, team members conduct short meetings to update on the state of their tasks and possibly discuss them. Then after each sprint the team members meet to assess the completion of the tasks and the general state of the project.

To help us manage the scrum tasks, we use a Trello board **[2]** where each team member can easily look up or update their tasks during the sprint. The **Figure1** shows how our Trello model looks like.

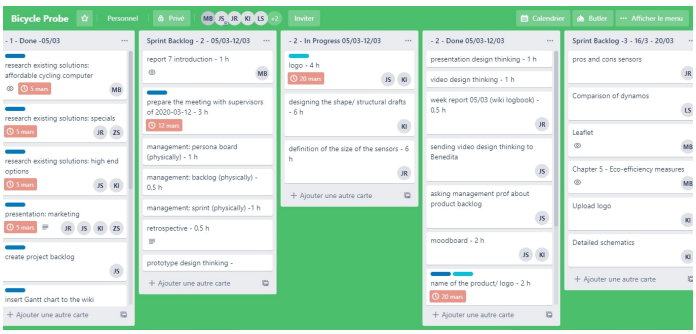


Figure 1: Our trello model

1.8 Report Structure

The report is structured as following (**Table 3**):

Table 3: Report structure

Chapter	Name	Description
1	Introduction	General information about the team and the project
2	State of the Art	Market research on already existing solutions
3	Project Management	Overview of the different aspects of project execution
4	Marketing Plan	Analysis of the market the product will be entering
5	Eco-efficiency Measures for Sustainability	Means of achieving sustainability of the project
6	Ethical and Deontological Concerns	Ethical aspects of the project
7	Project Development	The technical description of the project execution and steps taken to complete the product
8	Conclusions	Discussion on the project results

2 State of the Art

2.1 Introduction

A bicycle probe is a smart device used on a bicycle. The goal of GOairLight is to collect information about the air quality and in the meanwhile, that can keep the rider safe.

The European Road Safety Observatory (ERSO) is in charge of gathering information on road safety around the European countries. In 2016, 25 600 people were killed in road accidents. 2000 of the casualties were cyclists, which represents 8 % of the total deaths. The countries with the highest percentage of casualties are the Netherlands (19 %), Denmark (15 %) and Germany (12 %). ERSO also investigated the age of the cyclists who died on the road: most of the accidents occur for cyclists aged between 12 and 17, and those between 65 to 70 years old. Cyclist's fatalities are more likely to occur between 14:00 to 18:00 from Monday to Friday and on Sunday from 16:00 to 20:00. That information is important so that we can see more clearly to which people the bicycle probe would be more interesting. The ERSO showed as well that 26 % of cyclist fatalities occurred when there was no or poor lighting. We can see that light signalization must be a core component to improve the cyclist's safety. Furthermore, the studies show that the body parts injured were upper extremities, lower extremities and the head **[3]**.

Mobility is at the core challenges of the cities of today as it is a huge source of pollution and energy consumption. For all Europe, 30 % of the energy consumption is used for mobility, as stated by the European Environment Agency **[4]**, against 30 % in 2008 **[5]**. The European Commission wants to put the focus on the clean and cheap urban transport: the bike. According to the European Commission, "half of all car trips are of less than five kilometers". As a result, the Commission works on reinforcing the cycling aspects in the cities with the wish to offer more road safety for cyclists and reinforcing transport statistics **[6]**.

Sustainable mobility like bicycles could help to deal with air pollution issues. Air pollution problems have been addressed since the '70s and are seriously taken into account by the European Commission. The Air Quality Framework Directive 96/62/EC is the leading directive towards the reduction in the atmospheric pollutants. The air pollutants that have a limit value are the following: ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$), and nitrogen dioxide (NO_2). Nowadays, the Ambient Air Quality Directive regulates the air quality of the European countries. The air quality legislation wants each country to divide the territory into smaller zones and agglomerations. The air quality in each of those zones must be assessed and disseminated to the public. If the measures do not match with the EU limitations, the Member States must prepare an air quality program to address the pollution **[7]**.

The bicycle probe will collect information about the air pollution conditions in the cities. The goal here is then to transfer the data to a cloud so that the public can see in real-time the air conditions. The bicycle probe could fit with the Ambient Air Quality Directive as it represents an interactive way to get data from the air quality.

2.2 Existing Solutions

Firstly we decided to research affordable devices for a bike. Next we moved on to the higher end solutions of the same problems. Then we looked into devices with very specific applications in order to fully grasp the variety of the market. Finally, we searched for devices made with mapping polution in mind in order to see how other companies solved the problem and make sure no solution very simmilar to ours exists yet.

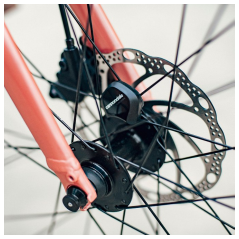
2.2.1 Affordable cycling computer

A lot of different cycling computers already exist on the market. For most of those devices, they are capable of monitoring the speed such as the current speed, the average speed or the maximum speed, and they have a time or a distance function as well.

Cycling computers are devices that the user positions on the handlebar of the bike to measure the performance on the move. **Table 4** shows different already existing cycling computers.

Table 4: Affordable Cycling Computer Options

Name	Features	Price (€)	Picture
B'TWIN 500 WIRELESS CYCLOMETER – BLACK **[8]**	* Speed function : current, average, max speed * Distance function: ride distance and total distance * Time function : time and stopwatch * Other parameters: temperature, back-lit screen	23	
BRYTON GPS CYCLOMETER BRYTON RIDER 15 **[9]**	* Direction: compass mode and Map mode * Connectivity function: Bluetooth technology * 30 real-time functions: duration, speed, distance, calories, pace, altitude, heart rate * Synchronization with Bryton app : training data	58	
MSW Miniac 322 GPS Bike Computer GPS, Wireless, Black **[10]**	* Direction: GPS enabled * Speed function : current, average, max speed * Distance function: ride distance and total distance, altitude * Time function : time and stopwatch * Synchronization with an app for cycling: training data	65	

Name	Features	Price (€)	Picture
CYCPLUS S1 Wireless BT & ANT+ Bike Bicycle Speed Sensor **[11]**	* Data feedback such as gradient will be shown, along with speed, distance and duration * Sleep mode will be activated when not in motion * Standby time: 300 days.	21	
Cannondale Wheel Sensor **[12]**	* Speedometer and GPS sensors provide route and distance data * The probe provides an alert for next service due * Compatiable with the Cannondale app * Life of 900 hours.	50	
RPM CADENCE **[13]**	* Cadence measurement * LED indicator lights * Bike Mount. Indoor spin compatibility * Bluetooth * Battery life: 1 year.	39.99	

2.2.2 High End Options

There are already a lot of bicycle probes available on the market. On the high-end spectrum, the devices are equipped with high-quality sensors and materials, but the prices show that as well. These probes are more targeted to fanatic cyclist and not the everyday person (see **Table 5**).

Table 5: High End Options

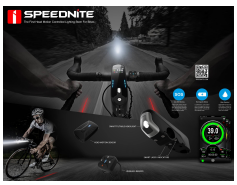
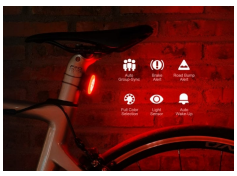
Name	Features	Price (€)	Picture
Beeline **[14]**	* Two navigation modes * Worldwide coverage (Google Maps) * Ride tracking & sharing * GPX import *Automatic backlight for night rides * Lifetime app and firmware updates * App supports English, French, German, Japanese languages	99	
Cobi **[15]**	* Smartphone App: Easy to read and 100 % optimised for use by cyclists * Owner activation lock * Bike voice navigation * Worldwide offline maps * Ultra-precise bike weather * Trip planning and touring and GPX route import (via Komoot) * Apple Health / Google Fit Integration * Charging mount: Integrated charging station and control unit * AmbiSense light system: Automated front and wireless rear lights (to German StVZO road use regulations)	219	
Wraapit **[16]**	* Flexible: Smart snap wrap band dedicated to mount on sleeves or handlebars * Reliable: Long time battery life: about 7 days (regular usage) * Multifunction: Phone calls, Messages & e-mails, Music remote control * Azimuth navigation * Turn by turn navigation * Speedometer * Compass	-	
Smarthalo 2 **[17]**	* Compas Navigation * Turn-by-turn Navigation * Automated Light * Anti-theft alarm * Fitness tracker * Customizable assistant * Wheather proof * Long battery life * Unique tool prevents teft	159	

Name	Features	Price (€)	Picture
Bisecu **[18]**	* Smart Lock * Theft prevention with alarm * Bike sharing through application * Real-time riding data analysis * 6 months usable battery life * Speedometer	169	
BH51 (Range) helmet **[19]**	* Hands-free operation * Smart Lighting * Fall Detection * SOS-Button * One-click answer to phone * PTT Walkie-Talkie * Voice navigation * Waterproof * Open speaker design	158	

2.2.3 Specials

In specials, you can find devices with more special features. Many of these products were found in a website called Indiegogo, so many of these products are using brand new designing and latest technology. **Table 6** shows the already existing products.

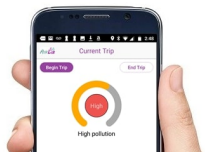
Table 6: Special Options

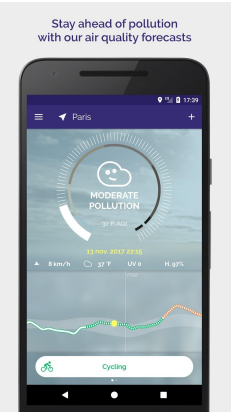
Name	Features	Price (€)	Picture
Speednite **[20]**	Turning indicator when tilting head Brake light SOS feature Handlebar remote	129	
Raz Pro **[21]**	Brake light Road bumb alert Light sensor and auto on/off	50	
I LOCK IT GPS **[22]**	Automatic bike lock and unlock Anti-theft sensor and alarm Sharing bike without key Real-time alarm notification on your smartphone Live GPS-tracking	200	
Garmin Varia™ RTL510 **[23]**	Visual and audible alerts to warn of vehicles approaching from behind	200	

2.2.4 Air pollution products creating maps

There are some air pollution products creating maps on the market. Some of them are gathered in **Table 7**.

Table 7: Air pollution products creating maps

Name	Features	Price (€)	Picture
AirBliss+ **[24]**	is working on delivering a connected respiratory protection wearable where every wearer is protected against air pollution and provided real-time crowdsourced ambient pollution data * Navigate in a polluted area with the crowdsourced pollution map * Rewarded for making your city a better place	-	
Airlib **[25]**	High-resolution urban air quality maps from automotive sensor data creating a groundbreaking air quality data analytics platform * Visualize and understand the pollution around, with unprecedented detail * Tells when not to go out * Recommends healthier routes	-	

Name	Features	Price (€)	
			
Plume Labs Flow 2 **[26]**	Personal air pollution sensor - Strapped to your bag, your bike, your belt, the real-time measurement of what's in the air, anywhere. * Every urban area on the planet is now covered by real-time air quality data—as well as forecasts for the coming 24 hours * Fluid timeline * Detailed data * Easily compare air quality worldwide * Get the info you need * UX/UI overhaul	159	

2.3 Conclusion

The market research shows that there are a lot of applications dedicated to bikes, with a broad range of different features. Some of the most basic being speed, temperature, health parameters sensors along with at least some form of navigation and in some cases an application dedicated to the device. More advanced products feature automated lights, weather forecasts, known already from some car products – handless phone features handling, along with some anti-theft safeguards. We can see that there is also an entire market dedicated to highly specialized devices tailored more to bikes than general use. In this case, possibilities are endless, however, the ones we found include fall and road bump detection, an SOS button, brake lights and turn lights controlled by head movements.

Another market we investigated was products meant to give information on air quality. We found applications offering both wearable pollution sensors and relying on the user's community to provide pollution maps of the city. Most of those solutions included an application showing warnings about the air quality from the community data and a personal sensor to measure it in the user's immediate area. While there are many solutions in this department already existing, none of them are dedicated solely for bikes, therefore they have no added benefits whatsoever.

Taking all those factors into consideration, we can say that while there are a lot of solutions for bikes, we failed to find one that would combine active measurement of air quality during the ride with bike specialized safety features that would encourage the user to engage with the device daily. We are aware that this sole functionality might not be enough to attract users. Since we are very concerned with general safety, other than allow individual users to avoid more polluted areas while they exert themselves, we thought that automatic lights might be a good idea to implement along with the pollution sensors. After carefully considering the market, we deemed that while there are already light sensor-controlled and indicator lights, we failed to find any eco-friendly alternatives and this is what we can propose.

Having defined our end goal, we now could concentrate on the path to achieve it. That being said, the next chapter concerns Project Management – the organizational "how" of our journey.

3 Project Management

In this chapter we will provide an overview of our project management methods and analysis of many different aspects connected to managing people, resources, costs, risks and time.

3.1 Scope

Product scope is defined as the functions and features that characterize a product or a service. Project scope, on the other hand, is the work that must be done in order to deliver a product according to the product's scope (required functions and features) **[27]**.

We created the following Work Breakdown Structure (WBS) as shown in **Figure 2**. Where we have six different stages:

1. Proposal
2. Design
3. Interim
4. Executive
5. Testing
6. Final

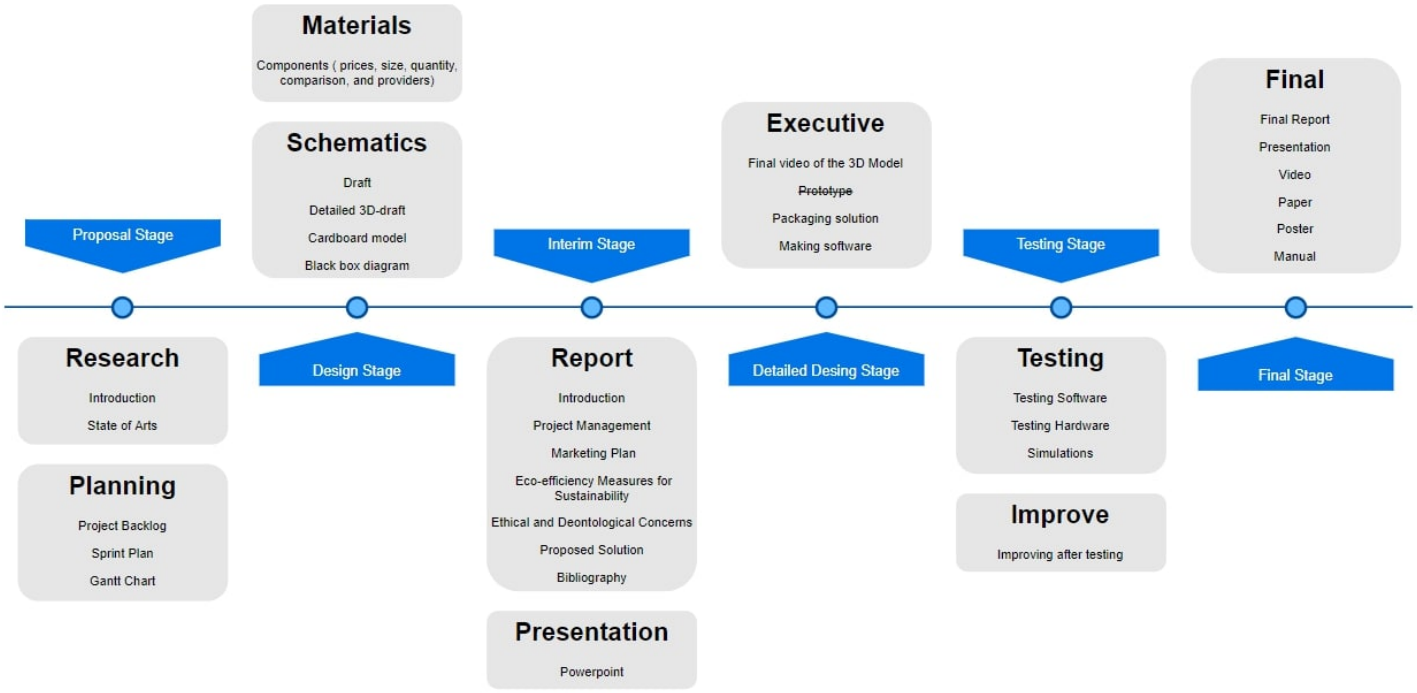


Figure 2: Work Breakdown Structure

3.2 Time

In this project we have limited time so we had to make Gantt Chart help us organize our time. We created our Gantt Chart **Figure 4** using given deadlines. We created our first version of Gantt Chart early and kept updating it (see **Figure 3**). Gantt Chart changed a bit because of COVID-19, for example we didn't build prototype, because it was impossible.

