# Report

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## Acknowledgement

The team would like to thank the Instituto Superior de Engenharia do Porto (ISEP) for allowing us to work on this project. The team would also like to thank the teachers and supervisors who accompanied us, helped us and gave us valuable advice throughout the semester in order to successfully complete our European Projects Semester (EPS).

## Glossary

| Abbreviation | Description |
|---|---|
| EPS | European Project Semester |
| ISEP | Instituto Superior de Engenharia do Porto |
| USB | Universal Serial Bus |
| SWOT | Strenghts Weaknesses Opportunities Threaths |
| ETC | Et cetera |
| PDCA | Plan Do Check Act |

| Abbreviation | Description |
|---|---|
| ISO | International organization for standardization |
| LCA | Life cycle analysis |
| SDG | Sustainable Development Goals |
| R&D | Research and Development |
| PBI | Product Backlog Items |
| CE | Conformité Européenne (European Conformity) |
| EU | European Union |
| PESTEL | Political, Economic, Social, Technologies, Environmental and Legal |
| PLA | Polylactic Acid |
| ECG | Electrocardiogram |
| IoT | Internet of Things |
| PSRAM | Pseudo-Static Random Access Memory |
| LCD | Liquid Crystal Display |
| TTL | Transistor-Transistor Logic |
| TFT | Thin-Film Transistor |
| I2C | Inter-Integrated Circuit |
| IO | Input/Output |
| GPIO | General Purpose Input/Output |
| SPI | Serial Peripheral Interface |
| LED | Light Emitting Diode |
| EMCD | Electromagnetic Compatibility Directive |
| LVD | Low Voltage Directive |
| MD | Machinery Directive |
| RED | Radio Equipment Directive |
| ROHS | Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive |
| NSPE | National Society of Professional Engineers |
| PMMA | Polymethyl Methacrylate |
| FEM | Finite Element Method |
| API | Application Programming Interface |

# 1. Introduction

Smart health and well being is the monitoring of health through the use of new technologies. This report describes the work carried out by a group of 6 students from different universities and countries who all took part in a European Project Semester (EPS) at Instituto Superior de Engenharia do Porto (ISEP). The aim of the EPS is to work on a project that responds to a real and topical problem and to develop a number of skills, such as teamwork, communication and improving the team's English skills.

Billy is a friendly, and also fun, pill dispenser for children suffering from long-term illnesses, allergies

or epilepsy. Billy makes it easier for children to take their medicine, reassures parents and ensures that they never forget to take their medicine.

This document outlines the various stages and elements involved in the making of this project.

## 1.1 Presentation

The team is composed of 6 people from different parts of Europe working on the same project for a semester. The team members have different educational backgrounds and will use each other's knowledge to complete the project. Moreover, the project will be carried out entirely in English, which is not the native language of the team members. This will enable the team to gain a wide range of skills, whether technical, linguistic or soft skills. Table 1 below shows the home towns of the team members and their educational backgrounds.

Table 1: Team Camelia

| Name | Studies | Location |
|---|---|---|
| Łukasz | Computer Science | Poland, Łódź |
| Tibo | Electronics & ICT | Belgium, Ghent |
| Lena | Media Technology | Austria, St Pölten |
| Tamara | Production and logistic engineering | Germany, Köln |
| Noé | General engineering | France, Tarbes |
| Stijn | Construction | Belgium, Ghent |

## 1.2 Motivation

All the members of the team came to Porto with the aim of working on an innovative and collaborative project, contributing with their own skills and knowledge. Below you will find the personal motivations of each team member and the reasons that led the team to choose this subject.

Personal motivation :

- Łukasz : I think EPS is a great program that brings people together and prepares them for future work.
- Tibo : I wanted to do the EPS project to open myself up more and also to develop my general knowledge and soft skills.
- Lena : My personal motivation for doing the European Project Semester is wanting to grow professionally as well as personally. Doing a project with people from different countries, cultures and academic background requires a lot of adaptability, understanding and structuring while also having to gain knowledge in the field of expertise. Aside from studying, moving abroad gives you a once-in-a-lifetime experience, forcing you to become more independent and gifts you with life long friends.
- Tamara : I choose the EPS to kind of challenge myself with living in a different country and working with an international team. I hope to get out of my comfort zone, and I hope to improve my English skills. Moreover, I am interested in gaining knowledge about other cultures!

- Noé : I wanted to do an EPS because I thought it would be more interesting to work on a multi-disciplinary and multi-cultural project than to do a “classic” Erasmus. I also have friends who have already done an EPS and who have strongly recommended it to me. Moreover, I wanted to improve my English and meet new people. I think this will also be an interesting point to add on my resume.
- Stijn : Going abroad and explore new things. That was my main motivation why I choose EPS. Meeting and working with students from all over Europe, improve my English and soft/social skills, only benefits if you ask me!

Project Choice motivation :

After brainstorming about the different topics that the team wanted to cover during this EPS, it was decided to put smart health and well-being at the top of the list. For the team, this was an opportunity to work on a subject that was close to their hearts. What's more, the team was very enthusiastic about the idea of working on a project that aimed to help people directly, in this case, their health. So the team chose “Billy” for their project, a friendly pill dispenser for children suffering from long-term illnesses, allergies or epilepsy. Billy makes it easier for children to take their medicine, reassures parents and ensures that they never forget to take their medicine. By combining the knowledge of all team members, the team believes that it can develop a concept and propose a solution to address this problem.

## 1.3 Problem

A lot of people all over the world are struggling with health issues and have to take certain measurements in order to get better or not get sicker the very least. Taking pills is a big part of the way how medicine needs to be taken, depending on the region and country, these statistics may vary, but for example 51 % of American adults take two or more pills each day **[Express Medical Supply, 2012]**. When thinking about a sick person taking their pills, in most cases an elderly person comes to mind which is not wrong since most people of an older generation have health issues. However, since it’s a well-known problem, there are a lot of solutions to fight the problem.

Children are the target group of this project. These days, more and more children suffer from allergies, long-term illnesses or epilepsy. This requires the regular use of pills. More than 10 % of children suffer from asthma, 4-8 % of pre-school children have a food allergy, and 20 % of the general population suffer from allergic rhinitis **[American Hospital of Paris, 2024]**. In France, 4,000 children under the age of 10 develop epilepsy every year, and around 40,000 children under the age of 15 are treated daily with an anti-epileptic drug **[Hôpital Fondation Rothschild, 2024]**. All these data and statistics show that there are more sick children than someone might imagine and for them it’s even harder to take their pills than for elderly people since in a lot of cases they associate it with a negative experience. That is what the team wants to change by developing a pill dispenser for children to take the right amount of medicine at the right time, the right dosage of it and to be monitored doing it at the same time. While doing all of that, the main goal of this project is to make the intake of medication fun and playful so it’s something the children look forward doing to.

## 1.4 Objectives

This project aims to create a playful way for children who have to take pills regularly. In order to achieve this goal, the team will develop a pill dispenser that stores the pills a child has to take

throughout the week, also dividing it into different times a day. By a fingerprint sensor, it is being controlled so that only certain people have access to the dispenser. To make sure that the pills are actually being taken, a camera will be installed.

In addition, Billy, the pill dispenser includes a reward system addressing the fun factor of the product. Those rewards are being put in by the person or the person taking care of the child, therefore, the system can be adapted individually to the child. This makes it even more fun for the child since the dispenser only contains presents they like. The reward could be a sweet, an activity, a game, an outing like going to the cinema or playing in the park. The Billy team encourages parents to offer their children rewards that are both fun and educational. Billy's goal is to reduce the negative impact of having to take medication on children.

## 1.5 Requirements

During the process of this project, the following requirements and limitations will be followed:

**Initial requirements:**

1. Comply with the following EU Directives:
    1. Electromagnetic Compatibility Directive (EMCD);
    2. Low Voltage Directive (LVD);
    3. Machinery Directive (MD);
    4. Radio Equipment Directive (RED);
    5. Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (ROHS);
2. Mandatory adoption and use of the International System of Units (The NIST International Guide for the use of the International System of Units)
3. Use open source software and technologies.

**Budget requirements:**

- 100 € max for the prototype.

**Product requirements:**

- Easy to use
- Attractive to children
- Deliver the right dose of medicine at the right time
- Store medicines in a safe place
- Box for gifts
- Checks that children have taken their pills
- Sustainable

## 1.6 Functional Tests

The aim of the project is to produce a prototype at the end. To ensure that this prototype works properly, a number of tests need to carried out. The tests are described below and will be developed in the project development section.

**Functionality tests :**

- When the buzzer vibrates and the child places their finger on the fingerprint sensor, a dose of medicine is dispensed.
- When the parent selects parent mode and places their finger on the fingerprint sensor, the various doors open.
- A picture of the child is taken while he is swallowing his medicine.

**Safety tests :** For safety, no doses are administered if the alarm has not rung or if another person places their finger on the fingerprint sensor. These initial tests will enable the team to see whether the concept, the ideas and the elements used to make them are sufficiently effective to produce the product.

## 1.7 Project Planning

In order to manage this project as effectively as possible, a software package called Jira is used, it uses the Scrum method **[Scrum.org, 2021]**. This method is illustrated in Figure 1.

The aim of the scrum method is to divide a project into a number of small tasks that are more manageable and achievable. To define the work and tasks required to complete a project, you need to define the project scope. The backlog forms an overview of all the needed tasks. These tasks are then gathered into sprints, which correspond to a period of work during which the team wants to complete a certain number of tasks. For the project, the team has decided that a sprint will last 1 week (from Thursday to Wednesday). All team members are assigned to tasks in each sprint.

At the end of each sprint, the team carries out a review to see the progress made but also the problems encountered.

By applying these tools, the team will be able to manage its project properly by concentrating initially on the important and urgent tasks in order to meet the deadlines. This method enables the team to work efficiently and productively throughout the various sprints.


Figure 1: Scrum illustration **[iam2mai, 2021]**

## 1.8 Report Structure

The report is divided in eight chapters as can be seen in Table 2 below.

Table 2: Report structure

| Task | Description |
|---|---|
| Introduction | Team introduction, definition of the problem and the requirements of the project. |
| State of Art | Research of existing products. |
| Project Management | Overview of the management of the project. |
| Marketing Plan | Marketing research and analysis of the product. |
| Eco-efficiency measures for Sustainability | Structurally demonstrate sustainability through research. |
| Ethical and Deontological Concerns | Ethical analysis of possible concerns. |
| Project Development | Course and evolution of the project with the result. |
| Conclusions | Overal toughts about the work. |
| Bibliography | A list of references and sources used. |

# 2. State of the Art

As the topic for this project, the team chose “Smart Health and Well-being.” But why? This topic was selected because the team wanted to invent a product that is not currently on the market and that can make a significant impact in improving health issues. But first of all, what does smart health mean? Smart health refers to the integration of technology, data analytics, and communication tools into healthcare systems to improve the efficiency, accessibility, and quality of healthcare services. This approach utilizes various digital devices, such as wearables, mobile apps, sensors, and electronic health records, to monitor health metrics, deliver personalized care, facilitate remote consultations, and empower individuals to manage their health proactively.

With the help of workshops, the team began brainstorming different problems and project ideas. Several project ideas related to the project's topic came to mind. This was done by picking types of products that were the most interesting for the chosen topic of the project. One issue that stood out to the team was the challenge of self-medication for the elderly, sick, mentally disabled etc…

In the sections that follow, the team researched existing products related to smart health and then focused on the different types of pill dispenser available on the market.

## 2.1 Smart Apps

Even though there are various products and accessories, most people spend most of their time with their smartphones. This device is with us almost constantly and it is also a very smart device. Using smart software, it is possible to gather a lot of information from a smartphone. The standard installed apps such as Health from Apple **[Apple Health, 2024]** are able to provide insight into the number of

steps and stairs you take daily, the number of hours you sleep, send reminders for taking medication and much more (see Figure 2).