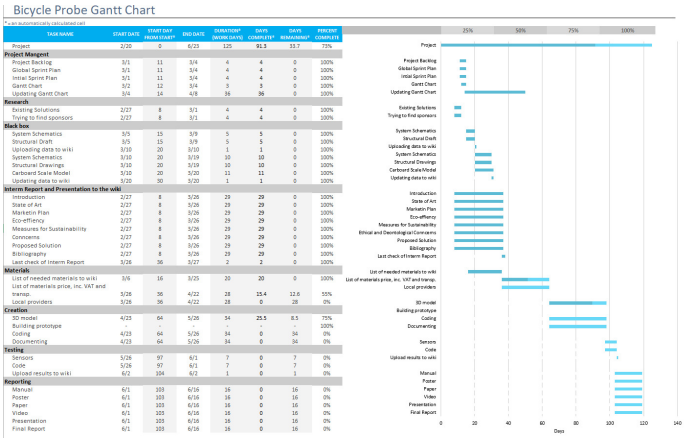


Figure 3: Previous Gantt Chart before COVID-19

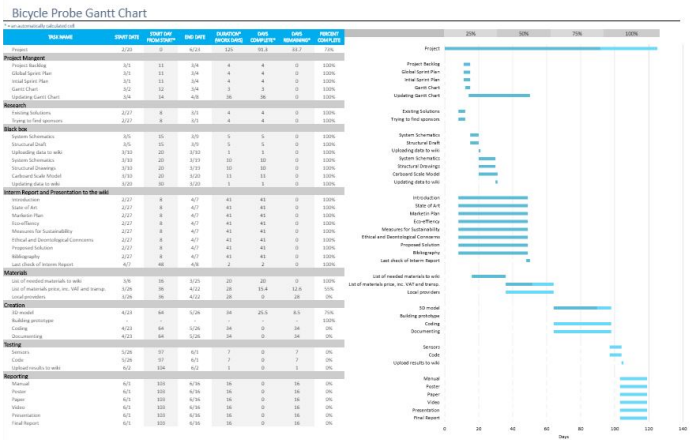


Figure 4: Updated Gantt Chart

3.3 Cost

This chapter helps the reader with a better understanding of how much the whole project will cost regarding the final product cost as well as the working cost.

3.3.1 Material costs calculations

The following **Table 8** provides information about the cost of components.

Table 8: GOairLight's list of components

N°	Item	Part of the device	Provider	Cost (per unit)	Quantity	Total cost for the prototype
1	AXA HR Traction Power Control Dynamo	Fitted to front wheel of bicycle	Bike-Discount	28.50	1	28.50
2	LADDA Rechargeable battery, HR6 AA 1.2 - 1.5V	Inside main casing	IKEA	1.56	4	6.24
3	1A Step-up (Boost) Converter	Between dynamo and battery connection	Hobby Components	2.26	1	2.26
4	SSC Seoul P4 (U-bin) LED emitter	Front of main casing	FASTTECH	0.75	3	2.26
5	4 x 1.5V battery box (RS PRO AA PCB Battery Holder)	Inside main casing	RS Components	0.66	1	0.66
6	1N4007 diodes (bridge rectifier)	Inside main casing	RS Components	0.06	4	0.24
7	Electrical wire	Inside main casing and connection from dynamo to battery	RS Components	0.33	1 (meter)	0.33
8	Arduino Nano BLE Sense	Inside the main casing	Arduino store	27.00 + tax	1	27.00 + tax
9	Adafruit CCS811 Air Quality Sensor	19.95	1	19.95		
10	5 Ohm resistor	Inside the main casing	0.37	Banggood	10	3,67

3.3.2 Working cost calculations

3.4 Quality

Quality metrics are the key components of an effective quality management plan as it is used to provide the customer with an effective final product. It must help answering the needs of the customer with acceptable performances. Metrics should be clear, measurables, controlable and reportable. The limits or thresholds will be assessed in this section. Based on customer product requirements and deliverables, the following metrics will be assessed:

- Data quality
- Service quality
- Material quality
- Product quality
- Limits and thresholds

3.4.1 Quality metrics

As an innovative device, GOairLight must ensure the customers with good information and good quality product.

Data quality : It is important to provide effective information to the customer. GOairLight is based on the sharing of information throughout the community. This is a fundamental requirement to provide the customers with good information and datas. Sensible data will be recorded, we have to make sure the sensors are well calibrated. A light intensity sensor i integrated to the whole system.

Service quality : The service quality will be ensure via the GOairLight app. The results from GOairLight sensors will be shown with the Android application, where the user could see the air quality data, recorded on an interactive map. We would like this application to give as well information about the better routes to take (instead of the polluted routes), and the humidity. Lights will turn on depending on the light intensity.

Material quality : We must make sure every component arrive in good shape (no outside/inside damages). They must comply with EU directives on health and low voltage.

Product quality : The general product quality is the most important part of the quality section. We have to make sure that the final product is well designed to fit on every bikes, otherwise we could loose a market segment.

3.4.2 Limits and thresholds

Due to the circumstances of COVID-19, no physical prototype will be built. No physical tests will be done neither meaning that we can't do the performance metrics. This is a big problem regarding the quality of the final product.

3.5 People

Stakeholders are a very crucial part of each project. Their involvement can make or break the project, therefore it is crucial to identify them beforehand in order to properly manage them during the execution. In our project, first and foremost, the key stakeholders are team members and the supervisors. Each of them has different investment in the basic tasks the project is comprised of. Their involvement can be observed in the following responsibility assignment matrix (**Table 9**), where:

- R – Responsible – the person that is in charge of completing the task
- A – Accountable - the person responsible for decisions about the task and making sure its final outcome meets requirements
- C – Consulted – The person whose opinions influence the execution of the task
- I - informed – The person who has no direct influence on the task but is being updated on its progression

Table 9: Responsibility Assignment Matrix

Task/Person	Kaan	Melissa	Zuzanna	Juho	Logan	Julia*	Supervisors
Task identification and allocation							C, I
Gantt chart	A	A	A	R	A	A	C, I
State of art	R	R	R	R	R	R	C, I
Component research	I	I	R	R	R	-	C, I
Design schematics	R	C	C	C	C	-	C, I
3D model	R	C	C	C	C	-	C, I
Black box diagram	R	R	C	C	C	-	C, I
Technical schematics					R	-	C, I

Task/Person	Kaan	Melissa	Zuzanna	Juho	Logan	Julia*	Supervisors
Project management	I	R	R	R	R	-	C, I
Marketing plan		R				-	C, I
Eco-efficiency and sustainability	I	R	I	I	I	-	C, I
Ethics and deontology			R			-	C, I
Interim presentation	R	R	R	R	R	-	C, I
Interim report	R	R	R	R	R	-	C, I
Arduino software			R			-	C, I
Application				R		-	C, I
IoT platform				R		-	C, I
Final 3D model	R	C	C	C	C	C	C, I
Hardware simulation?						-	C, I
Testing software						-	C, I
Final report	R	R	R	R	R	-	C, I
Leaflet	I	R	I	I	I	-	C, I
Packaging solution						-	C, I
Poster						-	C, I
Manual						-	C, I
Final presentation						-	C, I
Paper						-	C, I
Video						-	C, I

** Unfortunately Julia has left our project, however she still completed several tasks at the beggining of it.*

For these tasks to be completed and for them to fit into the entire project properly, good communication between the team members themselves and the team and supervisors is needed, which we will discuss in the next subchapter.

3.6 Communications

For a project, especially one conducted remotely like ours, communication is one of the most crucial aspects. Each team member needs to be aware of the overall situation of the project, their own responsibilities and whether another member might need help with their task. Even the slightest misunderstanding might in the long run turn out to be detrimental to the project as a whole. Another crucial aspect is communication the one with the supervisors. It is required in order to assure that the project is going in the correct direction and to obtain help resolving issues we are not equipped to deal with on our own.
In the following table (**Table 10**), we can see different types of communication utilized in the project:

Table 10: Methods of communication

Type	Medium	Schedule	Participants	Objectives
Project meeting	Microsoft Teams	Every Thursday	Team Supervisors	Updating the supervisors on the progress, resolving issues and seeking guidance, receiving feedback on completed tasks
Project planning	Microsoft Teams / Zoom	Beginning of every sprint	Team	Set tasks for the new sprint cycle
Team meetings	Microsoft Teams / Zoom / Whatsapp	When needed	Team	Discuss the current tasks and ideas, help each other
Briefing meetings	Microsoft Teams / Zoom	Thursday after project meeting	Team	Discuss the feedback from supervisors, reorganize project accordingly
Supervisor consultation	Microsoft Teams / Zoom /e-mail	When needed / during class	Team Supervisor	Discuss problems in specific field

Due to the circumstances beyond our control, we had to resign from face to face meetings, however at the beginning of the project all of the communication via Microsoft Teams or Zoom was done in person.
This was one of the risks we took up when starting this project – possibility of outside influences on the project completion, on which we shall elaborate more in the Risks subchapter.

3.7 Risk

Undertaking any kind of project, or more accurately, investing time and money in it unavoidably comes with risks, being a possibility of something going unexpectedly wrong in the project. In order to have a chance to counteract them, risks need to be assessed and identified at the beginning of the project.
Risks can have varying impact on the project as well as probability; both of those factors make up how severe the problem is, when initially assessing it.
In the following table (**Table 11**), we have listed the possible risks connected to our project:

Table 11: Risk assesment table

Key	Risk	Cause	Detection	Impact	Probability	Resolution
Internal risks						
1	Conflict between members	Disagreement,Personal problems between members	Difficult cooperation	High	Low	Team members not involved in conflict mediating, in extreme case reassigning tasks not to force the parties to directly work together
2	Member leaving project	Personal matters, health issues	Information from the member	High	Average	Reassigning the missing member's tasks
3	Insufficient knowledge	Lack of specialists in particular field in the team, lack of experience	Problem with completing a task	Average	Average	Avoid setting tasks that might exceed our limits. Not setting unrealistic goals, research possible different solutions

Key	Risk	Cause	Detection	Impact	Probability	Resolution
External risks						
4	National/international emergency	Epidemic, natural catastrophe etc.	News alerts	Very high	Average	Proceed with project to the best of our capabilities in the situation
5	Materials being out of stock	Oversight when choosing materials, changing market situation	Not being able to buy component	Average	Low	Enquire the supplier about product availability, change the component to a similar one available
6	Faulty components	Manufacturer's mistake	Product not working properly	High	Low	Test the components at acquisition, ask manufacturer for refund/ replacement
Technical risks						
7	Software or hardware not working properly	Lack of tests in all execution stages	Later testing, product not working on final presentation	Very high	Very low	Thorough testing while the project is still in progress
8	Components do not fit together	Carelessness	Problems during assembly of the product	High	Low	Careful design and selection of components beforehand
9	Data theft	Insufficient encryption when transferring data to cloud	Hard to detect unless exposed	High	Average	Limiting sensitive data being sent to cloud, ensure the data is properly encrypted
10	Air access design not waterproof	Insufficient humidity protection	Electronics malfunction	High	Low	Testing the design before placing the electronics

These aforementioned risks can be compiled into the following risk matrix that shows which risks are more severe:

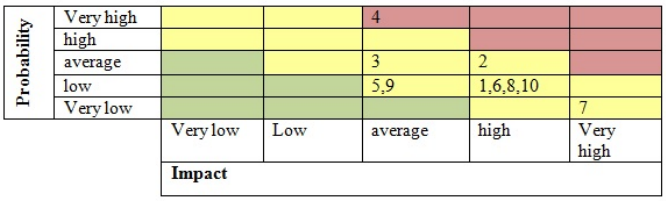


Figure 5: Risk matrix

As we can see from this table, the most crucial risks for our project would be a team member leaving, an emergency of a high caliber and possibly us having insufficient knowledge to complete the project. While the first two are something mostly beyond our control in the current situation and we can only work on how to minimize their impact, we can only do our best to avoid the third one, by being resourceful with our current knowledge and seeking help from supervisors when needed.
Having the risks analysed and defined, we can move on to managing the procuremnet strategies.

3.8 Procurement

The procurement strategy that we adopted was mainly focused and relied, on the common sense of the team. Knowing our budget of 100.00 €, we had to carefully design and develop our bicycle probe in order to acquire our materials and components for under the set budget.

When sourcing our products, it was crucial that they were found at a cost-effective price. During the task of searching for materials and components, we had to find different versions of the same component and then compare each one. This was done to assure the best quality and reasonably priced product would be incorporated into our probe. Where possible we also looked for providers with either free delivery or Porto / Portuguese based company.

We made sure that our total procurement price will be less than the price of our bicycle probe. This ensures a profit is made for GoAirLight.

Our main thoughts whilst procuring components and materials:

* Low cost yet high quality

* Reliably and legitimately sourced

* Compatibility with the rest of our bicycle probe

3.9 Stakeholders Management

As already stated in subchapter 3.5 stakeholders are crucial to the very existence of a Project. Having this in mind, one needs to be aware of each of their roles, investment in the project and their influence on it. Knowing all those factors we can then decide how to manage each group so that they are satisfied and continue supporting our undertaking.
Firstly we need to identify key roles in the project and people connected to them in order to be able to assess their interest and power over the project. For the purpose of analyzing those factors we used the following **Table 12**

Table 12: Stakeholder analysis table

Key	Stakeholder	Role	Power (1-5)	Interest (1-5)
A	Team	Execution of the project	5	5
B	Supervisors	Controling	3	5
C	Suppliers	Supplying materials for the project	2	1
D	Customers	Buying and using the product	2	3
E	Sponsors	Supporting the project	2	5
F	Competitors	Competing	1	1
G	ISEP	Sponsor	5	2

Having gathered this information, we created a stakeholder analysis matrix shown in **Figure6**, to help us visualize better our stakeholders and decide how we should manage them during the project.

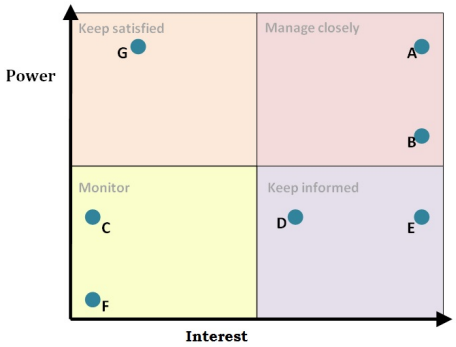


Figure 6: Stakeholder analysis matrix

- **Manage closely** - As we can see from the matrix, our main priority are team members and the supervisors, since they have the most power and interest. As established in previous chapters, they are the key stakeholders. Other than the team, we will engage this group by regular updates and consultations with them.
- **Keep satisfied** – Those are the high power stakeholders who hold no particular interest in the project. We should exercise caution in interacting with those stakeholders and bring in the best possible results, to keep them satisfied. In our project this role fits the ISEP.
- **Keep informed** – this is the group that has little power over the project. However they do have a high interest in it and it is in our best interest to keep them informed of the work progress, for them not to lose that interest in our final product. In our project this can both be said about customers and the sponsors.
- **Monitor** – these are groups who have very little interest and power over the project. They are related to it in some way and need to be watched for their indirect influence. In our case this would be component suppliers, whose only impact on the project is the quality of their services and our competitors, whose products rival ours and might affect out sales.

3.10 Sprint Outcomes

This part will go through the Global Sprint Plan, the Project Backlog and the Sprint Plan of the project. This chapter will help the reader understand how our work was divided through the time, how we deal with the different tasks, and how much time was allocated for each task. The Sprint planning takes part in the SCRUM methdology and includes the work that has to be performed in the Sprint. The following **Table 13** presents our Sprint Planning:

Table 13: Report structure

Sprint n°	Lasts
1	Week 10
2	Week 11
3	Week 12
4	Week 13
5	Week 14
Easter Break	
6	Week 16
7	Week 17
8	Week 18
International Student Week	
9	Week 20
10	Week 21
11	Week 22
12	Week 23
13	Week 24
14	Week 25
15	Week 26

In order to see the tasks we have to complete for the week to come, we are using a Trello model as you can see on Our Trello model. The Trello model is an intersting tool because we have a clear view about what's need to be done, who is doing what, what is already done, etc. This application allows us to set the deadlines for each of the tasks and a colour code makes it easier to see the oncoming deadlines.

The Sprint Backlog is the set of the Product Backlog items selected for the Sprint. The Sprint Backlog is interesting because it makes it easier to see which tasks have been done, which ones are still in progress, or the ones that are already finished.

3.11 Sprint Evaluations

Include the summary of all the sprint retrospectives, including any actions implemented as part of the team's continuous improvement strategy.

3.12 Conclusion

4 Marketing Plan

4.1 Introduction

The role of marketing in an organization is to create strong profitable relationships with the customers. The role of the marketer is to choose the right people to target, to catch interesting market opportunities, to communicate on which products or services to offer and at what price or to decide which distribution system to use. Marketers create the link between the firm and the market. The marketing program can be summarized in how the company attracts, retains and grow its customers **[28]** . According to Investopia, a market is "a place where two parties can gather to facilitate the exchange of goods and services" **[29]** . It is represented by customers, competitors and trade.

This chapter will explore the marketing management of GOairLight, make a SWOT analysis, will define the strategic objectives of the product, will define the segmentation of the project, its position on the market and its budget.

4.2 Marketing management

The marketing management can be divided into 4 steps, according to An introductory note on marketing management, Michael Pearce (2008) **[30]** :

1. Define the marketing challenges
2. Identify attractive market opportunities
3. Select a primary target market
4. Decide on the product offering

4.2.1 Marketing challenges

GOairLight main goal is the ensure the security of the cyclist by helping him with automatic light system, and also to provide information to the cyclists' community by gathering air quality information on a mutual cloud. The challenge here is to create a strong functional value proposition because GOairLight product takes part in an already existing solution (see section 2.2 Existing solutions). The aim of the marketing management here is to get the potential customers to know about the benefits of our product in term of health and security. We also want to raise the awareness of the customers regarding air quality issues as well as road safety. By raising up information about those two points, we can create the need for the customer to have the GOairLight device. We need to put the focus on the creation of emotional branding.

4.2.2 Attractive market opportunities

By identifying attractive market opportunities means identifying what the marketers could do, even before the product is made. As already explained in the previous part, we know that a market already exists in the fields of computer bikes and air pollution interactive maps. The project GOairLight is to combine those two existing solutions in order to provide the customers with more information and an all-included device. Analyzing opportunities must be done following the 4 steps:

- Environmental scanning: can be done following the political development, economic issues, social trends and technology developments, legal and environmental forces – also called PESTLE analysis **[31]** . It can help the marketers with a better understanding of the external factors which can impact upon strategy and influence business decisions. The **figure 7** shows the 6 different factors and the elements that can influence the environment.

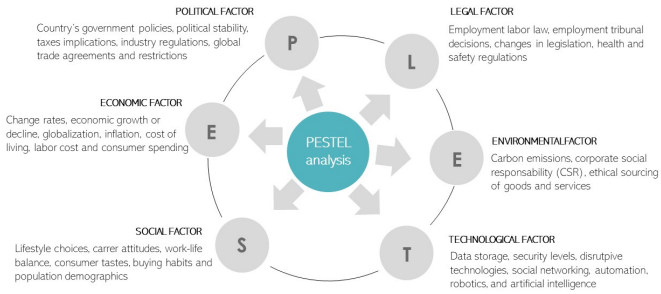


Figure 7: The PESTLE analysis

- Competitive analysis: can be done via a competitive matrix, it helps answering the question: Who else is offering something similar to what we are planning to offer? The competitive analysis shows the differences between marketing programs as well as marketing performances. The **Table 14** shows the differences between GOairLight sensor and other similar products.

Table 14: GOairLight competitive matrix

	Cannondale Wheel sensor's Strengths (+) and Weaknesses (-)	**Smarthalo 2 sensor's Strenghts (+) and Weaknesses (-)**	**Cobi app's Strenghts (+) and Weaknesses (-)**	**GOairLight sensor's Strenghts (+) and Weaknesses (-)**
Target market(s)	Non-leisure cyclists only: restrictive (-)	Bike delivery companies (+), upscale, modern class	Active people, upscale, modern working people	Active people, upscale, modern working people, elderly people, city bikes (+)
Product	* Automatic wheel sensor (+) * Connectivity with Cannondale app (+) * Less modern and useful device (-) * Least functionalities (-)	* Modern design (+) * Improved vision at night (+) * Routes custom-made for cyclists GPS (+) * Parked bike indicator (+) * Anti-theft alarm system (+)	* GPS and weather datas (+) * Automated light system (+) * Anti-theft alarm system (+) * Charging mount (+) * Advertising from the brand BOSCH (+)	* Fits on every bike (+) * Bluetooth connection with an app (+) * Unique combination (light and air quality sensor) (+) * No GPS (-) * Non anti-theft alarm system (-)
Price	Lowest available retail price (+)	High retail price (-)	Higher retail price (-)	Unknown retail price (?)
Place	Online shop: less advertising (-) but with online retailers (+)	Online shop: less advertising (-)	Same as for Smarthalo2	Same as for Smarthalo2
Promotion	* Facebook and Instagram up to date page (+) * Modern website (+)	Same as Cannondale	* Active on Instagram (+) but not on Facebook(-) * Modern website (+)	* Social networks: young population of viewers (+) * Hard to get known (-)
(Potential) Competitive barriers	Inferior product (-)	Superior product (+), a lot of functionalities (+)	Complete product (+), is part of BOSCH company (+)	Medium product (-), huge community must use it to see the effects (-), creation of a community system (+)

The competitive differentiation seeks to exploit deficiencies in competitive products or prices that could matter to the customer. The **Table 14** can help the reader to better understand the differences between similar products. We can see that GOairLight is located quite in the middle between the Cannondale wheel sensor which is a basic sensor without a lot functionalities (speed, distance, time) but with a connection app, and two high-tech devices like Smarthalo 2 and Cobi app, that are used to help the cyclist with environmental information (GPS, weather, alarms) and security functions like automated lights. Our product will have one big advantage compared to the others: it will be at the core of a huge community system thanks to the air pollution sensor.

- Customer analysis: is used to make a better understanding of the end users, buyers and intermediate buyers/sellers. As already mentioned, GOairLight sensor must be placed on a bike, which means the customer must have a bicycle or at least have the money to buy one (GOairLight can be a motivation for someone to start moving using a bike!). It is also mandatory for the user to have a smartphone in order to use the GOairLight app. From a general point of view, we would like to target each of the bike user groups, which means teenagers, workers, commuters, or elderly people. Groups of customers are known as segments which will be discussed in the section 4.5: Segmentation.

- Self-analysis: corresponds to the analysis of strengths, weaknesses, opportunities and threats (SWOT analysis, see section 4.3: SWOT analysis).

4.2.3 Primary target market

The primary target market is the segment of the marketplace a company is willing to have the best chance to sell **[32]** . In order to know our target market, we need to know worldwide conditions related to the use of bikes, the willingness of people to have a smartphone and their willingness to buy GOairLight regarding GDP.

4.2.3.1 Countries GDP

In order to target the most willingness-to-pay population, it is important to see the regions with most higher growth domestic product (GDP) per capita. According to the World Bank, the countries with the higher GDP are the ones with the deep blue color inside, as shown in the **figure 8** . We can see that Europe and Northern America gather the most important part of rich countries.

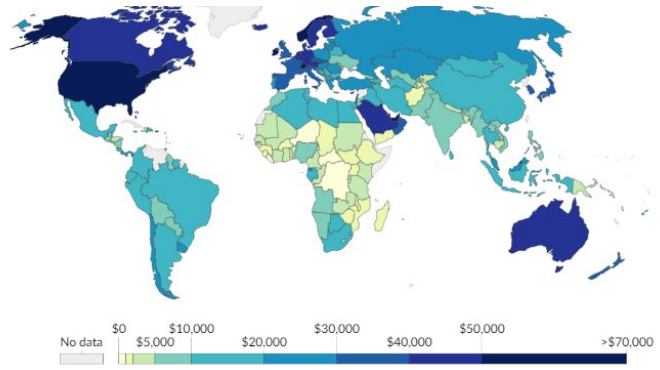
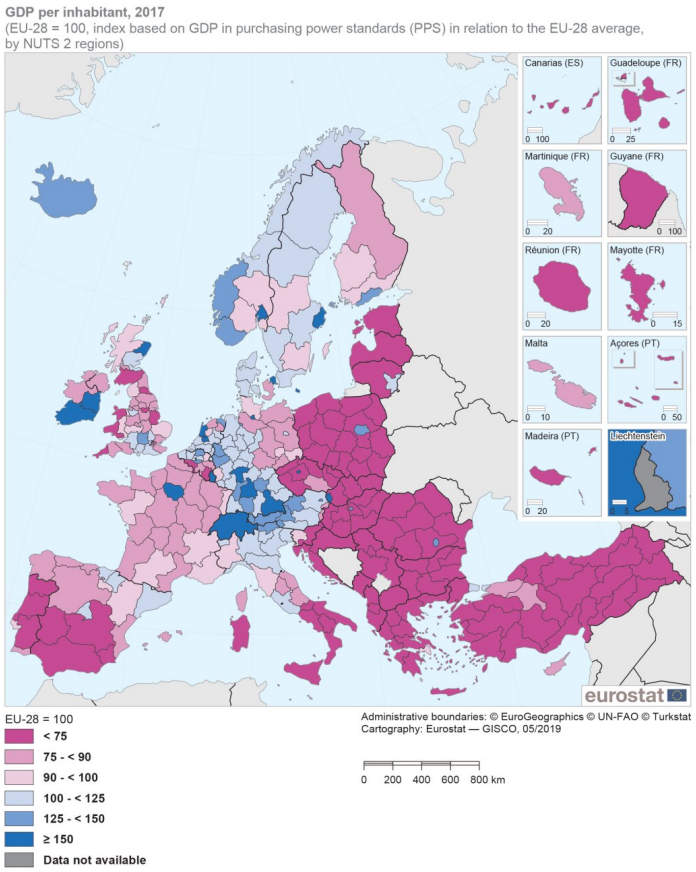


Figure 8: GDP by country **[33]**

Let's take a closer look at the European Union. The **figure 9** shows the GDP per capita by regions, in Europe-26. This map from Eurostat is interesting because we can clearly see which region we can target with more certainty of the people to buy. The regions located in Netherlands, Germany, Switzerland, Austria as much as the region of Paris are the richest regions in Europe.



Note: Norway, Montenegro and Albania, 2016. Switzerland: national data.
Source: Eurostat (online data codes: nama_10r_2gdp, nama_10r_3popgdp, nama_10_gdp and nama_10_pe)

Figure 9: GDP by country within Europe **[34]**

4.2.3.2 Smartphone utilization in Europe

It is interesting to think about which countries use the most smartphones. GOairLight can't work without the use of a smartphone. The following graph (**figure 10**) gathers some datas from Statista regarding smartphone consumption in countries from Europe. As for the previous map (**figure 9**), the Netherlands and Germany are the countries with the most higher smartphone adoption rate, so do Sweden or Spain.

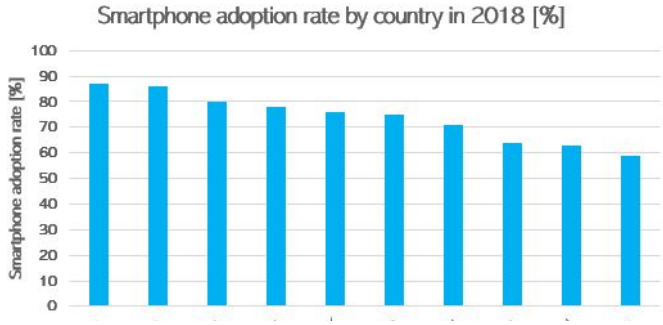


Figure 10: Smartphone adoption rate by country in 2018 **[35]**

4.2.3.3 Bike utilization in Europe

To see which country could be smartly targeted, analyzing the number of sales in European countries can be interesting. The chart below (**figure 11**) depicts the number of sales per country. As we can clearly see on this chart, Germany was the first buyer of bikes and electronically power assisted cycles (EPAC) for the 2016 year, followed by France and Great Britain, and then Italy. Someone who is willing to buy a new bike or EPAC is potentially willing to buy GOairLight sensor for example.