Figure 2: Health app Apple **[Apple Health, 2024]**

There are also many other apps that monitor your well-being and maintain your fitness. For even more accurate data, this app can be combined with the Apple Watch, more on such devices in the next section 2.2 Smart Wearables. In addition, there are many other apps that often focus on a specific part of your health. There are apps, for example, Calorie and Nutrition Tracker from Virtuagym, which provide an overview of the amount of calories you take in per day **[Virtuagym, 2024]** (see Figure 3).

Figure 3: Virtuagym Food **[Virtuagym, 2024]**

Keeping track of your calories makes it easier to stick to a particular diet or goal. When you grab next to your goals, the app gives a notification about this to encourage you to stick to the plan. There are also apps that allow you to use your smartphone to measure your heart rate and blood pressure. This is done using a sensor in your smartphone and is measured by the software in the app and displayed in the app **[Aiby, 2024]**. This does not replace a doctor's examination when in doubt, but it can give an insight into your state of health.

The development costs for specialized applications and the programming knowledge required for them are far beyond the reach of this course.

## 2.2 Smart Wearables

Smart wearables, like watches and fitness trackers, have become really popular. They are everywhere and mix technology with daily routines smoothly. Right now, there are many of them available, each designed for different purposes and styles. This shows that more and more people want gadgets that help them stay healthy and feel good.

### Types of Smart Wearables

**Smartwatches** have become much more than just watches. They now do lots of things like tracking fitness, giving you notifications, and even letting you pay with your phone, an example can be seen in Figure 4. The Apple Watch is the top choice for health features because it's the best-selling connected watch in the world **[Apple Watch, 2024]**. However, other brands like Samsung, Garmin, and Huawei also have some great options.

**Fitness trackers** are still really important in the world of smart gadgets. They are affordable and do a great job of keeping an eye on how active you are. Brands like Fitbit **[Fitbit, 2024]**, Garmin **[Garmin Watch, 2024]**, and Xiaomi **[Xiaomi, 2024]** are the most important here. They make devices with fancy sensors that can track things like steps, calories burned, sleep, and heart rate, an example can be seen in Figure 4.

**Smart clothing**, although not super common yet, is becoming more popular with fitness lovers and tech fans. Brands like Athos **[Smart Clothing Lab, 2024]** and Sensoria **[Sensoria Fitness, 2024]** make clothes with special sensors built-in, as you can see in Figure 4. These sensors keep track of things like your heart rate, how your muscles are working, and even how you are standing or moving. This information can help you perform better and avoid injuries.


Apple Watch Ultra 2

Garmin Veno 3

Sensoria textile sensor infused sock and balance data heat map

Figure 4: Types of smart wearables

### Functions and Features

**Keeping an eye on your health** is a big deal for all types of smart wearables. They come with sensors that can monitor important things like your heart rate, how you sleep, and how active you are. This helps you understand more about your health and gives you advice on how to stay well.

**Tracking your activities** has gotten much better, thanks to better sensors and smarter ways of analyzing data. Now, you can keep an eye on lots of different things like running, biking, swimming, and even yoga. The details you get are more accurate and precise than before.

**Coaching**: Nowadays, many smart gadgets offer personalized coaching to help you reach your fitness goals. They might suggest workouts, give you tips on how to do exercises correctly, or even cheer you on when things get tough. These features are meant to keep you motivated and accountable on your fitness journey.

## 2.3 Smart products

Another example of smart health is all the everyday objects that have become connected, most of them are objects that contain a large number of electronic components such as sensors or micro-controllers. The field of health objects has been expanding rapidly for several years now. This category can include all the different types of equipment that are used daily in hospitals, such as blood pressure monitors, scanners, ultrasounds, etc... But the team's research were mainly focused on objects that can be used by everyone, not just healthcare professionals. The aim of these smart products is to make it easier to monitor a patient's health or take a treatment, in order to improve the quality of life and preserve the long-term health of all users. Connected devices and technologies enable remote monitoring of patients, allowing healthcare professionals to provide high-quality healthcare that truly matches the patient's needs.

There are many products in this category. One of the best known is undoubtedly the connected scale Withings Body Scan that delivers precise weight, segmental body composition and heart health with a 6-lead electrocardiogram (ECG), Vascular Age and Nerve tracking for better health. This scale is even able to locate your fat and muscle mass to get you in shape. All this data is then stored on an application to help you improve your health by suggesting sports programs, for example **[WithingsBodyScan, 2023]**.

Another example of a smart product is the Dyson PH04, an air purifier. An object like this is considered smart because it has sensors, can deal with a problem on its own and is connected to an application. It captures dust, fine particles, viruses and allergens, or humidifies a room. All this to improve the quality of the air in your home, for a cleaner, more comfortable environment. It's a smart health product because it can help allergy sufferers live better at home by creating a healthy environment **[DysonPH04, 2021]**.

The Pillo pill dispenser is a good example of a smart product. It reminds patients to take their medication at the right time of day. Pillo Health devices use camera and biometric technology to ensure that information and medication are provided to the correct user. This dispenser allows patients to take their treatment independently and also allows carers or family members to monitor it remotely **[PilloHealth, 2020]**.

Moreover, the world of sports includes many equipment that fit into the smart product category, such as the jump rope from Crossrope. It's capable of tracking your workouts via a mobile application, giving you real-time feedback and monitoring your progress **[Crossrope, 2024]**. For each example there is a picture of them in Figure 5.

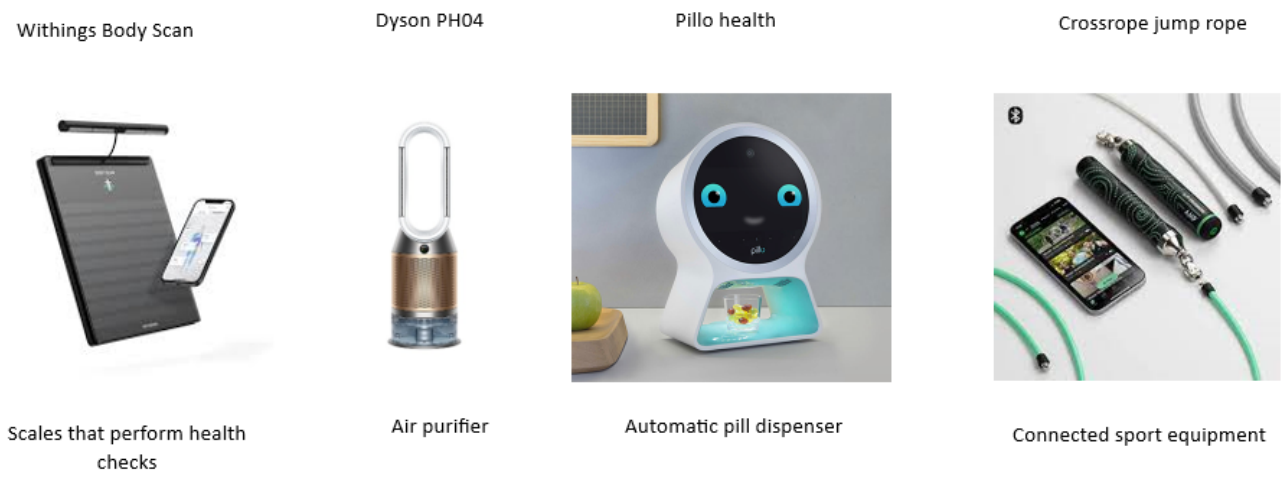



Figure 5: Different type of already existing smart health products

In conclusion, smart products are becoming increasingly popular and more and more present in daily lives thanks to their benefits in terms of managing and monitoring health. The use of this kind of technology in homes allows users to monitor their own health independently, therefore improving their well-being.

## 2.4 Smart Medication Dispensor

After looking at the different types of smart apps, wearables and products, the team focused on refining their research into the different pill dispensing systems that already exist nowadays. Already existing products on the market aimed at addressing this issue of helping people to take their medication. Research has shown that there are many different types of pill dispenser on the market today. There are very basic models, others that are much more modern and full of technology, and above all they come at all prices.

One of the most common types of pill dispensers in the world is the simple plastic box on which the days and times when the medicine should be taken are usually written. They are on the market in different shapes and colours. Products in this category include Gogooda **[Gogooda, 2024]** and LiveFine **[LiveFine, 2024]**, which are very affordable, less than 100 €. These products are easy to use, but if you are not careful, you could make a mistake by taking the wrong medicine on a different day because there is no security system. Given the price, these products are rather fragile and therefore risk being replaced often, which is not sustainable.

Another example of an intelligent pill dispenser on the market is Karie, a personal health companion. It is filled and configured by a pharmacist every month. It is secured by a pin code and facial recognition system. Patients are alerted at the right time to take their medication. In the event of forgetfulness, Karie helps with medication adherence by notifying select caregivers and family members when a dose is taken too early, too late or missed **[Karie, 2024]**. This service is more expensive than the previous examples, costing several hundred euros, as a monthly subscription (in addition to the purchase of the product) is required to benefit from the pharmacist's services.

Pillo, described above, is an intelligent pill dispenser that differs from Karie in that a caregiver, not a pharmacist, must refill the dispenser from time to time. And its interface is much friendlier than Karie's, making it a health companion **[PilloHealth, 2020]**. However, its price is higher. It costs around 300 €.

There is one final type of pill dispenser. These dispensers are much more expensive but much more effective. This is the case with Hero **[HeroHealth, 2024]** and Medacube **[Medacube, 2024]**. They can both be configured using an application and can hold up to 90 days' worth of daily treatment. The main difference between these two systems, compared with other existing products, is the fact that the dispenser itself is able to prepare each dose by taking the medicines one by one from their storage area. The occasional intervention of an external person to prepare the different mixes of medicines over a period of time is no longer necessary. The dispenser is capable of doing this itself, once configured. In addition, Medacube has an interface directly on the dispenser, making it easy to configure. These advanced functions make these products very expensive, 1000 € or more. All the examples can be seen in the Figure 6 below.


Figure 6: Different types of medication boxes and pill dispensers

In conclusion, there are many types of pill dispensers on the market, at different prices and offering different functionalities and user experiences. However, they are all intended for the elderly and none are suitable for children.

## 2.5 Pill dispenser for kids

The team sought to identify an innovation that none of the existing dispensers offered. While there is a significant market for pill dispensers that can give signals, interact with users, or are connected to an app for easier monitoring, a gap was identified in addressing the needs of children. These pill dispensers are not intended for children. Most dispensers on the market are not appealing to the younger generation. Except for basic pill dispensers, which are colourful and could therefore be attractive to children, however, this type of dispenser is not intended for children. The proof is in the fact that all the advertising by the manufacturers mentioned above uses images of older people and is aimed solely at them, do not allow parents to allow their children to take their medication in complete safety on their own.

To fill this gap, the team aims to create a pill dispenser with a more playful and colourful design, facilitating direct interaction with the product. The team also envisions incorporating elements of gamification, allowing children to engage in a game with the goal of receiving a reward upon medication adherence. Additionally, the goal is to enable children to take medication without supervision, a feature not found in current products.

The proposed solution entails employing a system that is attractive to children by using a reward system. For this, several solutions already exist such as the sweet dispenser, for example, the ones sold by Drinkstuff **[DrinkStuff, 2024]**. Another example of system that is attractive to children are vending machines, like the ones produced by Smile Makers **[SmileMakers, 2024]**. They are attractive to children because they can see, through a glass window, what they could win. This makes them want to win, so they concentrate and make the effort needed to get the reward.

Another example of a stimulating game for children that contains no technology are the famous pop it games that have become very popular in recent years. The game stimulates children by simply pressing buttons, and is attractive because of its bright colours. The examples mentioned earlier can be seen in Figure 7 below.


Figure 7: Examples of games that are attractive to kids.

Thanks to the fact that this type of game requires concentration and is attractive to children, particularly because they can see the reward and because of the use of attractive colours. The team believes that this is a very good way of stimulating children while they are taking their medication, making it less restrictive and therefore more enjoyable.

## 2.6 Comparison

Now that the team wants to work on the development of a children's pill dispenser and to ensure the best possible results, the different types of pill dispenser, already on the market, have been compared in Table 3 below.