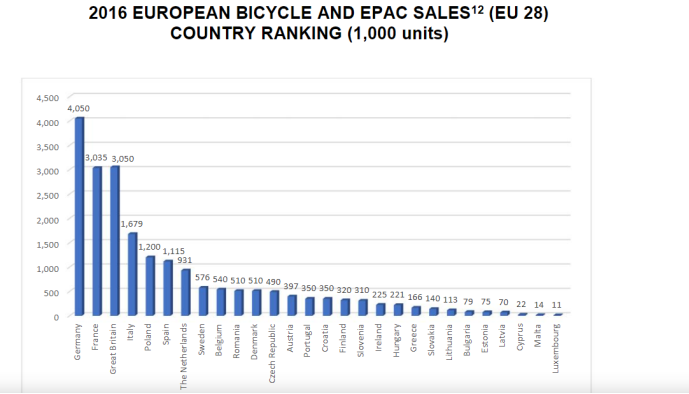


Figure 11: Bike sales in Europe in 2016 **[36]**

4.2.4 Conclusion

Regarding the market analysis, it could be a good strategy to target Germany, as the GDP, the smartphone adoption rate, and the bike sales in this country are the highest. Furthermore, the name of our product (GOairLight) is an international english name which can be easily understood by the German population.

4.3 SWOT Analysis

SWOT analysis is a management tool used to identify strategies for success. It can be used to guide individual thinking, group discussion or a large formal planning process. SWOT comes from **[37]**:

- Strengths: characteristics and capabilities that are superior to competition and that can be drawn to exploit opportunities and deal with threats.
- Weaknesses: deficiencies where the company needs improvement to remain competitive.
- Opportunities: external factors that could give an organization a competitive advantage.
- Threats: factors that have the potential to harm an organization.

Strengths and weaknesses are relative to specific threats and opportunities.

We can divide the SWOT analysis of our project into two distinct sections: the product SWOT analysis and the team SWOT analysis.

The team SWOT analysis

The team SWOT analysis shows the internal and external factors within our team work. You can see the details in the **figure 12**.

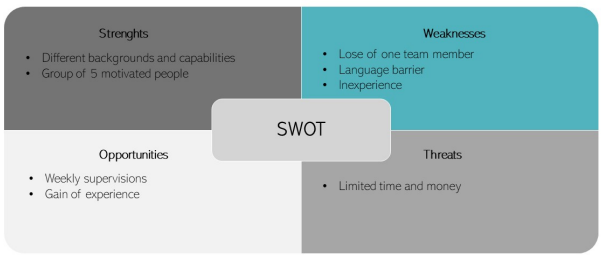


Figure 12: Team SWOT analysis

The product SWOT analysis

The product SWOT analysis shows the internal and external factors of the final product. You can see in it (**figure 13**) some innovative ideas as well.

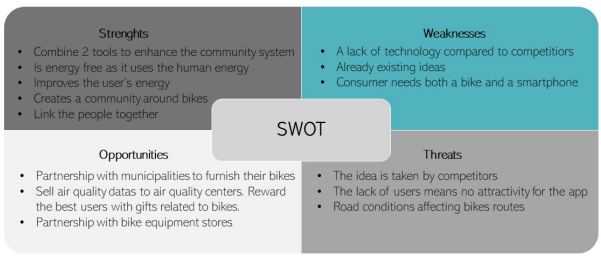


Figure 13: Product SWOT analysis

4.4 Strategic Objectives

4.5 Segmentation

According to the definition from Investopia **[38]** , segmentation refers to "aggregating prospective buyers into groups or segments with common needs and who respond similarly to a marketing action". This part is important in the marketing field because it helps understanding who the final user really is. This subchapter will go through the need created by GOairLight, the user's motivation, and the information point about the product and the ways they can get it.

4.5.1 Needs, motivation, information and purchase

According to An introductory note on marketing management, Michael Pearce (2008) **[39]**, the marketer should answer the following questions while trying to think about the needs, motivations, information and purchase:

Needs: "What wants and needs are people trying to satisfy? What is particularly important to them? [...] Are the needs and wants strong or weak?".

Motivations: "What motivation lie behind the choice of a product? [...] Is the buyer more interested in low initial price or low operating costs?"

Information: "Where do they get information about products [...] as they proceed through a process of considering a purchase? Where do they shop, and why there?"

Purchase "When do they go through this shopping/purchasing process?"

The following figure (**figure 14**) shows the answers to those questions.

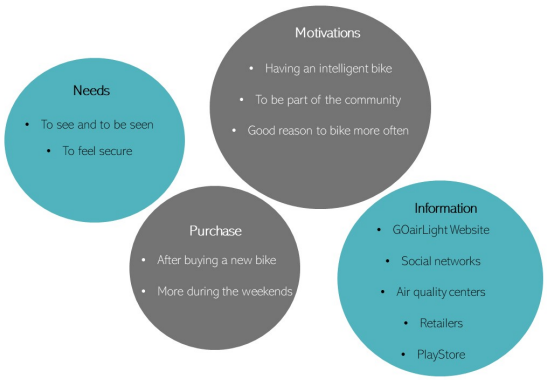


Figure 14: GOairLight needs, motivation information and purchase

4.5.2 Conclusion about segmentation

The bike segmentation is quite difficult to undertake because the choice of dimensions (customer-bases, sensitivity, place of distribution, etc.) is endless. The following table (**Table 15**) shows the different user types for bikes. A quick explanation is given in order to show why the user type is an interesting target or not.

Table 15: Different kinds of bike users

Type of bike user	**Positive (+) and negative (-) points**	**Target market?**
Leisure/tourism	A huge number of users (+), Huge area of diffusion (+), No relevant data during rush hours (-)	No
Off-road	No relevant data during rush hours (-), Not relevant use (-), Not in the cities (-)	No
Racers	Same as off-road users	No
Teenagers/children	Too young to get the point (-), Not enough diffusion (-)	No
Workers/commuters	Relevant data during rush hours (+), Huge number of users (+), Good area diffusion (+), Category the most affected by air pollution (+)	Yes

4.6 Strategy/Positioning

GOairLight aims to create a community around the city air quality, in order to raise people's awareness regarding air pollution. We are planning ot sell a quality product, meaning we want the customer to have faith into the product, rather than focusing on the number of sales. This is an outside-in approach, also called customer-centric perspective **[40]** . In order to understand where GOairLight is positioned within the market, a positioning matrix was made (see **Figure 15**). Regarding the 8 bike-computers assessed, the graph shows that there is a gap in the low to medium multifunctional devices.

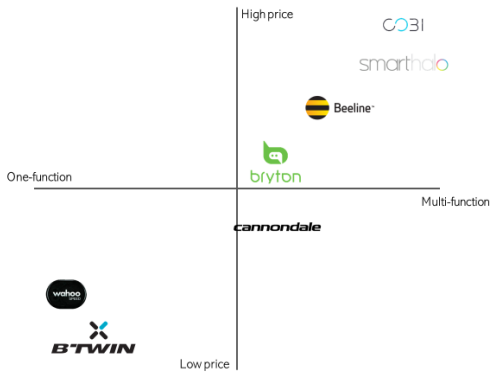


Figure 15: GOairLight positioning matrix (need to be reviewed)

The matrix above shows the situation of GOairLight compared to its competitors. According to Porter's generic strategy **[41]**, to be the leader in the market, our product must be the lowest-cost in the production and on the market. It must differentiate from the competitors thanks to innovation and its high-quality: we want to offer the customer a high quality computer bike sensor. GOairLight is offering a new combination of two useful tools : one improving the safey of the cyclist and another one which help the community a better knowledge about the city's air quality.

4.7 Adapted Marketing-Mix

An adapting marketing taken by marketers to actively track and respond to consumers. It refers to how the marketers adapt to the target market to suit the particular geography in which the firm is operating **[42]**. To better understand this approach, we are going to use the four Ps of marketing mix: price, product, place, promotion as shown in the **Figure 16**.

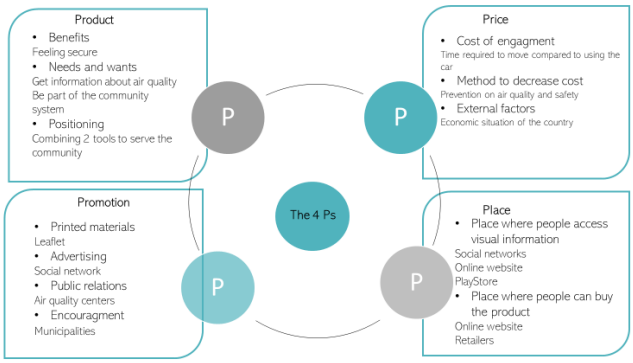


Figure 16: GOairLight adapted marketing mix

4.8 Budget

4.9 Strategy Control

4.10 Conclusion

Provide here the conclusions of this chapter and introduce the next chapter.

Based on this market/economic analysis, the team decided to create <*specify the type of product*> intended for <*specify the market niche*> because ... Consequently, the team decided to create a product with <*specify the features*>.

5 Eco-efficiency Measures for Sustainability

5.1 Introduction on Agenda 21

« Our common future » is the report of the World Commission on Environment and Development (1987), where we can see the following definition: "Humanity can make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs » **[43]**. Sustainable means maintaining the world we live in, by acting responsibly so that the resources on the planet will be able to support many generations to come. A sustainable world would preserve resources, generate energy thanks to renewable energy and protect biodiversity. In 2015 was held COP21 where the 17 sustainable development goals (SDGs) have been set. This chapter provides clues regarding our measures towards eco-efficiency. In the meanwhile, a life cycle assessment will be carried out to consider all aspects of resource use and environmental releases.

The Agenda 21 was the first report to gathering a global set of actions, that has to be undertaken within the frontiers of the United Nations System. Actions must be implemented at the local, regional and national scale, thanks to regulations and laws. The Agenda 21 planning was set 5 years after the Brundtland Commission, to monitor and report on the implementations and progresses throughout the United Nations. The following subchapters are from the Agenda 21 official report **[44]**, and shows the objectives and activities regarding:

- Energy development, efficiency, and consumption
- Transportation

Those two chapters can help the rider with a better understanding of the situation related to the importance of bikes in the cities, as well as the necessity of using renewable sources of energy.

Energy development, efficiency, and consumption

Protection of the atmosphere must be undertaken by each country on this planet. This is a global issue especially in the energy field where energy is essential to all kinds of activity on Earth. On the Agenda 21 has been declared that the energy must be based on efficiency: "All energy sources will need to be used in ways that respect the atmosphere, human health and the environment as a whole" **[45]**. Among other things:

- Governments from the United Nations should develop an economically viable and eco-friendly grid of energy to meet with the increasing energy demand.
- They have to make efforts on improving energy-efficient technologies and practices as well.
- The development of renewable sources of energy must be seriously considered.

Transportation

Transportation is "the movement of people or goods from one place to another" **[46]**. Transportation has good impacts on societies as it allows the movement of streams but is mainly criticized because it is the first responsible for atmospheric emissions **[47]**. The need to review the current transportation system is important. Some solutions were proposed to improve the transportation system in an international, regional, sub-regional and national level:

- Safe, less polluting, efficient access to means of transport,
- Collection and analysis of information between environment and transportation, with the focus on emissions,
- Development of strategies to implement transport planning seeking for fewer emissions and a better impact on the environment.

GOairLight must be the most eco-friendly and efficient as possible. Agenda 21 helped to set the directions for The Sustainable Development Goals (SDGs) of 2015. They will help us have a clear idea about the conditions to meet to have an energy-efficient and eco-friendly final product.

5.2 Sustainable development goals

The Sustainable Development Goals (SDGs) were set up at the Conference of Parties (COP) in 2015. The review of the 17 SDGs is shown in **Figure 17**. The SDGs take part in "The 2030 Agenda for Sustainable Development" seeking peace and prosperity for people and the planet. Our product can fit with two of the 17 SDGs :

- 11 : Sustainable cities and communities
- 7 : Affordable and clean energy

Figure 17: The Sustainable Development Goals

5.2.1 Sustainable cities and communities

The goal of GOairLight is to ensure the safety of the bike user, by using front and sidelight. The awareness of the other road users (car drivers for instance) would then increase and the risk of the accident would decrease. Moreover, having an air quality sensor will help the community dealing with the air pollution issue: by referencing the pollution on the roads, all the bike users can be aware of which road to use to avoid pollution. This is a community approach. According to the United Nations report, the proportion of inhabitants who have decent access to public transports remains low, with an average of 53 percent for urban areas **[48]**. The symbol of the 11th SDG is shown in the **Figure 18**.

Figure 18: Goal 11, Sustainable cities and communities

Improving road safety is a major theme in the 11th SDG. The promotion of walking and cycling is also important because bicycling is by far the most energy-effective mean of transport. It is also the most affordable for the urban poor. According to the European Commission in their report on "Smart choices for cities – Cycling in the city" of 2016 **[49]**, the reasons why people should use a bike is to make the city more livable. Bicycles use less space on the road than cars as well as the parking spaces. Bikes do not contribute to atmospheric emissions, except at the production stage. At the opposite, cars and other road vehicles emit particulate matters ($PM_{2.5}$ and PM_{10}), as well as nitrous oxides (NO and NO_2) among others. Riding bikes daily may improve the global health of the population. A study conducted by de Hartog et al. in 2010 **[50]** shown that using a bike daily increases the life expectancy of 3 to 4 years.

5.2.2 Afforable and clean energy

GOairLight sensors must use electrical energy to run. We want to convert mechanical energy (human energy thanks to the pedals) into electrical energy via the use of a dynamo. The mechanical energy runs to the dynamo. The dynamo is then used to power the battery contained in the sensor. Using human energy may help to deal with the issue of the energy source as it is not dependent on the energy grid. From a global point of view, the renewable energy sector provides more jobs to people than the fossil fuel energy sector **[51]**. The symbol of the 7th SDG is shown in the **Figure 19**.

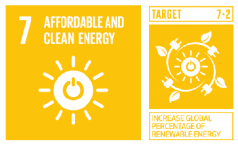


Figure 19: Goal 7, Affordable and clean energy

According to the United Nations, the transport keeps the transition towards renewables very slow. Transport and heating/cooling account for 80 % of the global energy consumption and they didn't match the waited progress on renewable energies. The following picture (**Figure 20**) from the Energy Progress Report shows the total percentage of renewable energy used in the transport field. We can conclude that there are still efforts and innovations to make to reach the goal of the 20 % share of renewables until 2020 **[52]**.