Table 3: Product comparison

| Products | Price | Fonctionality | Sustainable | Ease of use | Appealing to kids | Reward |
|---|---|---|---|---|---|---|
| Plastic Medication Dispenser (gogooda) | 5-10 € | Just a plastic box | No | No | Yes | No |
| LiveFine | 60 € | Plastic box with an alarm | No | Yes | No | No |
| Hero | 44.99 €/ rent a month | Alarm system plus notification of medication taken to relatives. Connected to an app, self picking system but no security system. 90 days' worth of daily treatment | Yes | Yes, but the configuration is difficult | No | No |

| Products | Price | Fonctionality | Sustainable | Ease of use | Appealing to kids | Reward |
|---|---|---|---|---|---|---|
| Karie | 200 € + subscription | Alarm system plus face recognition. Connected to an app to notify that the medication is taken to relatives, pin code security system. | Yes | Yes but a pharmacist is needed to fill the dispenser | No | No |
| PilloHealth | 300 € | Alarm system plus face recognition. Connected to an app to notify that the medication is taken to relatives, pin code security system. | Yes | Yes | Yes | No |
| MedaCube | 1700 € | Alarm system Connected to an app to notify that the medication is taken to relatives, pin code security system, self picking system. 90 days' worth of daily treatment | Yes | Yes, but the configuration is difficult | No | No |
| Billy | 250 € | Alarm system. Connected to an app to notify that the medication is taken to relatives, fingerprint reader security system. 21 doses of medication. Screen that shows information and games. Camera to take a photo when the kid takes its pills. | Yes | Yes | Yes | Yes |

## 2.7 Conclusion

In conclusion, the exploration of smart health technologies reveals a landscape filled with diverse solutions aimed at improving well-being and addressing health challenges. From smart apps to wearables and innovative smart products, the market offers a variety of options for monitoring and managing health effectively. These technologies not only empower individuals to take control of their health but also enable remote monitoring and personalized care by healthcare professionals.

Based on the state of the art above, the team chose to focus on making a pill dispenser for kids that makes the annoying daily task of taking pills more fun. This device can be used with children and mentally disabled people. These users, most of the time, need to be under supervision. This is why the pill dispenser that the team wants to develop will be equipped with a fingerprint sensor. This will enable several profiles to be configured, such as one for the person filling the dispenser and one for

the person receiving their medication. The child will only be able to take their medication once the alarm has sounded and they have placed their finger on the fingerprint reader, to ensure that it is indeed the sick child who is taking it. This also prevents users from taking more pills than they are supposed to. The dispenser will also feature a touch screen, to make it easier to configure the device and, in the long term, to play with it. Lastly, a reward system will be installed under a transparent dome to recall the principle of vending machines, explained in the state of the art. Access to the mechanism and the drug storage area will be reserved for parents, with a locking system that can only be activated by a fingerprint reader. A camera system will also allow children to take photos of themselves when taking their medication. At the end of a period defined by the parents, and if the child has taken his medication correctly during this period, th child will be able to receive his reward. This device makes it possible for these people to take their pills on their own. And feel a sense of independence.

This product will be a good alternative to existing products, combining several features and being easy to use, as well as being attractive and fun for children while having a reasonable price.

The following chapter describes the project management used to carry out this project by addressing several subjects, describing the work planned each week and the progress made.

# 3. Project Management

This chapter deals with project management, an essential key to the success of a project, which the team has put in place in order to organize itself as well as possible throughout the project period. It deals with all the main aspects of project management, such as deadlines, the different stakeholders involved in the project and their management, cost and quality control, a risk analysis and, of course, a detailed planning of all the tasks carried out and a retrospective on the periods of work.

## 3.1 Scope

The scope of the project defines the steps that need to be taken during the development of a project. All the deliverables are stated in the scope as well, allowing the team members to have an overview of what needs to be achieved at all times. However, the scope only gives key functions, therefore, the person responsible for the certain task has his individual freedom in creating.

As listed in the scope, in Figure 8, the project is divided into six steps which are named “Initial”, “Design”, “Interim”, “Executive”, “Testing” and “Final”. Those six chapters are then divided into even smaller tasks or chapters, representing all of the requirements. In Figure 9, the scope of the product is shown, which is specific to the pill dispenser that the team is developing.


Figure 8: Project scope

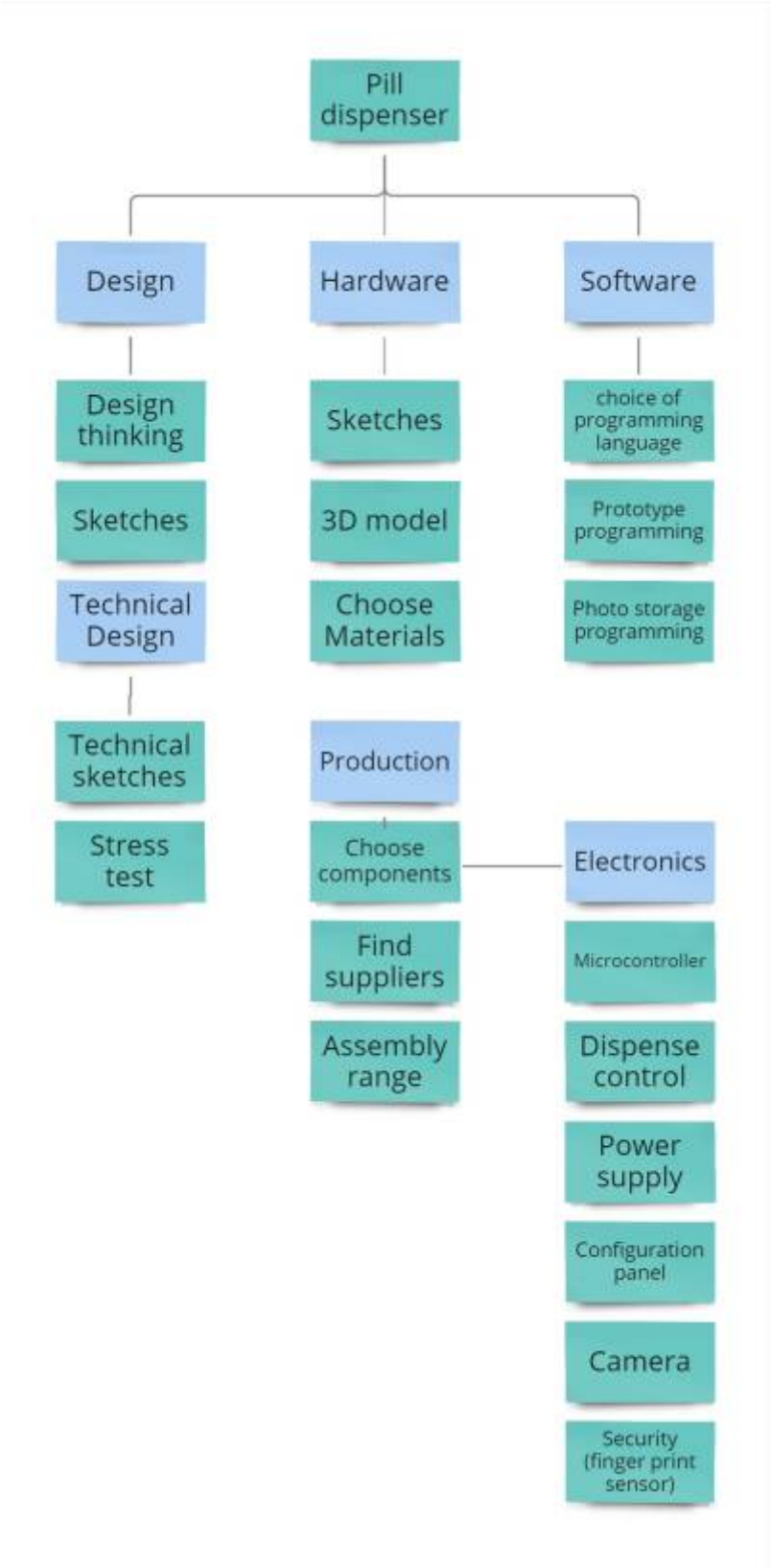



Figure 9: Product scope

## 3.2 Time

Below, is the list of the milestones all the teams had to follow:

- 2024-02-24 Choose a project proposal and send your choice via email to epsatisep@gmail.com
- 2024-03-06 Upload the “black box” System Diagrams & Structural Drafts to the wiki
- 2024-03-08 Define the Project Backlog (what must be done and key deliverables - every

member should preferably participate in every task), Global Sprint Plan, Initial Sprint Plan (which tasks should be included, who does what) and Release Gantt Chart of the project and insert them on the wiki (planning)
- 2024-03-13 Upload the List of Components and Materials (what & quantity) to the wiki
- 2024-03-20 Upload the detailed System Schematics & Structural Drawings to the wiki and do the cardboard scale model of the structure
- 2024-04-07 Upload the Interim Report and Presentation to the wiki. The report must contain the the following chapters: Introduction, Project Management, State of the Art, Marketing Plan, Eco-efficiency Measures for Sustainability, Ethical and Deontological Concerns, Proposed Solution and Bibliography. In particular, the Project Management chapter includes the updated project progress register, the sprint report for completed sprints (tasks that were included, statuses, assignees, allocations) and the updated release Gantt chart
- 2024-04-11 Interim Presentation, Discussion and Peer, Teacher and Supervisor Feedbacks
- 2024-04-17 Upload 3D model video to the wiki
- 2024-04-23 Upload the final List of Materials (local providers & price, including VAT and transportation)
- 2024-04-30 Upload refined Interim Report (based on Teacher & Supervisor Feedback)
- 2024-05-15 Upload packaging solution to Deliverables and Report
- 2024-05-28 Upload the results of the Functional Tests to the wiki
- 2024-06-16 Upload the Final Report, Presentation, Video, Paper, Poster and Manual
- 2024-06-20 Final Presentation, Individual Discussion and Assessment (reserve the whole day)
- 2024-06-25:
    1. Update the wiki, report, paper with all suggested corrections
    2. Place in the files section of the MS Teams channel of your team a folder with the refined deliverables (source + PDF) together with all code and drawings produced
    3. Hand in to the EPS coordinator a printed copy of the refined report and poster
- 2024-06-27:
    1. Hand in the prototype and user manual to the client
    2. Receive the EPS@ISEP certificate
    3. Bring typical food from your country

## 3.3 Cost

Regarding the cost of the project, certain factors need to be taken into account. The first is the cost of the various components that make up the product. In the Table 4 below you will find a list of all the components and their costs.

Table 4: Cost of the components for the prototype

| Component | Quantity | Price (with VAT) | Supplier | Shopping link |
|---|---|---|---|---|
| ESP32 CAM | 1 | 13.24 € | Mouser Portugal | Shopping link |
| FT232RL (USB to TTL Serial Converter) | 1 | 6.77 € | PT Robotics | Shopping link |
| DFRobot I2C LCD Screen | 1 | 9.21 € | Mouser Portugal | Shopping link |
| MCP23017 - i2c 16bit Expander | 1 | 2.58 € | PT Robotics | Shopping link |
| Passive buzzer | 1 | 0.56 € | Mouser Portugal | Shopping link |
| FPM10A (fingerprint sensor) | 1 | 18.55 € | Mouser Portugal | Shopping link |
| ULN2003 (moter driver) | 1 | 3.87 € | PT Robotics | Shopping link |

| Component | Quantity | Price (with VAT) | Supplier | Shopping link |
|---|---|---|---|---|
| Stepper motor | 1 | 7.44 € | Mouser Portugal | Shopping link |
| Servo Motor | 2 | 7 € | Mouser Portugal | Shopping link |
| 2×40 Pin Bar for PCB | 1 | 1.23 € | PT Robotics | Shopping link |
| AC/DC WALL MOUNT power supply 5V 15W | 1 | 4.67 € | PT Robotics | Shopping link |
| 220 Ohm Resistor | 1 | 0.22 € | Mouser Portugal | Shopping link |
| MULTICOLOR BUTTONS (10 pack) | 1 | 0.82 € | Mouser Portugal | Shopping link |
| LED RED | 4 | 1 € | PT Robotics | Shopping link |
| Capacitor Ceramic 100µF | 1 | 0.28 € | Mouser Portugal | Shopping link |
| BreadBoard | 1 | 2.99 € | Mouser Portugal | Shopping link |
| Jumper Wires Pack - M/M | 1 | 3.08 € | PT Robotics | Shopping link |
| USB micro-B Cable - 6 Foot | 1 | 0 € | Personal cable | |
| Screws M4*25 | 1 | 0.63 € | Leroy Merlin | Shopping link |
| PLA plastic for all the 3D printed parts (500 g because 1/2 scale prototype) | 1 | 8 € | - | Provided by the teachers |
| Vidro sintético TRANSPARENTE plank 500*500*2mm | 1 | 5.19 € | Leroy Merlin | Shopping link |
| Total | | 96.69 € | | |

The second factor to take into account would be the cost of labour. For 5 months (from February to June) 6 people worked full time on the project. This cost is difficult to estimate, but given that the project took place in Porto, Portugal, a beginner mechanical engineer earns around 1500 € per month. Multiplied by 6 people for 5 months, the total cost of labour represents a cost of **45 000 €**. Salary is not the only cost to consider here. In Portugal, employers must pay social security contributions representing 23.75 % of an employee's gross salary. Employees must also pay social security contributions amounting to 11 % of their gross salary. They must also pay 13.25 % income tax in Portugal. That would leave the employee 804 € a month after tax.

However, as this project is being carried out within the framework of the team members' studies, no salary was necessary. What's more, the cost of the room and the various associated charges (water, electricity, insurance, etc.) are not taken into account either, as the team work in a room provided by ISEP.

Finally, for the prototype the budget was 100 €, this was respected because the components were readjusted, for the prototype, to fit within the budget.

## 3.4 Quality

It is important not to forget quality management in a project **[William L. Dixon, 1987]**. It involves carrying out a project through its four phases (concept, development, execution, and finish) with zero deviations from the project specifications. The main benefits of quality management are: customer satisfaction (products meet customer expectations), cost reduction (by eliminating defects in the process, repair costs are also eliminated) and increased production.

To achieve this, the use of processes right from the start of the project to manage the quality is needed. The key components of quality management are:

- **Overall Quality Philosophy** - The involvement of all project participants in ensuring that project goals, requirements and performance standards comply with the expectations of both the client and the project team.
- **Quality Assurance** - The processes that determine the organization, design, objectives and resources and that provide the project team, client and shareholders with performance standards and feedback on the project's performance.
- **Quality Control** - The technical processes that verify, analyze and report the project's progress and compliance with performance requirements.

It is important to note that quality management is also carried out at the planning stage, for example by checking the production processes and checking their reliability.

For the project, quality management will begin by clearly defining objectives through sketches, models, component and material specifications. The goal is to design an automatic pill dispenser for children, ensuring safe medication intake with reduced restrictions. Quality assessment will involve prototyping and conducting trials and tests to evaluate if the product meets expectations.

## 3.5 People

Now, let's introduce the key people involved in the project.They are all listed in the Table 5 below. These people form part of the key elements in a project and its management. It is therefore important to know exactly who these stakeholders are and what their role is in order to understand the impact they could have on the project.

Table 5: Project Stakeholders

| **Stakeholder** | **Role** | **Power** | **Influence** |
|---|---|---|---|
| Team members | Owners | High | High |
| Benedita Malheiro | EPS coordinator | High | High |
| Supervisors | Supervising the project development | High | Medium |
| Teachers | Providing resources and support | High | Medium |
| ISEP | Main sponsor | High | Medium |
| Sick Kids | Main target group | High | High |
| Parents | Buyers (for the main target group) | High | High |
| Suppliers | Providing the components | Low | Medium |
| Competitors | External influence | Medium | Low |

It is important to note that the people with the greatest impact on the project are those who are the closest to it. For example, the team members who will be working directly on the project, taking on tasks according to their abilities and their desire, while collaborating with the others. But also the supervisors, who provide regular feedback on the project, raising problems that the team had not thought of and will therefore have to adapt to. Finally, the last people to have the greatest impact on the project are the parents and the sick children, because they are the ones who will be using the product.

The detailed role of each team member changes with each sprint, depending on the deadlines and the work required. This is detailed later in the sprint planning.

## 3.6 Communications

To work as well as possible within the team, communication is needed to achieve all the objectives. To do this, there are many different tools available to communicate easily these days. Right from the start of the project the team created a WhatsApp group, which was used mainly for all the informal exchanges, like small ideas, asking for/sharing opinions when the team members are each working on a task, because it is a quick way of getting in touch with the other members of the group.

Teams was also used to share ideas and finished products (examples : flyers, logos, etc.).

Finally, most of the communication between team members was in person at ISEP, where the team met to work on the project. The team also met every Wednesday at ISEP to prepare for the weekly meeting with the supervisors and see how everyone was doing. Daily standup meetings took place, which was put on Jira to see what everyone had done during the day. the team also held a meeting in person at the end of each sprint, also on Jira, to see whether or not the sprint objectives had been achieved.

The team also communicates with the teachers by taking part in weekly meetings.

## 3.7 Risk

Risk management is an important part of any project **[Lavanya N., Malarvizha T., 2008]**. It is important to do this in order to highlight the project tasks that are likely to represent a problem for the success of the project. To achieve the project's goals, identifying and assessing each task is essential. Through systematic evaluation, tasks can be prioritized, resources allocated efficiently, and potential risks identified and addressed proactively.

The steps to be taken to assess the risk are as follows:

- Risk identification
- Risk evaluation
- Risk handling
- Risk controlling

To assess the risk posed by each task, the probability of the risk occurring needs to be determined:

1. High probability – (80 % ≤ x ≤ 100 % )
2. Medium-high probability – (60 % ≤ x < 80 % )
3. Medium-Low probability – (30 % ≤ x < 60 % )
4. Low probability (0 % < x < 30 % )

But also the impact that the risk would have on the project:

1. High – Catastrophic (Rating A – 100)
2. Medium – Critical (Rating B – 50)
3. Low – Marginal (Rating C – 10)

Risk Score is obtained by multiplying the Impact Rating with Risk Probability, see illustration in Table 6:

| Impact | Probability | | | |
|---|---|---|---|---|
| | 1 = high (80 % ≤ x ≤ 100 %) | 2 = medium high (60 % ≤ x ≤ 80 %) | 3 = medium low (30 % ≤ x ≤ 60 %) | 4 = low (0 % ≤ x ≤ 30 %) |
| A = high (Rating 100) | (Exposure - Very High) (Score 100) | (Exposure - Very High) (Score 80) | (Exposure - High) (Score 60) | (Exposure - Moderate) (Score 30) |
| B = medium (Rating 50) | (Exposure - High) (Score 50) | (Exposure - Moderate) (Score 40) | (Exposure - Moderate) (Score | (Exposure - Low) (Score 15) |
| C = low (Rating 10) | (Exposure - Low) (Score 10) | (Exposure - VLow) (Score 8) | (Exposure - Low) (Score 6) | (Exposure - Low) (Score 3) |

Table 6: Risk exposure **[Lavanya N., Malarvizha T., 2008]**

It is beneficial to determine the timeframe of potential events to understand when risks might occur. See illustration in Table 7:

| Timeframe | Description |
|---|---|
| Near | Now - until one month |
| Mid | next 2 - 6 months |
| Far | > 6 months |

Table 7: Risk occurrence timeframe **[Lavanya N., Malarvizha T., 2008]**

The last step is the Risk Response. There are several types of responses:

- Avoid (seeking to eliminate uncertainty)
- Transfer (passing ownership and/or liability to a third party)
- Mitigate (reducing the probability and/or severity of the risk below a threshold of acceptability)
- Accept (recognizing residual risks and devising responses to control and monitor them)

Applying this approach to the project yields a risk matrix, in Table 8, which helps identify tasks or problems with potentially significant impacts on the project:

Table 8: Risk analysis of Billy

| Risk identification | Probability | Impact | Timeframe | Response | Risk handling |
|---|---|---|---|---|---|
| Member does not want to work | 4 | A | Mid | Accept | The team tries to motivate the person or works more to compensate |
| Wiki does not work | 2 | A | Near | Mitigate | Work on Teams to save the documents. |
| Lose documents | 4 | B | Mid | Mitigate | Keeping documents in safe places |
| Conflicts between team members | 2 | A | Near | Avoid | Working on communication and teamwork |
| Components are not delivered on time | 3 | A | Mid | Avoid | Order in advance and choose reliable suppliers |

| Risk identification | Probability | Impact | Timeframe | Response | Risk handling |
|---|---|---|---|---|---|
| Not respecting deadlines | 3 | B | Near | Mitigate | Use/Improve Sprint plan |
| Parents don't trust the product | 4 | A | Mid | Avoid | A good market analysis and advertising is needed to show how safe the product is |
| Kids are not interested in the product | 3 | A | Mid | Avoid | Target group needs to be perfectly define (age,boy,girl, etc...) |
| Lack of knowledge | 3 | B | Near | Transfer | Ask the teacher for help/ Research on the internet |
| Too expensive | 2 | C | Mid | Transfer | The components/materials can be changed to cheaper ones or borrowed from school |
| Product does not work well | 3 | B | Far | Mitigate | Functional tests on the prototype and on the dispense mechanism are needed to make sure everything works. |

## 3.8 Procurement

Procurement is a key element of a project in developing the prototype as proof of concept. This means analysing the costs and doing as much research as possible to keep within the 100 € budget. As the budget was very limited, the team decided to make most of the product themselves. Apart from the electronic components that were bought, all the assembly, programming, design and 3D printing of the pill dispenser were done by the students, to keep labour costs as low as possible, especially as the members of the group have experience in this field. Secondly, to reduce the cost of transportation for the components, most of the components were ordered from the same supplier, Mouser, a local Portuguese supplier, which allows the team to contribute to the local economy, to reduce transport costs and to stick to the planned schedule. Another advantage of working with local suppliers is the proximity that the team has with them. In other words, it is easier to talk to them if there is a problem for example if a component is not working, or to discuss delivery times.

However, some of the components used, have been loaned by the school (ISEP).

## 3.9 Stakeholders Management

The stakeholders are all the people involved in the project (team members, Supervisors, Teachers, ISEP, kids, parents, suppliers). It is therefore crucial to keep them engaged and happy for the project's success **[Pedro Serrador, 2009]**. Failure to identify stakeholders, understand stakeholder needs and meet their needs can result in spectacular project failures. It is therefore important to recognize the stakeholders and their influence on the project. The following Table 9 shows the influence and power of each stakeholder.

Table 9: Stakeholders management

| Stakeholders | Role | Influence | Power |
|---|---|---|---|
| Suppliers | Provide the components | Low | Mid |
| Team members | Build the project | High | High |
| Supervisors | Helping the team to carry out its project | High | High |
| Customers (parents and kids) | Buy the product | High | High |
| ISEP | Provide the premises and budget (sponsor) | Low | High |
| Teachers | Assists team members with courses | Low | High |
| Competitors | Work in the same field | Low | Low |

Stakeholders all have a different influence on the project. The team therefore needs to adapt their communication with them to keep them engaged. For example, teachers, supervisors, team members and parents will need to be closely managed through extensive communication such as meetings, listening to their feedback and needs and creating a relationship of trust. Secondly, teachers and ISEP must be satisfied. It is also needed to keep suppliers informed throughout the contract to avoid supply problems.

All of this can be put on a graph, see Figure 10, which makes it easier to show the influence and impact of each stakeholder.


Figure 10: Stakeholder Management analysis **[Magda E. Ramos, 2022]**

## 3.10 Project Plan

The Global Sprint Plan is shown in the Table 10. The table shows the duration of every sprint until the end of the project. A sprint corresponds to a period of work during which a certain number of tasks are completed. For the project, the team has decided that a sprint will last 1 week (from Thursday to Wednesday). Each team member is assigned a task for each sprint. To facilitate this, the first letters of team members' surnames and first names are used to designate them as being responsible for or involved in a task: Łukasz Borowski (LB), Tibo Clauwaert (TC), Lena Ehrenhofer (LE), Tamara Kronshagen (TK), Noé Oliveira (NO) and Stijn Steyaert (SS).