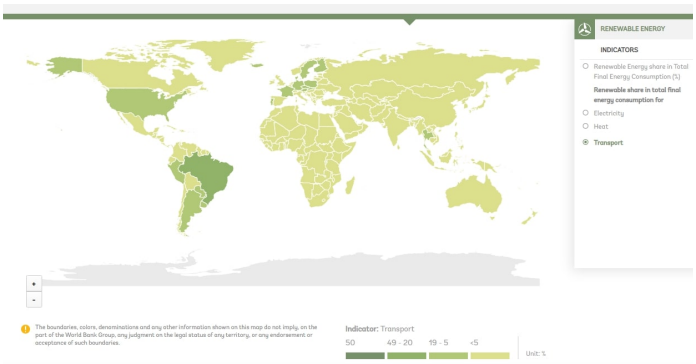


Figure 20: Global share of renewables used in transport **[53]**

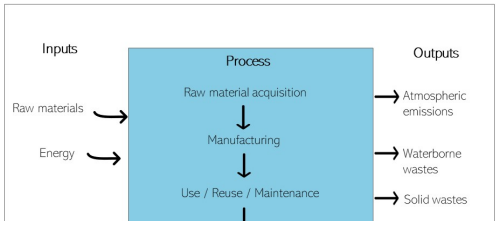
5.3 Life Cycle Analysis

5.3.1 Life Cycle Assessment

Life cycle analysis (LCA) is a tool by which a product's impact on the environment through its lifetime is evaluated **[54]**. It is a "cradle to grave" approach for assessing industrial systems. The LCA takes into account the inputs (flows and energy), the stages of the process, and the outputs represented by the atmospheric emissions, waterborn waste and solid wastes, as well as the main product and co-products. The typical LCA project plan follows the following stages **[55]**:

- Definition of the goal (see Section 1.4 Objectives) and scope (Section 3.1 Scope), identification of the context, the product or the technology and the system boundaries,
- Identification and quantification of energy, water and material inputs and outputs,
- Impact assessment on the potential human and ecological effects of the whole system. Quantification of metrics,
- Data interpretation for the selection of the preferred process or technology.

The following chart (**figure 21**) **[56]** shows the interconnections between inputs, the process and outputs.



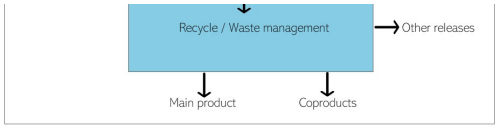
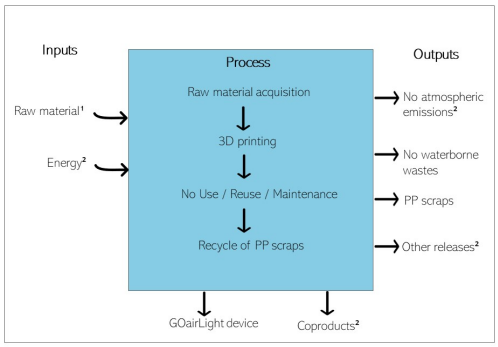


Figure 21: General LCA stages

GOairLight manufacturing process will follow the same trend. For the reason that we are not anymore building the prototype, the assessment of the whole system could be done, even though some important information are missing. We still can present the similar stages for GOairLight, compared to the **figure 22**.



[1]: *You can have a look at the complete list of components in Section 3.3 Material costs calculations*
[2]: *Unknown for now*
Figure 22: GOairLight LCA stages

5.3.2 Life Cycle Inventory

The life cycle inventory (LCI) is a tool to quantify inputs (energy and raw material requirements), and outputs (atmospehric emissions, waterborne emissions, solide wastes, and other releases) for the entire life cycle of the product.

GOairLight is a device working with electricty as the only source of energy.However, the energy (electricty) is created by the movement of the pedals, thanks to the human energy, which make it renewable, as long as the human has enough energy to pedal. Using another renewable source of energy (solar or wind) would have been to complicated to set up, and not suitable for our device as well. No material requirement is needed througout the life cycle of the device. Furthermore, no waste is porduced during the utilization phase. However, when comes the discard phase, the GOairLight must be split. The different components are not recyclable in the same ways.

5.4 Conclusion

GOairLight as the ambition to be energy-free thanks to the human energy input, meaning the cyclist have an control on the quantity of energy needed, and that no energy is wasted. We chose to create a PP based device, because PP is easily recyclable, and most of the sorting centers are equipped to deal with PP **[57]**. GOairLight is designed to have a real impact on the community as it aims to gather people around the air quality cause, while using low energy resources and materials. Our device deals with environmental concerns : The device will help people chosing their bike instead of their car, and is using human energy. However, the battery that is used is composed of Lithium which is responsible for damages on the environment when in the extraction phase. It is economic as it encourages people using or buying a new bike, and encourages the purchase of bike accessories. Finally, the social part is the power of the community, by the sharing of data to the common cloud.

6 Ethical and Deontological Concerns

In this chapter we will discuss the ethical aspects of our project. We will attempt to look at the task from different kinds of angles, presenting ethics from engineering, marketing, environmental and legal points of view.

6.1 Introduction

Ever since humanity started forming societies, it became apparent that to function together, we need a set of rules regulating our behavior towards each other. Be it religious commandments, human law or decorum, without them our world would fall into disarray. This is no different for our project, or companies in general. Without a set of ethics and laws, most of our everyday life could be very dangerous to navigate. Even with those mechanisms in place, sometimes we find it hard to trust companies.
In this chapter we will first go over the meanings of ethics in specific fields, such as engineering, marketing and environment, as well as legal aspects. Next we will try to relate those findings to our project.

6.2 Engineering Ethics

Engineers are some of the people with the most direct impact on people's quality of life. Ranging from civil engineer designing our bridges, through biomedical engineers designing life support systems, up to electrical and mechanical engineers taking care of our everyday mechanical appliances. Those and many more types of engineers oftentimes work on products and technologies that, if done incorrectly, could cost many people their lives and health. With so much pressure on them from just that it is natural that a set of rules other than law should be applied to their profession.
In response to that, many engineering societies devised principles of conduct to help guide engineers through moral dilemmas associated with their works.

One of those was American Society of Engineers, which created the following**[58]**:

1. Engineers shall hold paramount the safety, health, and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.
2. Engineers shall perform services only in areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
5. Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
6. Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero tolerance for bribery, fraud, and corruption.
7. Engineers shall continue their professional development throughout their careers, and shall provide opportunities for the professional development of those engineers under their supervision.

While some of those rules concern things already regulated by law, others are simply there to uphold the status and public opinion of the profession or simply the working comfort of fellow engineers. We believe it is crucial for our project to adhere to those guidelines in order to create a professional and trustworthy brand for our product.
Engineering however is not the only ethical aspect we will be dealing with during our project. While as engineers we cannot with good conscience release a faulty product, we cannot advertise it as something it is not either. This is where marketing practices come in.

6.3 Sales and Marketing Ethics

We all know that very often product advertisements blow their products properties out of proportion, or deal with half truths meant to convince the users they need the product. The variety of tactics used is enormous and more often than not, includes quite unethical methods as well, making users pointlessly lose money on products they only think they need. This is why it is so crucial for companies who want to keep their integrity to adhere to a set of ethics while promoting their product. While other methods proved to be effective, the only real and valid way to build a long standing brand is by gaining trust of your consumers.

To help with that, some general guidelines have been created:**[59]**

• All marketing communications share the common standard of truth.
• Marketing professionals abide by the highest standard of personal ethics.
• Advertising is clearly distinguished from news and entertainment content.
• Marketers should be transparent about who they pay to endorse their products.
• Consumers should be treated fairly based on the nature of the product and the nature of the consumer (e.g. marketing to children).
• The privacy of the consumer should never be compromised.
• Marketers must comply with regulations and standards established by governmental and professional organizations.
• Ethics should be discussed openly and honestly during all marketing decisions.

In our marketing we decided to be, first and foremost truthful to the users and generally fair towards our possible competition. We will try to create a brand that doesn't hurt its customers by false advertising and do our best to provide them with clear and comprehensible information on the product. We will also put an emphasis on environmental aspect of our product, which leads us to the next section – environment ethics.

6.4 Environmental Ethics

Ever since the industrial revolution, when various industries have begun to destroy the nature, either by resource exploitation, ecosystem destruction, pollution, or a combination of those**[60]**, it would seem that ethical production is the only way we can stop our planet from becoming uninhabitable. In current situation it is in the best interest of producers to look past contemporary gain, towards more long lasting consequences of their actions.
The concerns of the environmental ethics are endless. What are the best energy sources? How will they behave in long term exploitation? When will the production cost be returned? Are "cruelty free" materials environmentally friendly? There are no clear black and white answers to those questions. Oftentimes while trying to fix one problem with the product, producers are forced to use different solutions that are not ideal either.
One of the more famous examples of that is probably faux leather. On the outside it looks like an amazing solution to the problem of animal exploitation, which in turn would contribute to decreasing greenhouse gas emission.**[61]** However this very same leather, depending on the manufacturer, pollutes the environment during its production and later, decomposition after use. It is also relatively short lived as compared to leather. All that not even including the environmental racism connected to stigmatizing leather cloth, in relation to indigenous people. So which solution is better? There most likely is no clear answer to that question.**[62]**

In our project we are trying to choose the best options we can, taking under consideration the nature of the product and the technical aspects of materials we are forced to use. We are aware that our solution of powering our device using dynamo with batteries is not a perfect one, but it is still one step into the right direction and we will do our best to make sure our solutions are the best out of the ones available to us.

6.5 Liability

Liability concerns the legal aspect of creating a product. Its aim is to make sure the product follows adequate directives and laws.
Our project should adhere to the following European Union directives:

• **Machinery Directive** (2006/42/CE 2006-05-1705-05-1717) - ensures safety of the machinery and its components entering the European market. However, this particular directive doesn't concern our product **[63]**.
• **Electromagnetic Compatibility (EMC) Directive** (2004/108/EC 2004-12-15) – Due to the nature of electrical current, different household appliances ten to interfere with each other. The aim of this directive is to ensure such interference is minimal and doesn't pose danger to the user **[64]**.
• **Low Voltage Directive (LVD)** (2014/35/EU 2016-04-20) – Ensures the safety of electrical devices of voltage between 50 and 1000 V for alternating current or 75 and 1500 V for direct current **[65]**.
• **Radio Equipment Directive (RED)** (2014/53/EU 2014-04-16) – concerns products, which, like ours, use radio for communication. It ensures safety of the users and lack of interference of the radio with other devices. It is also responsible for regulating the safety of user data sent using those means **[66]**.
• **ROHS EU Directives** – restrict the usage of harmful substance in devices, allowing for a more efficient recycling **[67]**.
• **Measuring Instruments Directive** (2014/32/EU) – ensures that the scientific measurements (in our case CO2 level and temperature) are done accurately **[68]**.

As we can see, some of those directives apply to our project and we plan to heed them in our design. Most notable are the last three, as they most strictly apply to our project.

6.6 Conclusion

In response to our ethical and deontological research we believe that our team should first and foremost concentrate on sustaining our integrity as engineers. Only then we can be sure that the product we will provide will be created with the good and safety of the users in mind. We believe in adopting a policy of truth in contacts with our customers, making sure our company is as transparent as it can be without compromising our clients sensitive data. Moreover, for the sake of our projects success we will ensure that our products are compliant with European Union Directives, which not only will allow our project to be launched at European market, but also provide additional security standards for our users.
Finally, we will strive to choose the most environmentally friendly components and design possible, carefully considering the individual impact of each element. We are aware that environmental ethics are a multifaceted problem and we will try to solve our problems in accordance to our conscience.
That being said, the actual components and designs we have decided on using those criteria are depicted in the following chapter on Project Development.

7 Project Development

7.1 Introduction

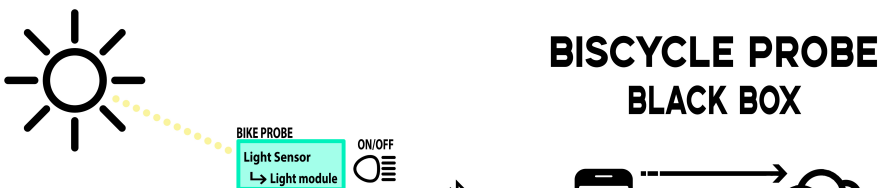
The design of the bicycle probe had to be thought of carefully for many reasons. The casing of the probe is designed so that the air quality sensor is protected even in the harshest of conditions. This was tackled by incorporating slits into the shell that allowed air to pass to the sensor, however not water. The device was also designed to be detachable, in order to prevent theft when the cyclist is not on the bicycle.

7.2 Architecture

In this chapter, will be presented: the black box diagram, the mood boards, all the (structural) drawings that were made along with the SolidWorks models and, finally, the detailed schematics of the electronic components.

7.2.1 Black box diagram

The black box diagram is used to visualize all inputs and outputs of a system without paying too much attention to the internal working.



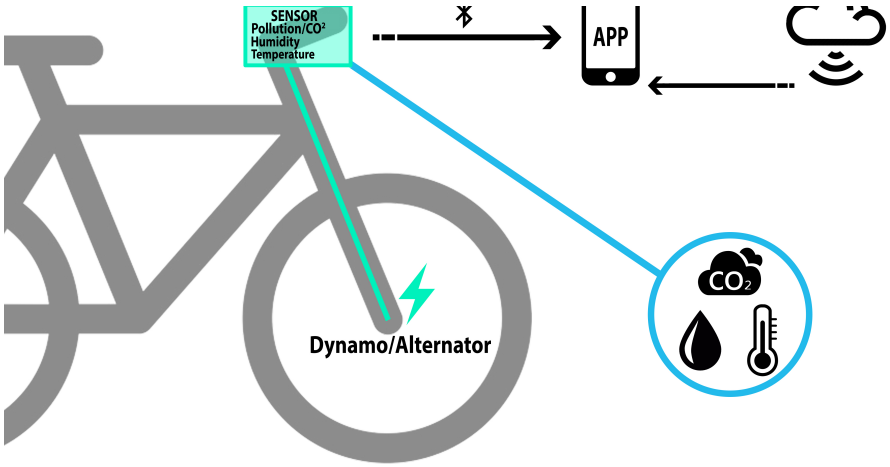


Figure 23: Black Box Bicycle Probe

The diagram (**figure 23**) shows that our main device will be powered by the energy generation of only a dynamo that will charge the battery in the device. The battery then has to power first the arduino and pollution sensor that will sense the air humidity, temperature and measure emission levels then transfer this data via Bluetooth to you're smartphone to the application and from that to the cloud where the data will be processed. Secondly the battery also has to power the LED-headlight that automatically turns ON & OFF when needed using a light sensor.

7.2.2 Look & Feel

This moodboard (**figure 24**) will help us with designing the how attractive the product looks, and hopefully will give the product a sophisticated appearance. We want to make the product feel more like an extension of the bike then that it feels like a bulky and useless gimmick. Clean and simple forms are key to our product to show that the product is user friendly, and hints of green/blue will indicate the ecological part of our product.