Table 10: Global Sprint Plan

| Sprint | Start | Finish |
|---|---|---|
| 0 | 22/02/2024 | 28/02/2024 |
| 1 | 29/02/2024 | 06/03/2024 |

| Sprint | Start | Finish |
|---|---|---|
| 2 | 07/03/2024 | 13/03/2024 |
| 3 | 14/03/2024 | 20/03/2024 |
| 4 | 21/03/2024 | 03/04/2024 |
| 5 | 04/04/2024 | 10/04/2024 |
| 6 | 11/04/2024 | 17/04/2024 |
| 7 | 18/04/2024 | 24/04/2024 |
| 8 | 25/04/2024 | 01/05/2024 |
| 9 | 02/05/2024 | 15/05/2024 |
| 10 | 16/05/2024 | 22/05/2024 |
| 11 | 23/05/2024 | 29/05/2024 |
| 12 | 30/05/2024 | 05/06/2024 |
| 13 | 06/06/2024 | 12/06/2024 |
| 14 | 13/06/2024 | 19/06/2024 |
| 15 | 20/06/2024 | 26/06/2024 |

Table 11 shows the Project Backlog, this covers all the major tasks involved in the project. A letter is attached to each task to make it easier to keep track of them. The team uses Prioritised Backlog Items (PBI) which keeps the higher priority items at the top, and lower priority at the bottom. It allows team members to concentrate on the most urgent tasks.

Table 11: Project Backlog

| PBI | Title | Status |
|---|---|---|
| A | Define Project | Done |
| B | System Diagrams (Black Box) & Structural Drafts | Done |
| C | Project Backlog | Done |
| D | Sprint & Initial Sprint Plan | Done |
| E | Gantt Chart | Done |
| F | List of Components and Materials | Done |
| G | System Schematics & Structural Drawings | Done |
| H | Cardboard scale model | Done |
| I | Interim Report and Presentation | Done |
| J | 3D model video | Done |
| K | Final List of Materials | Done |
| L | Refined Report | Done |
| M | Packaging solution | Done |
| N | Functional Tests | Done |
| O | Final Report & Presentation | Done |
| P | Video, Paper, Poster, Manual | Done |
| Q | Prototype and User Manual | Done |
| R | Upload | To do |

In the Table 12 the Sprint Plan is shown. At the start of each sprint, the team planned the work that was going to be done by grouping it in the Sprint Plan table.

Table 12: Sprint Plan

| Sprint | Task | Duration [d] | Responsible | Involved |
|---|---|---|---|---|
| 0 | A | 5 | All | All |
| 1 | B | 5 | SS | LE and TK |
| 2 | C | 5 | SS and NO | LE and TK |
| 2 | D | 5 | NO | LE and TK |
| 2 | E | 5 | NO | LE and TK |
| 2 | F | 5 | TC | LB |
| 3 | G | 5 | SS and NO | SS and NO |
| 3 | H | 5 | TK | LE |
| 4 | I | 5 | All | All |
| 5 | I | 5 | All | All |
| 6 | J | 5 | LE and NO | LE and NO |
| 6 | K | 5 | TC and LB | TC and LB |
| 7 | K | 5 | TC and LB | TC and LB |
| 8 | L | 5 | All | All |
| 9 | M | 5 | TK | TK and LE |
| 9 | N | 5 | TC and LB | TC and LB |
| 9 | P | 5 | SS and NO | SS and NO |
| 10 | P | 5 | SS and NO | SS and NO |
| 10 | Q | 5 | TK | TK |
| 10 | N | 5 | TC and LB | TC and LB |
| 11 | P | 5 | SS, NO, LE | SS, NO, LE |
| 11 | Q | 5 | TK | TK |
| 11 | N | 5 | TC and LB | TC and LB |
| 12 | P | 5 | LE, TK, NO | LE, TK, NO |
| 12 | O | 5 | All | All |
| 12 | Q | 5 | NO, TK | NO, TK |
| 13 | O | 5 | All | All |
| 13 | P | 5 | LE | All |
| 14 | O | 5 | LE | All |

At the end of each sprint, the Project Backlog Items are reviewed and updated on their status. This review is done in the Progress Register Table 13 below.

Table 13: Project Progress Register

| Sprint | PBI | Responsible | Involved | Status |
|---|---|---|---|---|
| 0 | A | All | All | Done |
| 1 | B | SS, NO | LE, TK | Done |
| 2 | C, D, E, F | NO, TC | All | Done |
| 3 | G, H | SS,TC, LE | All | Done |
| 4 | I | All | All | Done |
| 5 | I | All | All | Done |
| 6 | J, K | LE, NO | LE, NO | Done |

| Sprint | PBI | Responsible | Involved | Status |
|---|---|---|---|---|
| 7 | K | TC, LB | TC, LB, NO | Done |
| 8 | L | All | All | Done |
| 9 | M, N, P | All | All | Done |
| 10 | N, O, P, Q | All | All | Done |
| 11 | N, P, Q | All | All | Done |
| 12 | O, P, Q | LE, TC, NO, TK | All | Done |
| 13 | O, P | All | All | Done |
| 14 | O | All | All | In Progress |

For the global project planning, a Gantt chart contains the main project deliverables and deadlines. See the team's Gantt chart in Figure 11 below.

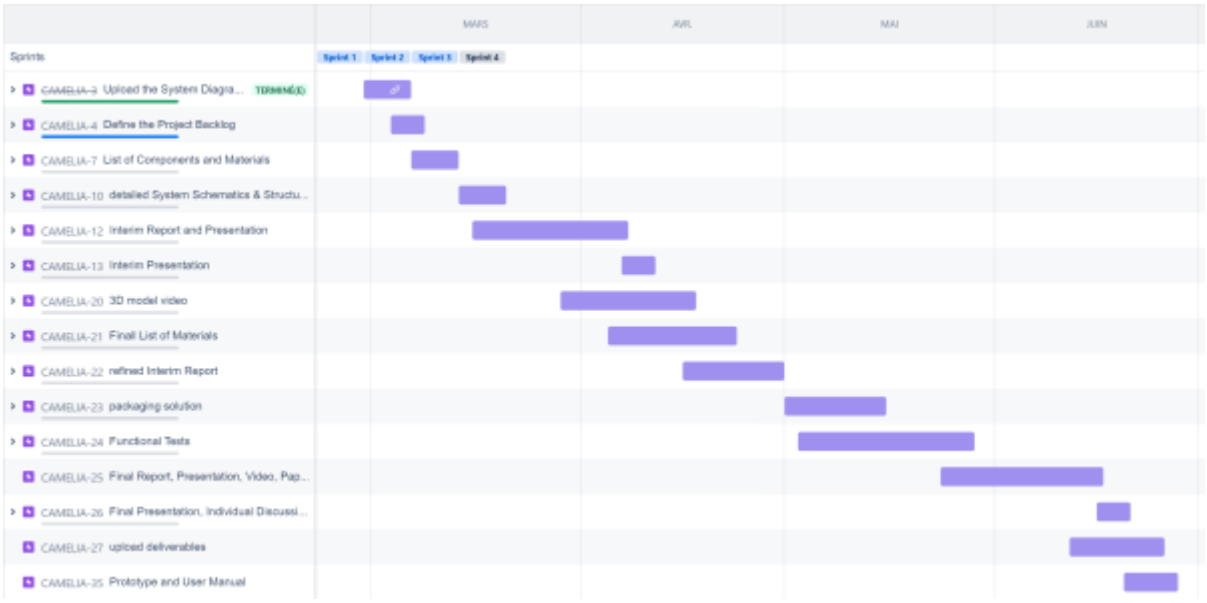



Figure 11: Gantt chart

## 3.11 Sprint Outcomes

To keep a clear view of how each sprint is progressing, it is important to keep track of them. To do this, every week the team met at the end of each sprint and discussed how the sprint was progressing. Whether the time spent was the same as planned, or more, or less, whether the task had been completed or not and whether there were any other elements to add to the task. The summaries of these meetings on the progress of the sprints are grouped together in the sprints outcomes from Table 14 to Table 28. A burndown graph is associated with each sprint outcome, illustrating the time spent on sprint tasks up to the end of the sprint. This is illustrated from Figure 12 to Figure 23. For more details on each sprint, this monitoring has also been carried out on Jira.

Table 14: Sprint 0 - 22/02-28/02. Velocity planned: 28,5 h. Real Velocity: 28,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Choose topic | All | 4 | X | | The team chose 3 topics |

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Get familiar with jira | All | 1 | X | | Take a look at Jira's functions |
| Classes | All | 23,5 | X | | |

Table 15: Sprint 1 - 29/02-06/03. Velocity planned: 37 h. Real Velocity: 37 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Define the target group | All | 2 | X | | - |
| Structural Drafts and System diagram | SS, NO | 3 | X | | BlackBox and Structural Drafts |
| Write our personal motivations on the wiki | All | 2 | X | | Start of the wiki editing |
| Classes | All | 30 | X | | |

Table 16: Sprint 2 - 07/03-13/03. Velocity planned: 34 h. Real Velocity: 34 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Define the project Backlog | NO | 1 | X | | Global and initial Sprint plan, Gantt chart |
| List of Components and Materials | TC, LB | 8 | X | | List of electronic and hardware components for the prototype and a list of materials |
| Create a flyer | LE, TK | 4 | X | | Create a flyer to present the project for communication class |
| Create a logo | LE, TK | 2 | X | | Create a logo for our product |
| Classes | All | 19 | X | | |

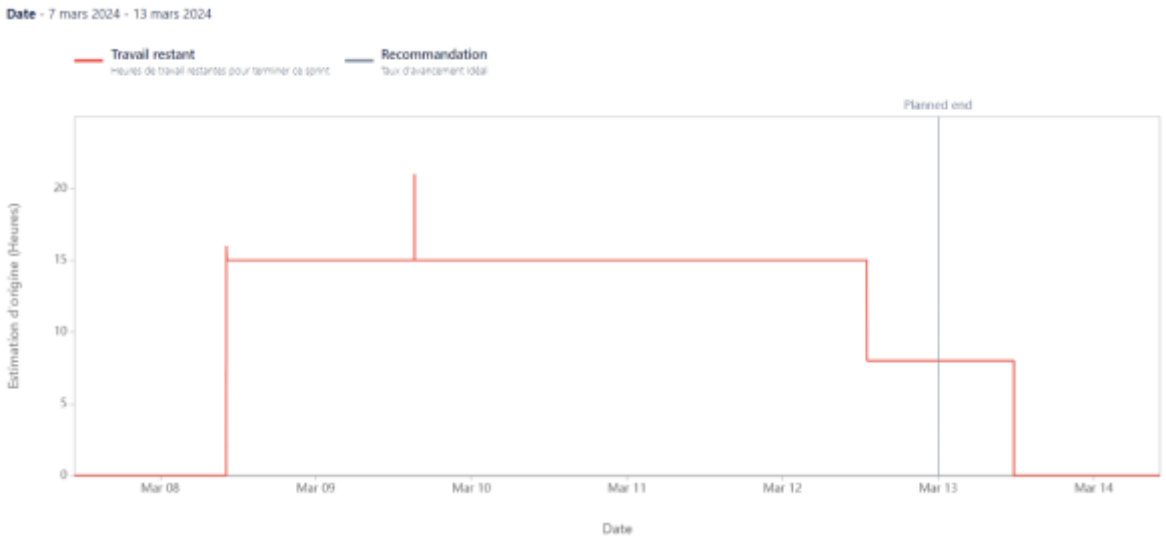



Figure 12: Sprint 2 burndown chart

Table 17: Sprint 3 - 14/03-20/03. Velocity planned: 37,5 h. Real Velocity: 37,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Detailed System schematics | TC | 5 | X | | Electronic schematics |
| Detailed Structural Drawings | SS,NO | 6 | X | | Do a detailed drawing of the product |
| Cardboard model | LE, TK | 4 | X | | Do a cardboard model of our product |
| Do the scope on the report | LE | 1,5 | X | | Start to write the project development part |
| Classes | All | 21 | X | | |

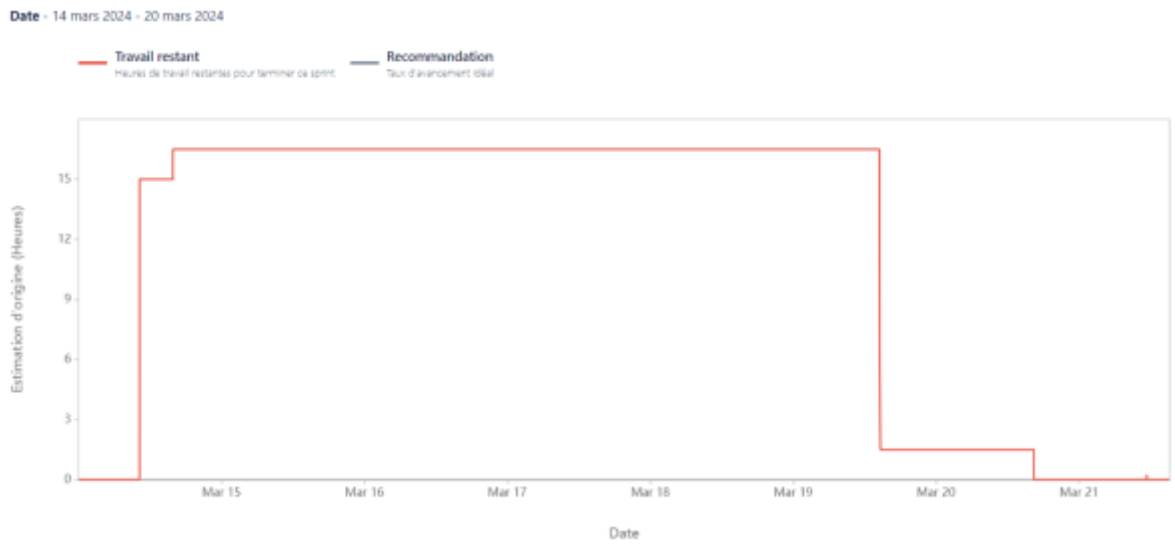



Figure 13: Sprint 3 burndown chart

Table 18: Sprint 4 - 21/03-04/04. Velocity planned: 80 h. Real Velocity: 81 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| State of the art | TK | 6 | X | | Finish the state of the art for the interim report |
| Wiki's introduction | NO | 1 | X | | Do the introduction for the interim report |
| Write the project management part on the wiki | NO | 14 | X | | Finish project development for the interim report |
| Ethics & deontology | LE | 8 | X | | Finish Ethics & deontology for the interim report |
| Marketing | SS | 24 | | X | Finish marketing for interim report - Did not have time to finish it, postponed to sprint 5 |

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Eco-efficiency Measures for sustainability | TK | 16 | | X | Finish Eco-efficiency - Did not have time to finish it Measures for sustainability for interim report, postponed to sprint 5 |
| Classes | All | 11 | X | | |

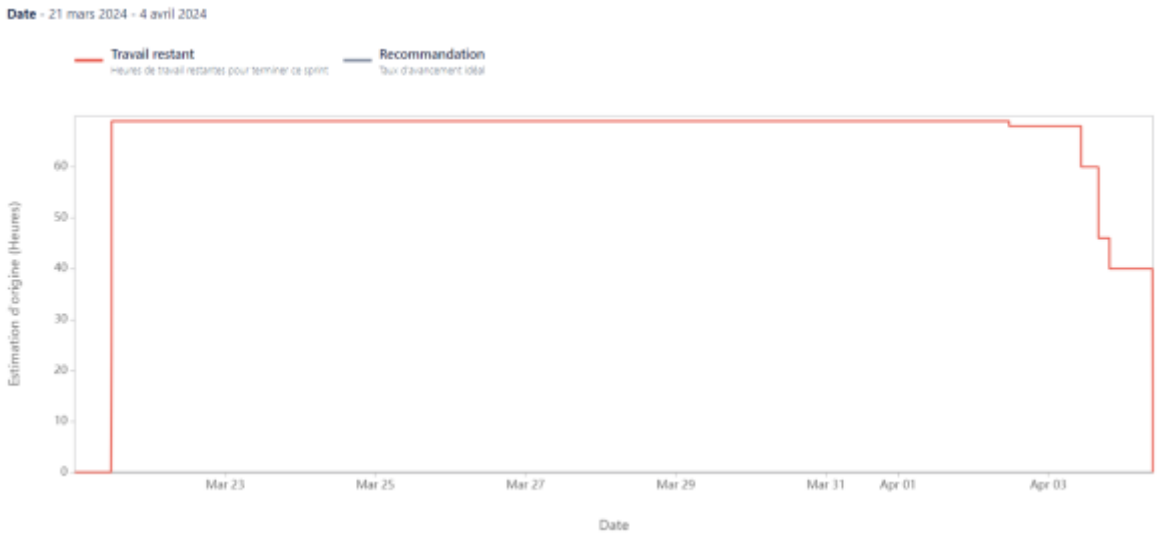



Figure 14: Sprint 4 burndown chart

Table 19: Sprint 5 - 04/04-10/04. Velocity planned: 28 h. Real Velocity: 29 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Interim presentation | LE | 5 | X | | Create the presentation and rehearse for the presentation, Presentation was on 1 day of the next sprint |
| Marketing | SS | 3 | X | | Continue and finish marketing for the interim report |
| Eco-efficiency Measures for sustainability | TK | 5 | X | | Continue and finish marketing for the interim report |
| 3D model video | LE, NO | 4 | | X | Started in sprint 5 but postponed to sprint 6 because it took more time than expected |
| Classes | All | 11 | X | | |

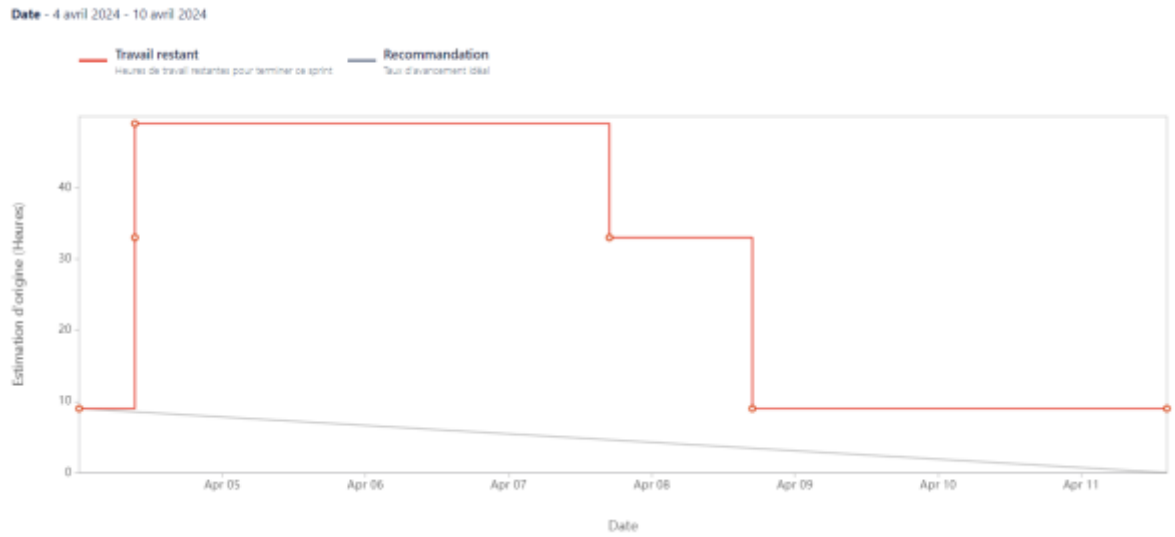



Figure 15: Sprint 5 burndown chart

Table 20: Sprint 6 - 11/04-17/04. Velocity planned: 25 h. Real Velocity: 27 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Modify the wiki based on the teachers feedback | SS | 3 | | X | Added to the sprint after the interim presentation (1st day of the sprint). Not finished during this sprint because it took more time than planned |
| Final list of components and materials | TC, LB | 4 | | X | Not finished during this sprint because team members were not as available as planned |
| 3D model video | LE, NO | 4 | X | | Took more time than planned but finished it. |
| Classes | All | 14 | X | | |

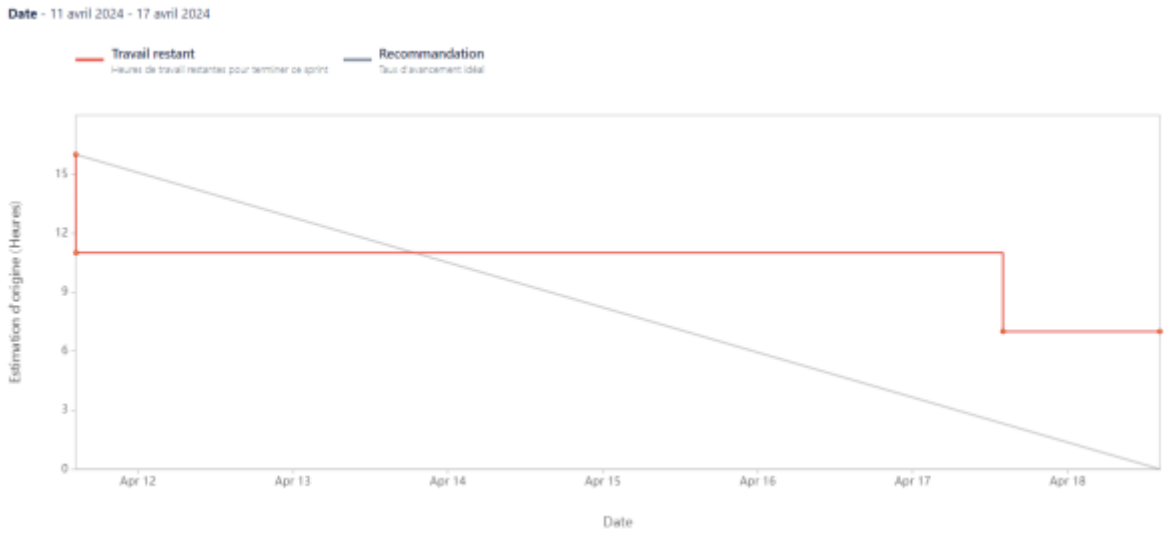



Figure 16: Sprint 6 burndown chart

Table 21: Sprint 7 - 18/04-24/04. Velocity planned: 36 h. Real Velocity: 32,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Modify the wiki based on the teachers feedback | SS | 3 | X | | - |
| Final list of components and materials | TC, LB | 4 | X | | Took more time than planned |
| Ethic case presentation | All | 4 | X | | Presentation, not for the project |
| Create the power budget in the wiki | LB | 2 | X | | Start to write the Product Development part on the wiki |
| Update the detailed schematics | TC | 1.50 | X | | - |
| Calculate transport cost for the components | TC | 0.50 | X | | - |
| Refine interim report | All | 5 | | X | Out of the sprint because not enough team members were available this week |
| Classes | All | 16 | X | | |