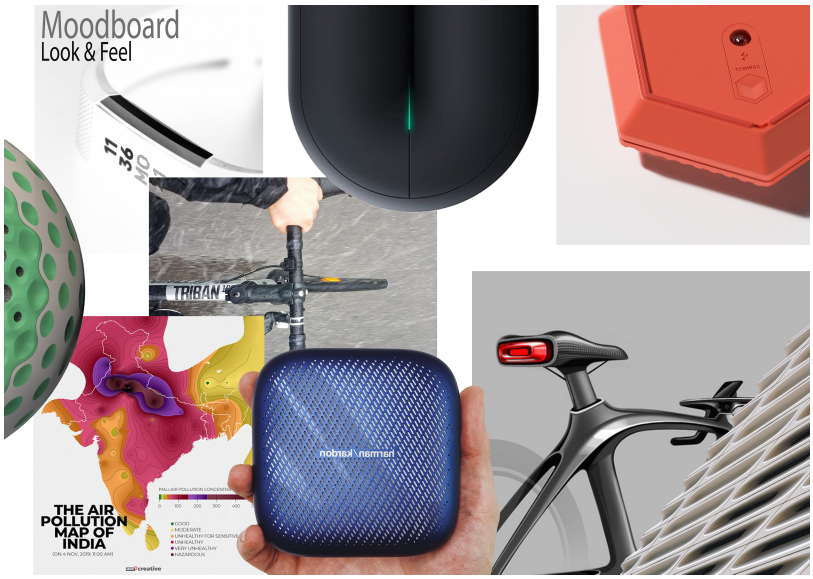


Figure 24: Moodboard Look & Feel

7.2.3 Drawings

In this part we will show the chronological order on how we came to our final design concept with drawings.

7.2.3.1 First Structural Drawings

In this first part, we made a few quick sketches (as shown in **figure 25**) in of what the concept may look like with some features that we are considering on the device.

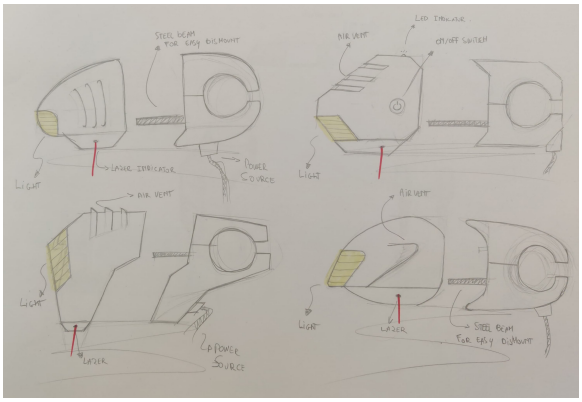


Figure 25: First Quick Designs

In the **figure 26**, we made the first sketch of the concept mounted on the fork of the bike with some of the features we are considering. Afterwards we saw that this option is not a good idea because of

the compatibility between other bike's and different kinds of forks.

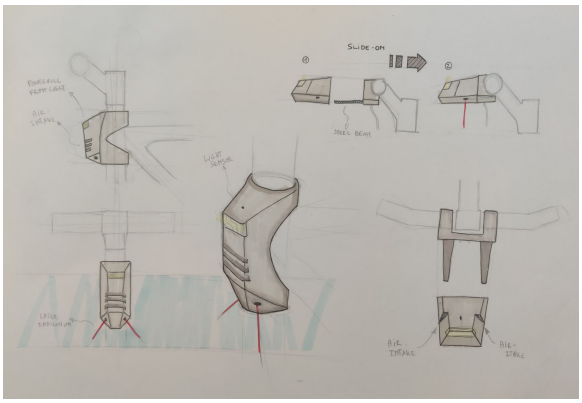


Figure 26: First Structural Sketch

7.2.3.2 Final Structural Drawings

For the final structural drawings we made two options (as you can see in **figure 27**). Afterwards we did a trade-off to choose which concept is better for this appliance. We made the trade-off based on user-friendliness, usability and which design corresponded better to our target audience. We concluded out of the trade-off that the right concept is the better option for our product.

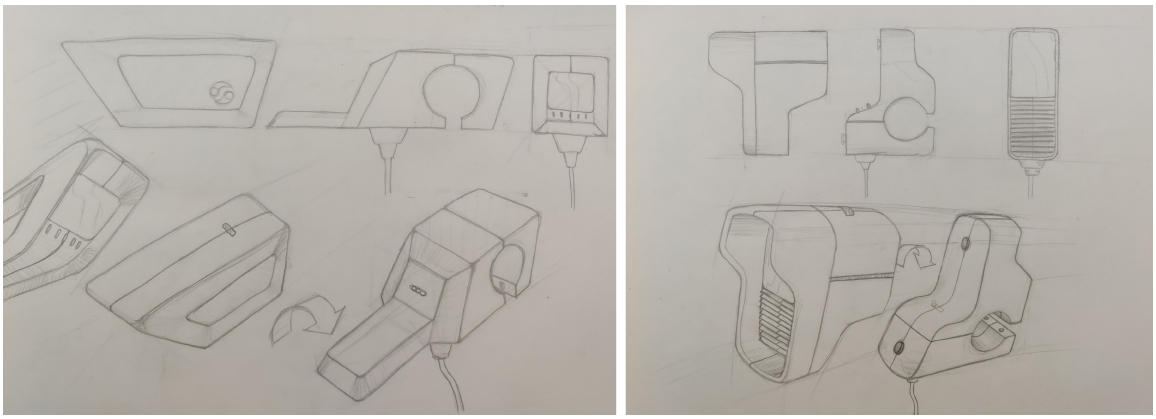


Figure 27: Decision between the 2 final structural drafts

We chose to use only black and gray colors in this concept (**figure 28**) to keep the product discreet and give it a sophisticated look. On the sides of the device we putted small accent lines that represent the product/company's logo, the green to blue gradient also stands for the eco-friendly aspect of our product.

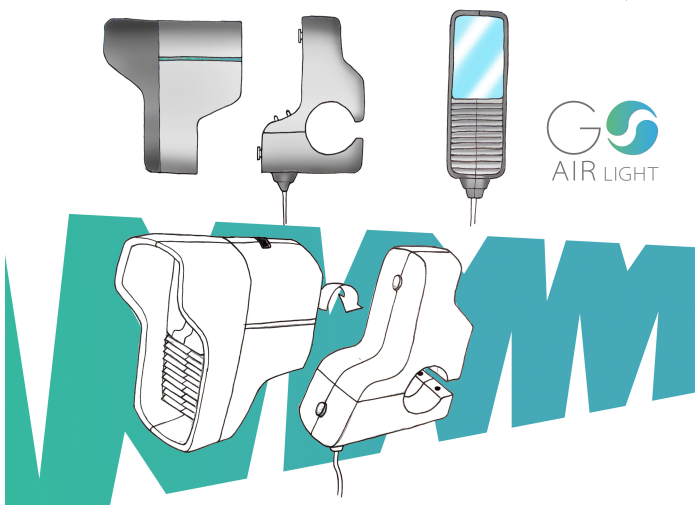


Figure 28: Final Structural Sketch

Our final structural concept will feature following things: An easy detachable main device with inside a head light that automatically turns on and off when it gets dark or light outside, an Arduino and pollution sensor that can measure humidity temperature and CO^2, this data will then be transfered via Bluetooth to the consumers smartphone.

7.2.4 Solidworks Model

7.2.4.1 Raw Solidworks Model

In this model (**figure 29**) you can see how the model is build en where all the parts are placed in the model. The Arduino sits on top, right under it you can see the pollution sensor to the right, and left you can see the reflector with the 3 LED lights. Then completely at the bottom you can see the 4 x AA rechargeable lithium-ion batteries. The outer left part is an extra cover to protect against rain and the outer right part is the mounting piece where the power of the dynamo comes threw.

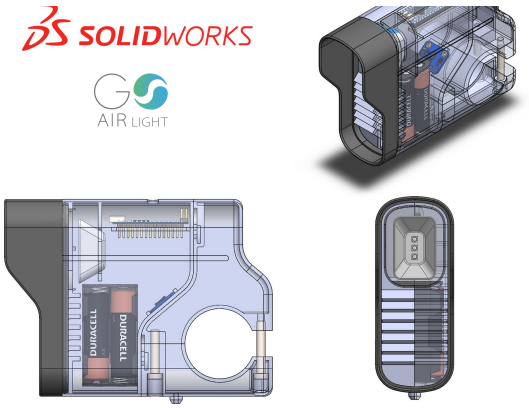


Figure 29: Raw Solidworks Model

7.2.4.2 Renders

Figure 30: Presentation Render

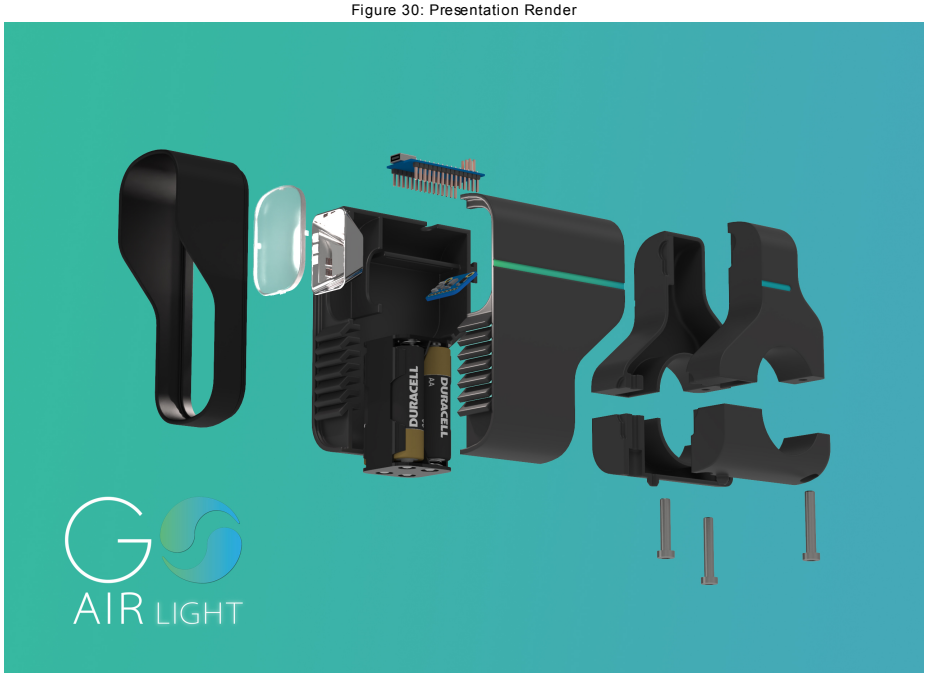


Figure 31: Exploded View

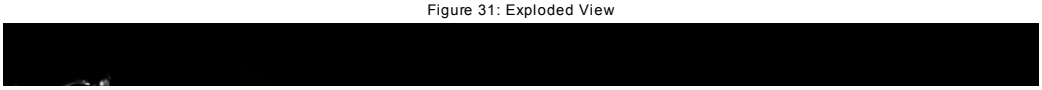
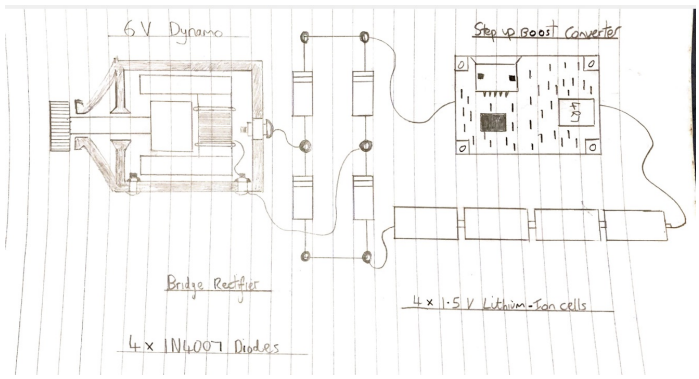
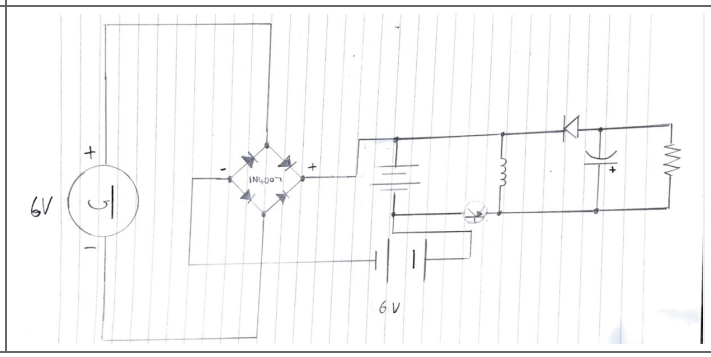


Figure 32: Mounting System

7.2.5 Schematics of the electronic components

Table 16: Dynamo to Battery Connection

Name	Picture
Dynamo to Battery Connection	
Dynamo to Battery Connection - Electrical Diagram	

The connection between the dynamo and the battery consists of few components to aid the charging of our 4 AA batteries. Firstly, there are four diodes in the circuit, also known as a half-bridge rectifier. The job of the H-bridge is to switch the polarity of the voltage, it also allows the load current to flow in both directions.

Next comes the step-up (boost) converter. The job of the boost converter is to determine the output voltage whilst charging the batteries. It then allows for a wide range of output voltages that can be decided by the manufacturer. The protection of the electrical components is provided by the step-up converter.

The boost converter then connects to the four lithium-ion batteries, which lead to the half-bridge, returning back to our power source of the dynamo.