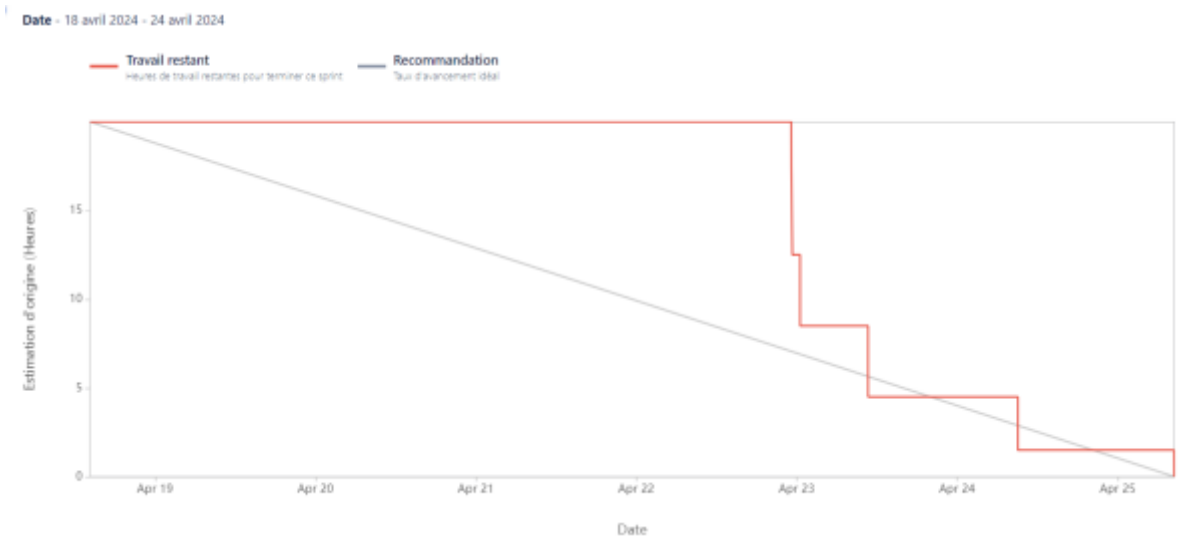



Figure 17: Sprint 7 burndown chart

Table 22: Sprint 8 - 25/04-02/05. Velocity planned: 19,5 h. Real Velocity: 17,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Refined interim report | All | 5 | X | | This task took 2 times the amount of planned hours |
| Start writing Software part in product development | TC, LB | 3 | | X | Task started but not completed |

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Update the detailed drawings | NO | 1,5 | X | | Done on time |
| Do a leaflet | LE, TK | 5 | | X | Task started but not completed |
| Create a web app prototype | LB | 5 | X | | This task was added to this sprint at the end of the sprint because a member of the team was able to start work on it earlier than expected. |
| Classes | All | 0 | X | | |

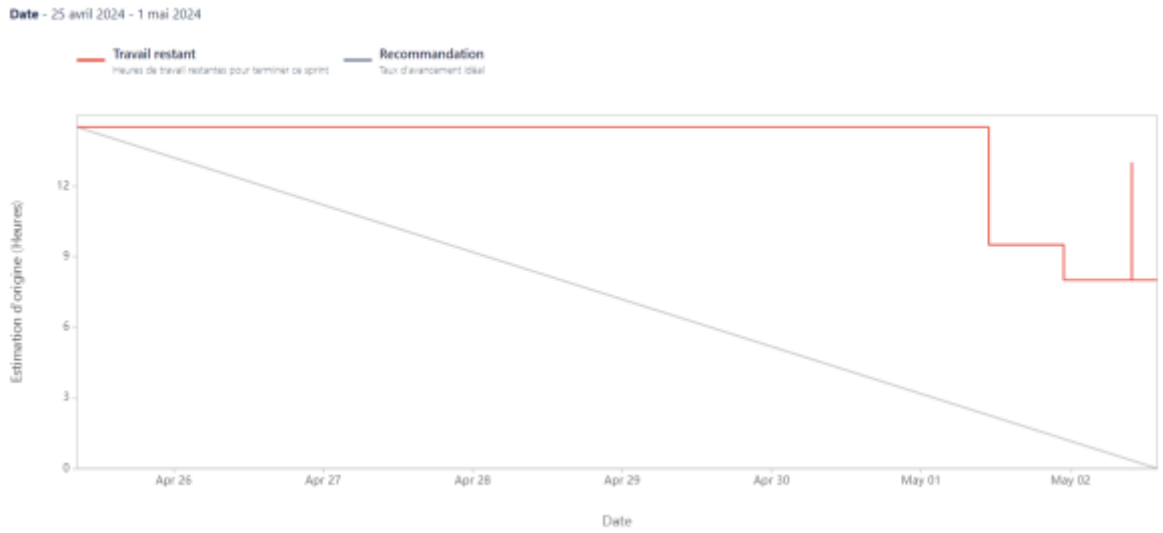



Figure 18: Sprint 8 burndown chart

Table 23: Sprint 9 - 02/05-15/05. Velocity planned: 90,5 h. Real Velocity: 78,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Packaging solution | TK | 16 | X | | - |
| Start writing Software part in product development | TC, LB | 3 | | X | Task almost done but not completed during this sprint |
| Do a 3D model stress analysis | NO | 6,5 | X | | We are waiting for feedback from the teachers |
| Do a leaflet | LE, TK | 5 | X | | - |
| Write the paper | SS | 24 | | X | Started but not completed |
| Start programming in simulation | TC | 12 | X | | Done, but simulation doesn't allow us to program everything |
| Code the web app local | LB | 24 | X | | - |

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Classes | All | 13 | X | | - |

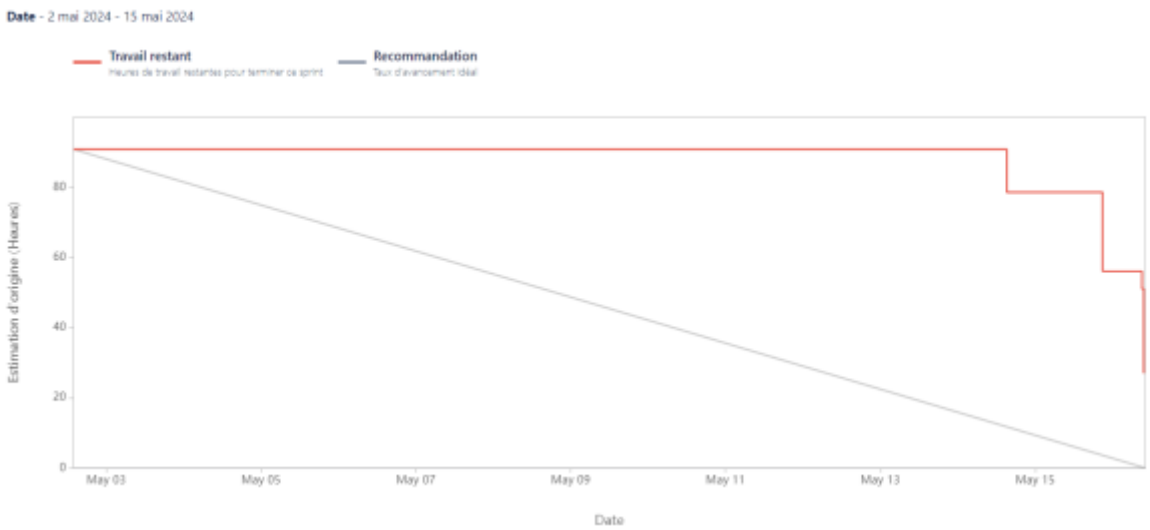



Figure 19: Sprint 9 burndown chart

Table 24: Sprint 10 - 16/05-22/05. Velocity planned: 71,5 h. Real Velocity: 64 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Do a poster | LE | 3 | | X | Started but not completed |
| Start writing Software part in product development | TC, LB | 3 | | X | No time for this task this week |
| Write hardware part in prototype on the wiki | NO | 2,5 | X | | |
| Write the stress analysis in design in the wiki | NO | 3 | X | | - |
| Write the paper | SS | 24 | | X | Continued but not completed |
| Moving from local to cloud solution | TC, LB | 4 | X | | |
| Finish the Pestel analysis | SS | 1 | X | | - |
| Program on physical components | TC | 2,5 | X | | |
| Write the user manual | TK | 10 | | X | Started but not finished |
| Classes | All | 18,5 | X | | - |

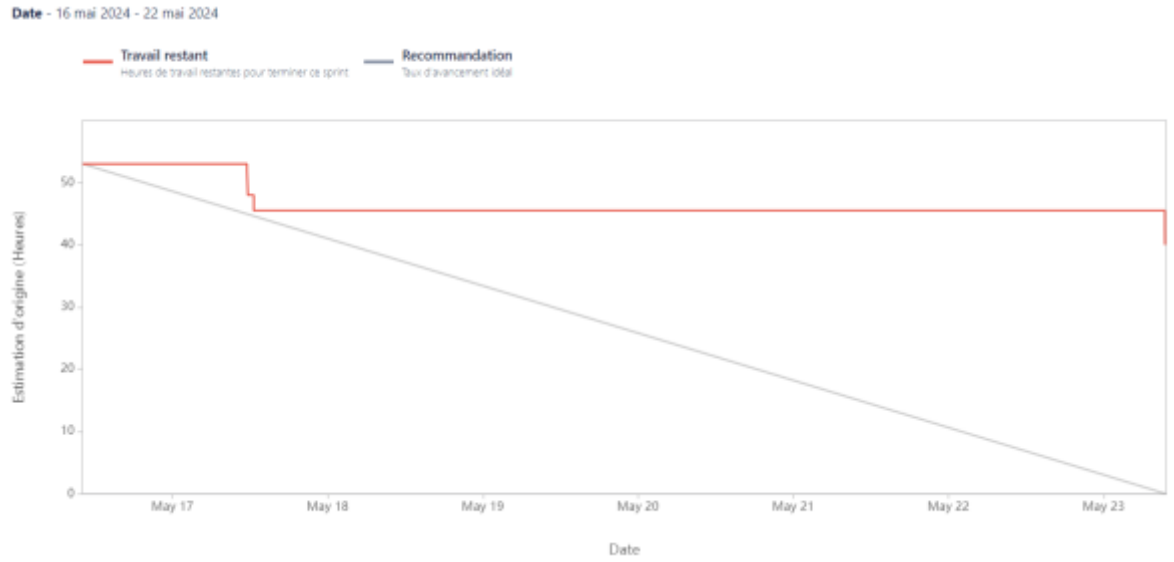



Figure 20: Sprint 10 burndown chart

Table 25: Sprint 11 - 23/05-29/05. Velocity planned: 65,5 h. Real Velocity: 55,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Do a poster | LE | 2 | X | | Positive feedback from the teacher |
| Start writing Software part in product development | TC, LB | 3 | | X | No time during this sprint because focused on other tasks |
| Do a concept diagram for the product | NO | 4 | | X | No time during this sprint because focused on other tasks |
| Write the paper | SS, NO | 19 | X | | |
| Functional test | TC | 8 | X | | Done on time |
| Improve the webapp | LB | 4 | X | | |
| Deploy project to the cloud | LB | 2 | X | | |
| Write the user manual | TK | 5 | | X | Not done, need to add some sections |
| Backend - embedded integration | LB | 4 | X | | |
| Classes | All | 14,5 | X | | - |

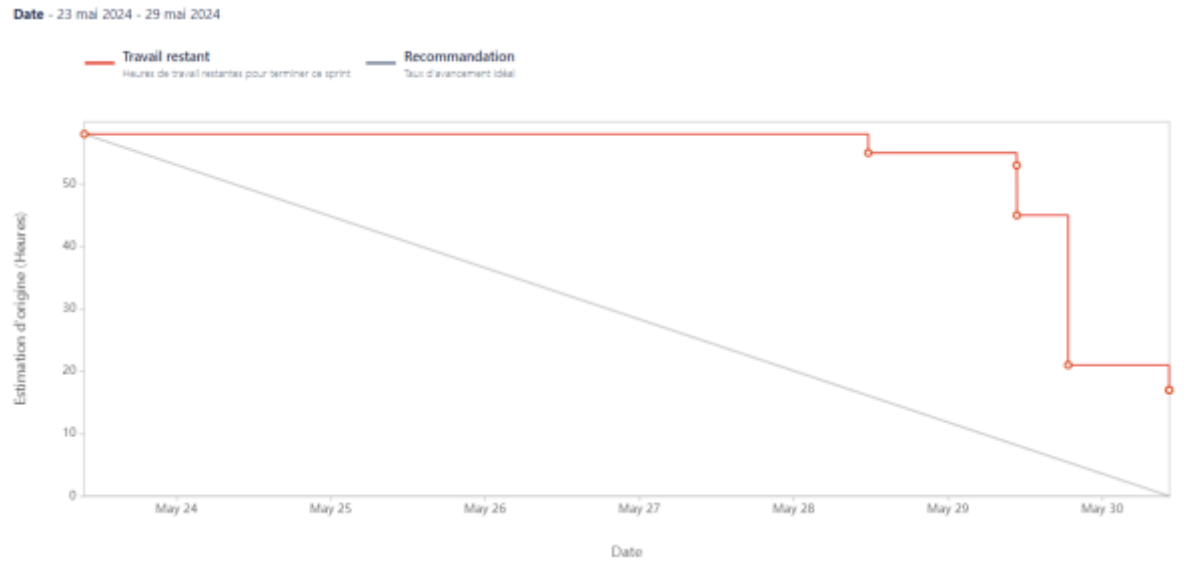



Figure 21: Sprint 11 burndown chart

Table 26: Sprint 12 - 30/05-05/06. Velocity planned: 33,5 h. Real Velocity: 24 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Start writing Software part in product development | TC, LB | 3 | | X | Started but not completed |
| Do a concept diagram for the product | NO | 4 | X | | No time during this sprint because focused on other tasks |
| Write the user manual | TK | 5 | X | | Not done,need to add some sections |
| Do the video | LE | 5 | | X | Started but not completed |
| Do the prototype | NO | 2 | X | | |
| Start writing Software part in prototype | LB | 4 | | X | Started but not completed |
| Write the discussion in the wiki | SS | 3 | X | | |
| Write future development in the wiki | NO | 1 | X | | |
| Classes | All | 6,5 | X | | |