General system schematic
In the **Figure33** we see a general sketch of the programing of the system and component connections:

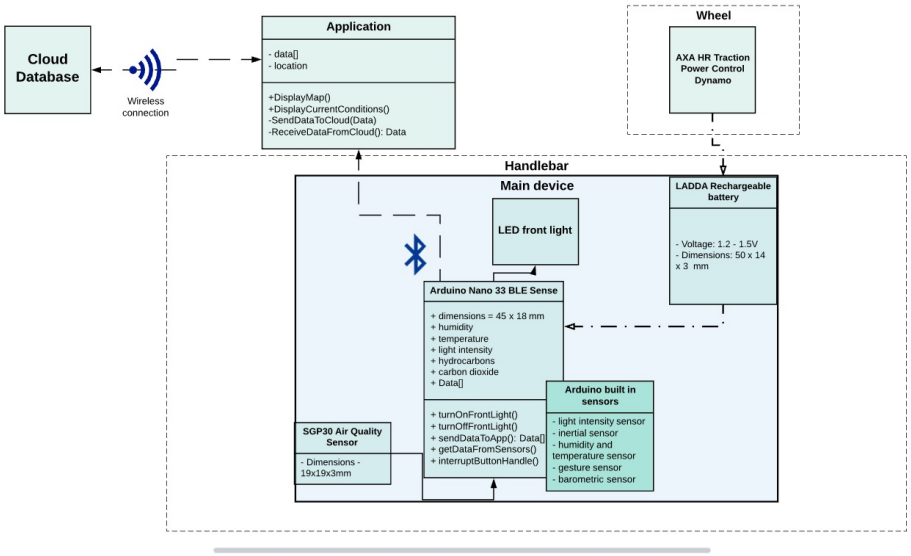


Figure 33: System schematic

7.3 Components

Air Quality Sensors

Table 17: Air Quality Sensors Comparision

Name	Pros	Cons
BME680 **[69]**	* Having 4 sensors in one is a big plus. Despite the high price, it's providing more value in comparison with the other sensors in this post. * High availability and produced by a well-known sensor company. * Best-in-class power consumption. * Best-in-class operating voltage range (1.8-3.6V).	* More difficult to integrate into Particle firmware. * Static library does take up more memory and flash space. This could make or break applications depending on the processor. * Humidity and Temperature measurements appear to be less accurate. It may still require another temperature, humidity sensor (Which defeats the purpose of an all-in-one device).
SGP30 **[70]**	* From a firmware perspective it's almost as easy as the CCS811. * This chip is way more sensitive than the CCS811. * This device is widely available through many channels.	* Requires extra hardware to run this device. Need small a regulator and some level shifting which will add another $0.5 in small volumes. * Requires extra floating-point operations to get the absolute humidity. (for the humidity compensation) This is not the end of the world but if you have a process without an FPU you could run into trouble. * Calculating the Maxim CRC8 makes it a bit troublesome if you don't have your head wrapped around it.
CCS811 **[71]**	* By far the easiest part to integrate. There are tons of open source libraries to use. * You can update the device via an I2C boot loader. * AMS is a great sensor company. They make awesome products. Lots of other companies have trusted with what AMS has built here. * Has a higher operation voltage range (1.8 - 3.3V).	* No stock. And if there is stock, it goes poof, fast. * Not sure how accurate it is. Wild C02 readings but also TVOC readings that don't match up with the other sensors what is compared here.

CCS811

After comparisons between all sensors we decided to use sensor CCS811 mainly because it doesn't need calibrations.

Dynamo Component

Table 18: Dynamo Comparision

Name	Characteristics	Price (€)	Picture
AXA HR Traction Power Control Dynamo **[72]**	* Extra large runner that offers high efficiency in adverse conditions * No cable or mount * Durable * Easy to use * Overvoltage to prevent extreme current flows * 6 V / 3 W	28.50	
SHIMANO Nexus Front Hub Dynamo **[73]**	* Comes with LED headlamp * 6 V / 3 W * Aluminium shell * Durable due to shell	43.83	

Name	Characteristics	Price (€)	Picture
Exposure Revo Dynamo Hub **[74]**	* Light weight * 6 V / 3 W * Quick release	76.85	

AXA HR Traction Power Control Dynamo

Comparing the three dynamo components together, it is clear that the dynamo that will be used to go forward with our project will be the AXA HR Traction Power Control Dynamo. This is due to a variety of reasons. These include; mounting - this dynamo is easier to connect to the bicycle in comparison with the other dynamo options. The dynamo's durability - the dynamo is manufactured from strong aluminum to protect the device in bad conditions. The AXA HR Traction Power Control Dynamo also has an overvoltage to prevent a very large current escaping from the output and finally, the dynamo is the most cost-effective out of all of our options.

Battery Component

Table 19: Battery Comparision

Name	Characteristics	Price (€)	Picture
6 Volt 4.5Ah Rechargeable Lead Acid Battery **[75]**	* Dimensions - 100x70x47 mm * Can be used in series and or parallel * Economical - made from low cost and readily available materials * Impact resistance case * Wide operating temperature * Service life of 4 to 5 years	10.81	
Power Sonic PS-630 6 Volt 3.4Ah Rechargeable Lead Acid Battery **[76]**	* Dimensions - 60x133x34 mm * High discharge rate * Impact resistance case * Easy to handle - classified as non-hazardous * Long service life	9.73	
Sealed Lead Acid Battery 6V 1.2Ah **[77]**	* Dimensions - 97x24x58 mm * Durable * Lead-acid * Long service life	6.99	
Duracell Recharge Plus, Rechargeable AA Batteries **[78]**	* Dimensions - 50×14(diameter) mm (x3) * Lithium-ion * Charged up to 400 times * Small size * Lightweight	4.50	
LADDA Rechargeable battery, HR6 AA 1.2 - 1.5V **[79]**	* Dimensions - 50×14(diameter) mm (x3) * Recharge 500 times * Life time: 5 years * Battery capacity: 2450 mAh * Lithium-ion	6.24 (4pk)	

LADDA Rechargeable battery, HR6 AA 1.2 - 1.5V

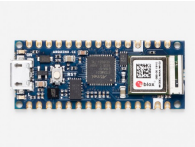
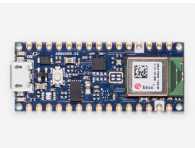
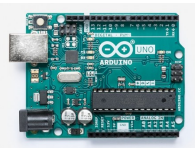
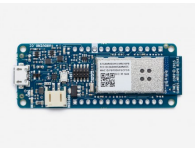
The battery that we decided to use is the LADDA Rechargeable battery, HR6 AA 1.2 - 1.5V (x4). We decided this as it the most cost-effective battery as well as being the easiest to access. The

batteries were also easy to charge when placed in a battery box and suited our voltage specifications.

Arduino Board Component

When thinking of microcontrollers, to a more seasoned programmer the first thing that comes to mind are most likely microcontrollers like AVR,**[80]** ARM**[81]** or similar. However those are generally very complex and time consuming to put together and require a very thorough knowledge that is usually hard to find.**[82]** We decided that using a premade board will allow us to both take advantage of the boards library, as well as, when needed, accessing more advanced options directly from the boards microcontroller. This led us to consider between Raspberry Pi**[83]** board and Arduino.**[84]**
Our first concern with Raspberry was that it doesn't operate well in a scenario of sudden shutdown due to power cutoff. In order for the program to work without deteriorating, Raspberry requires a proper shutdown. In our project this could prove difficult because of the very nature of our powering system. We'd like to believe no power shortages should occur, thanks to the batteries, but it is still a risk nonetheless. However an advantage of the board is being based on ARM microcontroller, which one of our team mates is more accustomed to than Arduinos AVR microcontroller. Still, the greater price, powering problems and Raspberry being overall more complicated than it is really needed for our project, are factors that spoke against it greatly.**[85]**
Finally we decided on Arduino, which is relatively simpler than Raspberry, offers a great variety of resources. Its one thread architecture is more than enough for the tasks we need it to perform and reacts better to power shortages than Raspberry. It is well adapted to working with peripheral devices like sensors, which are crucial in our project.**[86]**
However, since Arduino has a broad offer of different devices, we had to choose one best suited to our needs, which is depicted in **Table 20**:

Table 20: Arduino Boards Comparison

Name	Wireless Connection	Dimensions	Other Characteristics	Price (€ tax not included)	Photo
Arduino Nano 33 IoT **[87]**	Wi-Fi and Bluetooth	45 x 18 mm	* CPU Flash Memory 256 kB * SRAM 32 kB	16.00	
Arduino Nano 33 BLE **[88]**	Bluetooth with NFC	45 x 18 mm	* CPU Flash Memory 1 MB * SRAM 256 kB	17.50	
Arduino Uno Rev3 **[89]**	None	68.6 x 53.4 mm	* Flash Memory 32 kB * SRAM 2 kB	20.00	
Nano 33 BLE Sense **[90]**	Bluetooth	45 x 18 mm	* CPU Flash Memory 1 MB * SRAM 256 kB * 9 axis inertial sensor * humidity, and temperature * barometric * gesture, proximity, light colour and light intensity	27.00	
Arduino MKR Wi-Fi 1010 **[91]**	Wi-Fi and Bluetooth	61.5 x 25 mm	* CPU Flash Memory 256 kB * SRAM 32 kB * Battery Li-Po Single Cell	27.90	
Arduino MKR1000 **[92]**	Wi-Fi	61.5 x 25 mm	* Flash Memory 256 kB * SRAM 32 kB * Battery Li-Po Single Cell	30.99	

Nano 33 BLE Sense board

From the following possible products, we decided to finally use the Nano 33 BLE Sense board. The factors we took under consideration was whether the device had either a Wi-Fi or Bluetooth connection, since our project requires data transfer, outside of the device. We finally decided to concentrate on the Bluetooth module, since in general this form of communication has lower power consumption, which is crucial in a device powered by kinetic energy. It is also a more friendly option for users who lack mobile data on their phones. This left us with Arduino Nano 33 BLE and its extended version Nano 33 BLE Sense. The main difference between the two being the Sense version having already some sensors that interest us implemented. We believe using integrated sensors has the merit of them being picked by the manufacturer and dedicated to this specific board, bypassing the need to write specific drivers for each sensor.

1A Step-up (Boost) Converter

Table 21: Step-up (Boost) Converter

Name	Price (€)	Picture

Name	Price (€)	Picture
LiPo Charging With Step Up Boost Converter Module **[93]**	2.26	

A step-up (boost) converted was introduced to the dynamo - battery connection in order to determine the output voltage whilst charging the Lithium-ion batteries. It also allows for a wide range of input voltages. Overall, the step-up converter will additionally provide protection from voltage and current spikes.

LED Light

Table 22: LED Light

Name	Price (€)	Picture
SSC Seoul P4 (U-bin) LED emitter (x3) **[94]**	2.28	

This LED was chosen as it operates at an acceptable voltage of 3.7 volts. The three LED's will be attached to the front of the device to provide a light whilst the cyclist is in transit on the bike. It also projects a white light which is the most common for a forward-facing light. The dimensions of each LED is 8x5x8 mm.

Additional Components

1. 4 x 1.5V battery box
2. 4 x 1N4007 diodes (bridge rectifier)
3. Electrical wire

7.4 Functionalities

7.5 Tests and Results

7.6 Conclusion

Provide here the conclusions of this chapter and introduce the next chapter.

8 Conclusions

8.1 Discussion

Provide here what was achieved (related with the initial objectives) and what is missing (related with the initial objectives) of the project.

8.2 Future Development

Provide here your recommendations for future work.

Bibliography

Will be added automatically by citing, in the body of the report, entries specified in BibTeX format and stored in the http://www.eps2020-wiki4.dee.isep.ipp.pt/doku.php?id=refnotes:bib [http://www.eps2020-wiki4.dee.isep.ipp.pt/doku.php?id=refnotes:bib] file

PS - *If you have doubts on how to make citations, create captions, insert formulas, etc. visit this page [http://www.epswiki.dee.isep.ipp.pt/doku.php?id=example] with examples and select "Show pagesource" to see the source code.*

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[1] Jeff Sutherland Ken Schwaber. *Agile Scrum project development. [https://www.scrum.org/]*
[2] Avram Joel Spolsky. *Trello list making application. [https://trello.com]*
[3] European Commission. *Traffic Safety Basic Facts 2018. [https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/bfs20xx_cyclists.pdf]* European Road Safety Observatory, [Accessed in March, 2020].
[4] European Environment Agency. *Final energy consumption by sector and fuel in Europe. [https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-10/assessment]* European Environement Agency, [Accessed in March, 2020].
[5] European Commission. *Sustainable Transport and Mobility – Challenges and Approaches. [https://ec.europa.eu/regional_policy/en/newsroom/events/2008/01/sustainable-transport-and-mobility-challenges-and-approaches]* European Commission, [Accessed in March, 2020].
[6] European Commission. *Clean transport, Urban transport. [https://ec.europa.eu/transport/themes/clean-transport-urban-transport/cycling_en]* European Commission, [Accessed in March, 2020].
[7] European Commission. *Air quality - Introduction. [https://ec.europa.eu/environment/air/quality/index.htm]* European Commission, [Accessed in March, 2020].
[8] DECATHLON. *B'TWIN 500 WIRELESS CYCLOMETER - BLACK. [https://www.decathlon.co.uk/500-wireless-cyclometer-id_8382192.html]* DECATHLON, [Accessed in March, 2020].
[9] DECATHLON. *BRYTON GPS CYCLOMETER BRYTON RIDER 15. [https://www.decathlon.co.uk/bryton-rider-15-id_8587535.html]* DECATHLON, [Accessed in March, 2020].
[10] Worldwide Cyclery. *MSW Miniac 322 GPS Bike Computer. [https://www.worldwidecyclery.com/products/msw-gps-322-miniac-gps-computer-black]* Worldwide Cyclery, [Accessed in March, 2020].
[11] AliExpress. *CYCPLUS S1 Bluetooth Bicycle Speed Sensor Wireless BT & ANT+ Bike IPX7 8g Mini Road MTB Computer Speedometer Bicicleta 2018. [https://www.aliexpress.com/item/32856388932.html]* AliExpress, [Accessed in March, 2020].
[12] BIKE24. *Cannondale Wheel Sensor by Garmin. [https://www.bike24.com/p2354735.html]* BIKE24, [Accessed in March, 2020].
[13] wahoo. *WHAT DATA DO YOU NEED?. [https://uk.wahoofitness.com/devices/bike-sensors]* Wahoo Fitness, [Accessed in March, 2020].
[14] Beeline. *Beeline. [https://beeline.com/]* Beeline, [Accessed in March, 2020].
[15] COBI.Bike. *COBI.Bike. [https://www.bosch-ebike.com/de/produkte/cobibike/]* bosch, [Accessed in March, 2020].
[16] Wraapit. *Wraapit. [http://wraapit.com/]* Wraapit, [Accessed in March, 2020].
[17] SmartHalo2. *SmartHalo2. [https://www.smarthalo.bike/]* SmartHalo2, [Accessed in March, 2020].
[18] Bisecu. *Bisecu. [https://www.bisecu.com/]* Bisecu, [Accessed in March, 2020].
[19] BH51 Helmet. *BH51 Helmet. [https://www.livall.com/]* Livall, [Accessed in March, 2020].
[20] *Speednite. [Accessed in March, 2020]. [http://speednite.com/]*
[21] *Raz pro. [Accessed in March, 2020]. [https://www.shanrentech.com/html/about/razpro//]*
[22] *I LOCK IT. [Accessed in March, 2020]. [https://ilockit.bike/en/produkt/ilockit-gps/]*
[23] *Garmin Varia™ RTL510. [Accessed in March, 2020]. [https://buy.garmin.com/en-US/US/p/601468]*

[24] AirBliss+. *The World's Best Smart Air Pollution Mask. [https://airblissplus.com/]* AirBliss+, [Accessed in March, 2020].
[26] PlumeLabs. *The personal air pollution sensor. [https://plumelabs.com/en/flow/]* PlumeLabs, [Accessed in March, 2020].
[27] Wrike. *What is Scope in Project Management?. [https://www.wrike.com/project-management-guide/faq/what-is-scope-in-project-management/]* Wrike, [Accessed in March, 2020].
[28], **[30]**, **[39]** Michael Pearce. *An introductory note on marketing management.* The University of Western Ontario, [Accessed in April, 2020].
[29] Will Kenton. *What is a market?. [https://www.investopedia.com/terms/m/market.asp]* Investopia, [Accessed in April, 2020].
[31] GroupMap. *What is a PESTLE analysis?. [https://www.groupmap.com/map-templates/pestle-analysis/]* GroupMap, [Accessed in April, 2020].
[32] Chron. *What is primary target market?. [https://smallbusiness.chron.com/primary-target-market-1478.html]* SmallBusiness, [Accessed in April, 2020].
[33] Max Roser. *Economic growth. [https://ourworldindata.org/economic-growth]* Our World in Data, [Accessed in April, 2020].
[34] Eurostat. *GDP ate regional level. [https://ec.europa.eu/eurostat/statistics-explained/index.php/GDP_at_regional_level]* European Commission, [Accessed in April, 2020].
[35] Statista. *Smartphone ownership rate by country 2018. [https://www.statista.com/statistics/539395/smartphone-penetration-worldwide-by-country/]* S. O'Dea, [Accessed in April, 2020].
[36] CONEBI. *European bicycle market 2017. [https://issuu.com/conebi/docs/20170713_european_bicyle_industry_a]* ISSUU, [Accessed in April, 2020].
[37] Michelle Grant. *Strength, Weakness, Opportunity, and Threat (SWOT) Analysis. [https://www.investopedia.com/terms/s/swot.asp]* Investopedia, [Accessed in April, 2020].
[38] Evan Tarver. *Market segmentation. [https://www.investopedia.com/terms/m/marketsegmentation.asp]* Investopedia, [Accessed in April, 2020].
[40] Sarah-Jane Gilbert. *The Outside-In Approach to Customer Service. [https://hbswk.hbs.edu/item/the-outside-in-approach-to-customer-service]* Hardvard Business School, [Accessed in April, 2020].
[41] *Porter's Generic Strategies. [https://www.mindtools.com/pages/article/newSTR_82.htm]* MindTools, [Accessed in April, 2020].
[42] ActivEightDimensions. *What is Adaptive Marketing? And Should you Start Adapting?. [https://medium.com/@AED_in/what-is-adaptive-marketing-and-should-you-start-adapting-cbe60b69a683]* Medium, [Accessed in April, 2020].
[43] World Commission on Environment, Development. *Our Common Future. [https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf]* United Nations, [Accessed in March, 2020].
[44], **[45]** United Nations. *United Nations Conference on Environment and Development. [https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf]* United Nations, [Accessed in March, 2020].
[46] Cambridge Dictionnary. *Transportation. [https://dictionary.cambridge.org/dictionary/english/transportation]* Cambridge Dictionnary, [Accessed in March, 2020].
[47] M. Ge S. Wang. *Everything You Need to Know About the Fastest-Growing Source of Global Emissions: Transport. [https://www.wri.org/blog/2019/10/everything-you-need-know-about-fastest-growing-source-global-emissions-transport]* World Resources Institute, [Accessed in March, 2020].
[48] United Nations. *Special editions: Progress towards Sustainable Development Goals. [https://undocs.org/E/2019/68]* Economic and Social Council, [Accessed in March, 2020].
[49] United Nations. *Smart choices for cities - Cycling in the city. [https://ec.europa.eu/transport/sites/transport/files/cycling-guidance/smart_choices_for_the_city_cycling_in_the_city_0.pdf]* European Commission, [Accessed in March, 2020].
[50] Hoek G. H. Nijland H. Boogaard J. De Hartog. *Do the health benefits outweight the risks?.* United Nations, [Accessed in March, 2020].
[51] United Nations. *2018 HLPF Review of SDG implementation: SDG 7- Ensure access to affordable, reliable, sustainable and modern energy for all. [https://sustainabledevelopment.un.org/content/documents/195532018_background_notes_SDG_7Final1.pdf]* United Nations, [Accessed in March, 2020].
[52] European Environment Agency. *Share of renewable energy in gross final energy consumption in Europe. [https://www.eea.europa.eu/data-and-maps/indicators/renewable-gross-final-energy-consumption-4/assessment-4]* EEA, [Accessed in March, 2020].
[53] WHO World Bank Group UN Statistics Division IRENA IEA. *The energy progress report. [https://trackingsdg7.esmap.org/]* Energy Sector Management Assistance Program, [Accessed in March, 2020].
[54] Ramachandra Rao. *Resource Recovery and Recycling from Metallurgical Wastes. [https://www.sciencedirect.com/topics/earth-and-planetary-sciences/life-cycle-analysis]* SceinceDirect, [Accessed in April, 2020].
[55], **[56]** Mary Ann Curran. *Resource Recovery and Recycling from Metallurgical Wastes. [https://nepis.epa.gov/Exe/ZyPDF.cgi/P1000L86.PDF?Dockey=P1000L86.PDF]* Scientific Applications International Corporation, [Accessed in April, 2020].
[57] PAPREC. *Sorting plastic waste. [https://www.paprec.com/en/understanding-recycling/recycling-plastic/sorting-plastic-waste]* Paprec Group, [Accessed in April, 2020].
[58] The American Society of Civil Engineers. *The Seven Fundamental Canons of ASCE's Code of Ethics. [https://www.asce.org/question-of-ethics-articles/apr-2008/]* ASCE, [Accessed in April, 2020].
[59] *Ethical Marketing. [https://www.marketing-schools.org/types-of-marketing/ethical-marketing.html]* Marketing Schools, [Accessed in April, 2020].
[60] *The Causes of Climate Change. [https://climate.nasa.gov/causes/]* NASA, [Accessed in April, 2020].
[61] Gaughan John B. Bhatta Raghavendra Sullivan Megan Al-Hosni Yaqoub A. S. Lees Angela M. Ratnakaran Athira P. Bagath Madiajagan Sejian Veerasamy Jose V. Sanjo. Modeling of Greenhouse Gas Emission from Livestock. *Frontiers in Environmental Science", VOLUME=4, YEAR=2016, PAGES=27, URL=.*
[62] Rachel Moss. *Is 'Vegan Leather' Actually Sustainable? Here's The Truth About The Trend. [https://www.huffingtonpost.co.uk/entry/vegan-leather-explained-truth-sustainable-fashion_uk_5e314b41c5b6e8375f652471?guccounter=1]* Huffington Post, [Accessed in April, 2020].
[63] *Machinery Directive (2006/42/CE 2006-05-1705-05-1717). [https://ec.europa.eu/growth/sectors/mechanical-engineering/machinery]* European Commission, [Accessed in April, 2020].
[64] *Electromagnetic Compatibility (EMC) Directive (2004/108/EC 2004-12-15). [https://ec.europa.eu/growth/sectors/electrical-engineering/emc-directive]* European Commission, [Accessed in April, 2020].
[65] *Low Voltage Directive (LVD) (2014/35/EU 2016-04-20). [https://ec.europa.eu/growth/sectors/electrical-engineering/lvd-directive]* European Commission, [Accessed in April, 2020].
[66] *Radio Equipment Directive (RED) (2014/53/EU 2014-04-16). [https://ec.europa.eu/growth/sectors/electrical-engineering/red-directive_en]* European Commission, [Accessed in April, 2020].
[67] *ROHS EU Directives. [https://ec.europa.eu/environment/waste/rohs_eee/index_en.htm]* European Commission, [Accessed in April, 2020].
[68] *Measuring Instruments Directive 2014/32/EU. [https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/measuring-instruments_en]* European Commission, [Accessed in April, 2020].
[69], **[70]**, **[71]** Jared Wolff. *Which TVOC sensor is the Best for Air Quality? Lets's compare: BME680 vs CCS811 vs SGP30. [https://www.jaredwolff.com/finding-the-best-tvoc-sensor-ccs811-vs-bme680-vs-sgp30]* Jared Wolff, [Accessed in April, 2020].
[72] bike-discount. *Axa HR Traction Power Control Dynamo right. [https://www.bike-discount.de/en/buy/axa-hr-traction-power-control-dynamo-right-79157?currency=3&delivery_country=190]* bike-discount, [Accessed in March, 2020].
[73] wish. *SHIMANO Nexus Front Hub Dynamo DH-2N40-J 6V 2.4W 36H with Led Head Lamp LP-NX40 Bicycle Light. [https://www.wish.com/product/5884460582b935702dc82906?hide_login_modal=true&from_ad=goog_shopping&_display_country_code=GB&_force_currency_code=GBP&pid=googleadwords_int&c=%7BcampaignId%7D&ad_cid=5884460582b935702dc82906&ad_cc=GB&ad_curr=GBP&ad_price=37.00&campaign_id=9496441120&gclid=EAIaIQobChMI9cjprOCo6AIVx7TtCh22xwToEAQYAiABEgIuWPD_BwE&share=web]* wish, [Accessed in March, 2020].
[74] Wiggle. *Exposure Revo Dynamo Hub With Spoke Disc Brake Hub. [https://www.wiggle.co.uk/exposure-revo-dynamo-hub-with-spoke-disc-brake-hub/?lang=en&curr=GBP&dest=1&sku=100555553&kpid=100555553&utm_source=google&utm_term=&utm_campaign=Shopping+-+All+Products&utm_medium=base&utm_content=mckv%7CsPKW8QI8z_dc%7Cmcrid%7C2952697948595%7Cmkw%7C%7Cmmt%7C%7Cmrd%7C100555553uk%7Cmslid%7C%7C&mkwid=sPKW8QI8z_dc&pcrid=295269794859&prd=100555553uk&pgrid=64996676331&ptaid=pla-520648652816&gclid=EAIaIQobChMI9vy57_-z6AIVS8DeCh1vdgriEAQYBSABEgKsOvD_BwE]* Wiggle, [Accessed in March, 2020].
[75] Howes Models. *6 Volt 4.5Ah Rechargeable Lead Acid Battery. [https://howesmodels.co.uk/product/6-volt-4-5ah-rechargeable-lead-acid-battery/?gclid=EAIaIQobChMI6vuRp6us6AIVGYbVCh0FxQs7EAkYAyABEgKKjfD_BwE]* Howes Models, [Accessed in March, 2020].
[76] Howes Models. *Power Sonic PS-630 6 Volt 3.4Ah Rechargeable Lead Acid Battery. [https://howesmodels.co.uk/product/6-volt-3-4ah-rechargeable-lead-acid-battery/?gclid=EAIaIQobChMI6vuRp6us6AIVGYbVCh0FxQs7EAkYDCABEgJEXvD_BwE]* Howes Models, [Accessed in March, 2020].
[77] Toolstation. *Sealed Lead Acid Battery 6V 1.2Ah 97 x 24 x 58mm. [https://www.toolstation.com/sealed-lead-acid-battery/p62033]* Toolstation, [Accessed in March, 2020].
[78] John Lewis. *Duracell Recharge Plus, Rechargeable AA Batteries, Pack of 4. [https://www.johnlewis.com/duracell-recharge-plus-rechargeable-aa-batteries-pack-of-4/p3731474?sku=237597044&s_ppc=2dx92700046624588671&tmad=c&tmcampid=2&gclid=EAIaIQobChMI5YL73Ka76AIVibPtCh3wsQk0EAQYAyABEgIdsfD_BwE&gclsrc=aw.ds]* John Lewis, [Accessed in March, 2020].
[79] IKEA. *LADDA Rechargeable battery, HR6 AA 1.2V. [https://www.ikea.com/gb/en/p/ladda-rechargeable-battery-70303876/]* IKEA, [Accessed in March, 2020].
[80] Akshay Daga. *AVR Microcontroller : All You Need To Know. [https://www.engineersgarage.com/article_page/avr-microcontroller-all-you-need-to-know-part-1-46/]* Engineers Garage, [Accessed in April, 2020].
[81] Tarun Agarwal. *ARM Microcontroller Architecture and Programming. [https://www.edgefx.in/arm-microcontroller-architecture-and-its-programming/]* Edge Fx, [Accessed in April, 2020].
[82] Prakhar Bhatt. *AVR vs Arduino. [https://avrgeeks.com/avr-vs-arduino/]* AVR Geeks, [Accessed in April, 2020].
[83] *Raspberry Pi Website. [https://www.raspberrypi.org/]* Raspberry Pi, [Accessed in April, 2020].
[84] *Arduino Website. [https://www.arduino.cc/]* Arduino, [Accessed in April, 2020].
[85] *What are the differences between Raspberry Pi and Arduino?. [https://www.electronicshub.org/raspberry-pi-vs-arduino/]* Electronics Hub, [Accessed in April, 2020].
[86] Kevin Parrish. *Arduino vs. Raspberry Pi. [https://www.digitaltrends.com/computing/arduino-vs-raspberry-pi/]* Digital Trends, [Accessed in April, 2020].
[87] Arduino. *Arduino Nano 33 IOT. [https://store.arduino.cc/arduino-nano-33-iot]* Arduino, [Accessed in March, 2020].
[88] Arduino. *Arduino Nano 33 BLE. [https://store.arduino.cc/arduino-nano-33-ble]* Arduino, [Accessed in March, 2020].
[89] Arduino. *Arduino Uno Rev3. [https://store.arduino.cc/arduino-uno-rev3]* Arduino, [Accessed in March, 2020].
[90] Arduino. *Arduino Nano 33 BLE Sense. [https://store.arduino.cc/arduino-nano-33-ble-sense]* Arduino, [Accessed in March, 2020].
[91] Arduino. *Arduino MKR WiFi 1010. [https://store.arduino.cc/arduino-mkr-wifi-1010]* Arduino, [Accessed in March, 2020].
[92] Arduino. *Arduino MKR1000 WIFI. [https://store.arduino.cc/arduino-mkr1000-wifi]* Arduino, [Accessed in March, 2020].
[93] Hobby Components. *LiPo Charging With Step Up Boost Converter Module. [https://hobbycomponents.com/power/998-lipo-charging-with-step-up-boost-converter-module]* Hobby Components, [Accessed in April, 2020].
[94] FASTTECH. *SSC Seoul P4 (U-bin) SW0 Bare Emitter. [https://www.fasttech.com/product/1096601-ssc-seoul-p4-u-bin-sw0-bare-emitter?__cf_chl_jschl_tk__=3ad44d4d5d4999b93b03759b41ea4437024eedd8-1586190027-0-AfXdnY71syKV9TQ9bjcMYctJbzt-X09qWkkOQXlfSAir0ZshIDvXdTAHPMWtml0zYNRvdK9ghVH7xQ6gaDSm_XBjjGzgxFhcBvuzVYa3AQO4xI4gYgWJN8GUi7DnHwv-fN2rRnffv7t5del8PJKgjlUx-87rcEWXfcpcbuN3G6q5CP1EtGzirk5Pc5IPrx2oljmOa8Zy1_IyM1TOLSD08x7RO862YxKePz2bdv9WftG--GHEc2xXbqchNv2g0xbxhGhxi1Q4OzhXuE_Igj3TWiYky9kfsNH826GlOAcStXlvhjpBCQnVHMOsDKf6Tt9BAg5BtcP3VIgUjsYzbiBCyx4]* FASTTECH, [Accessed in March, 2020].