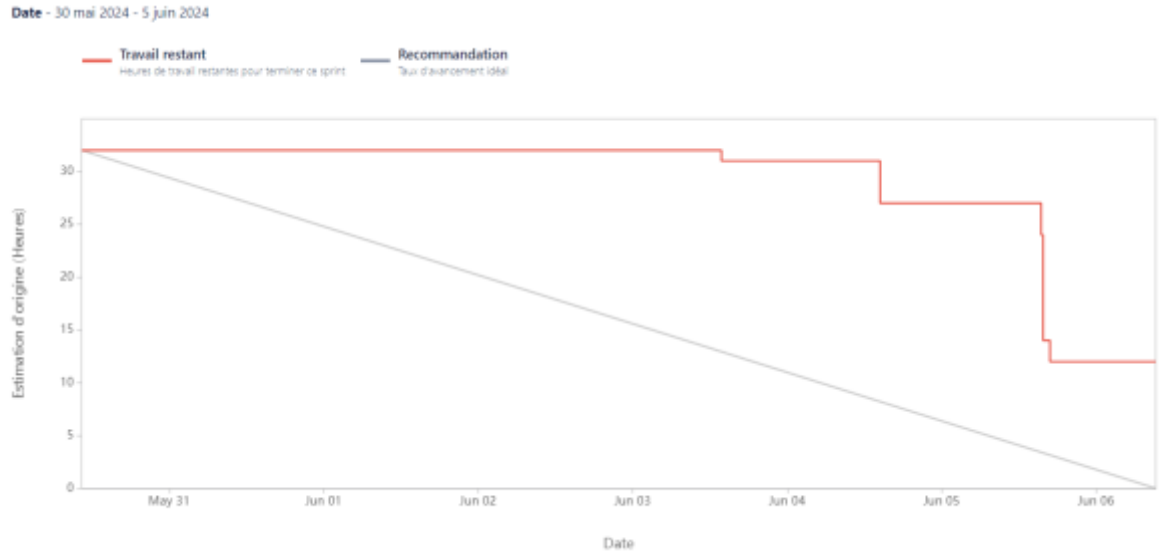



Figure 22: Sprint 12 burndown chart

Table 27: Sprint 13 - 06/06-12/06. Velocity planned: 28 h. Real Velocity: 18,5 h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Start writing Software part in product development | TC, LB | 3 | X | | |
| Do the video | LE | 5 | X | | |
| Start writing Software part in prototype | LB | 4 | | X | Started but not completed |
| Final presentation | All | 3 | | X | Started but not completed |
| Last reading of the report | NO | 3 | | X | Started but not completed |
| Upload final report | NO | 0,5 | | X | Too early |
| Classes | All | 9,5 | X | | |


Figure 23: Sprint 13 burndown chart

Table 28: Sprint 14 - 13/06-19/06. Velocity planned: 6,5 h. Real Velocity: h.

| Product Backlog Item | Assignee | Planned Effort [h] | Completed | Not completed | Notes |
|---|---|---|---|---|---|
| Final presentation | All | 3 | | | |
| Last reading of the report | All | 3 | X | | |
| Upload final report | NO | 0,5 | X | | |

## 3.12 Sprint Evaluations

At the end of each sprint, the sprint evaluation was done. It is made up of the sprint retrospectives, including any actions implemented as part of the team's continuous improvement strategy. The sprint retrospectives can be seen on Jira or in Table 29 below.

Table 29: Sprint evaluations

| Sprint | Positive | Negative | Start doing | Keep doing | Stop doing |
|---|---|---|---|---|---|
| 1 | Chose a project proposal - Brainstorming about ideas | - | Think about other ideas | Get to know each other | - |
| 2 | Completed the list of components and materials | Need to modify a little bit the list of components after the teacher's feedback | Think about solutions for the design of the product | Finish the task on time | |
| 3 | The team managed to finalize all the documents (structural drawing, detailed schematic and cardboard model) 1 day ahead of schedule. | Teachers told us to modify the design to make it more attractive | Nothing | Still working as we are doing | Nothing |
| 4 | The team managed to work on the wiki and finish some chapters | Not all team members are up to date about the work in progress | Prepare for the interim report | - | Communicating too little |
| 5 | The team managed to do a decent presentation for the interim report and got some good feedback | Saving problems in the wiki, forcing us to start again | Organize ourselves to edit the wiki | Working as we do | - |
| 6 | The team completed the 3D model video on time | Team members did not manage to improve the wiki as much as planned. The 3D model video took more time than planned | Trying to better estimate the duration of a task according to everyone's availability | - | - |

| Sprint | Positive | Negative | Start doing | Keep doing | Stop doing |
|---|---|---|---|---|---|
| 7 | The final list of components and material was appreciated by the teachers | This list wasted too much time focusing on unnecessary details and not making decisions | Be more responsive and take decisions more quickly | - | Waste time on small details |
| 8 | The refined report has been uploaded and the team received positive feedback on the changes made | The leaflet is not completed and the software part in the wiki is not done. | Define a period of work in our personal schedule to make sure that every task in the sprint is completed. | Continue to plan correctly | - |
| 9 | The packaging solution was presented to the teachers and got some positive feedback | The paper is not done and the team got stuck because the components to program were not here | - | - | Stop planning too many tasks or tasks that are too long |
| 10 | The leaflet and stress analysis are done. The code of the prototype has improved | The paper is not done yet but the team got some positive feedback on it | | Continue to work as we do | Procrastinate |
| 11 | Positive feedback on updated leaflet, poster, flyer, user manual and functional test completed on time | Nothing about software is written on the wiki | Start planning work session to write the software part | Meet deadlines on time | |
| 12 | The user manual, and the conclusion on the wiki is done, the team also started to work on the video. The paper is also done. | The software part on the wiki is still not done | Work on the software part on the wiki | | Stay focused on the project |
| 13 | The wiki is completed. The video and the user manual are also done | | | Stay focused for the presentation | |

## 3.13 Conclusion

In conclusion, this section explains that project management is one of the key elements in project implementation. Project management gave the team all the elements needed to organize its work in the best possible way by clearly identifying the objectives, the associated deadlines and stay within the budget. This enabled the team members to concentrate on the important tasks at the right time

and to be more productive when working.

What's more, the fact that the team carried out an analysis of risk, cost, quality and communication meant that no aspect or potential problem in managing this project has been overlooked. It also enabled the team to know how to respond when a problem arose, but above all to do it quickly, to get back to work quickly and lose as little time as possible. Project management also enables clear communication with stakeholders, ensuring that expectations are well-managed and project progress is communicated transparently.

Finally, the daily and weekly monitoring of the work, thanks to the use of the Scrum method and the Jira, enabled the students to be less stressed, happier, and to make their daily lives easier by not forgetting any tasks in the project.

The next chapter deals with marketing and its importance to the success of a project, detailing the strategy adopted and the people targeted by the project.

# 4. Marketing Plan

The marketing plan or analysis starts with evaluating various factors that influence a company's marketing strategies, such as market trends, consumer behavior, and competitor actions. It provides valuable insights to guide businesses in making informed decisions about product development, pricing, promotion, and distribution. It is kind of a tactic the company has to develop to fulfil specific business goals. The company must make a marketing plan for the product it wants to bring on the market. Therefore, it is important to have a look on the target group. One has to make a market analysis to gain better knowledge of the needs and behaviours a certain target group has. Moreover, it is important to know the needs in detail to be able to fulfil them and therefore gain the best chances for the product on the market. The overview of the marketing analysis is best derived from the SWOT (Strengths Weaknesses Opportunities Threats) analysis. It shows the strengths and weaknesses of the product, as well as the opportunities and threats of the market. After that, the team is able to develop strategies to improve the market performance.

## 4.1 Market Analysis

A marketing analysis serves as a guide for a company during the development of a product or service. It gives a view of where the project and company are in the market. In addition, the different components of a market analysis are interesting for a company to gain more insight and knowledge about their potential customers.

### 4.1.1 Value proposition pitch

An elevator pitch is meant to give a potential customer or investor a concise and compelling summary that describes the product in a clear and effective way. The main goal is to captivate and excite the listener to learn more about the product. While this is a brief getting-to-know-you session, it is not to be underestimated. A comprehensive and detailed value proposition can be found in the next section, the pitch is below in Figure 24.

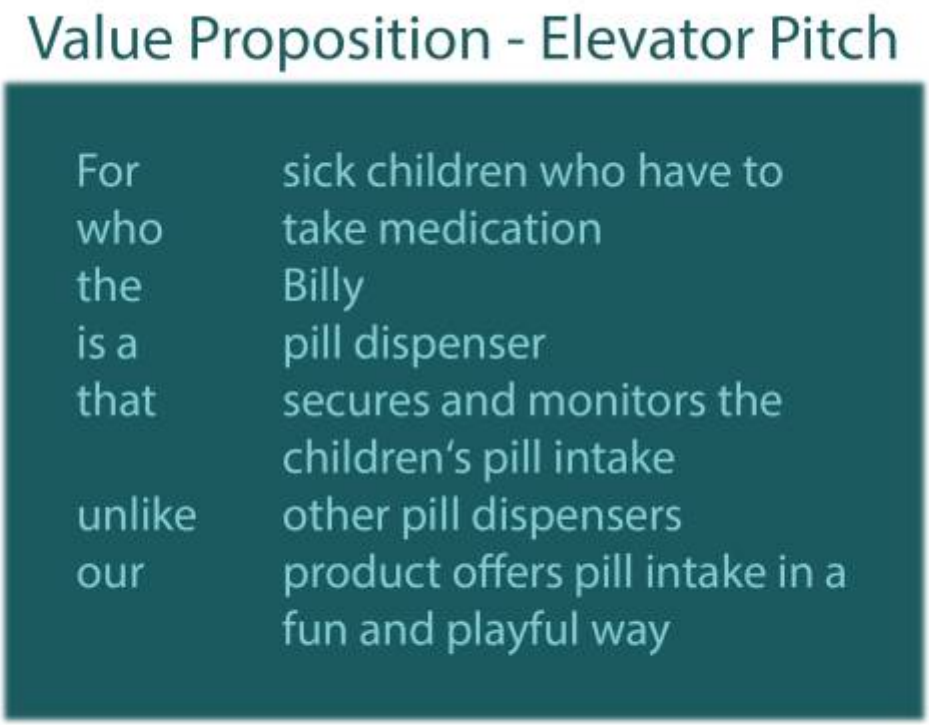



Figure 24: Value Proposition

### 4.1.2 Value proposition

Every day, companies design products to improve consumers' lives. But 72 % of newly launched products fail to meet expectations **[Strategyzer, 2024]**. To prevent this from happening, there is a tool called business canvas model, that gives more insight into numerous aspects important for a successful product launch. These include key partners and activities, cost structure and customer relationships. The value propostion canva is a tool that visualizes, designs and tests. It focuses on value propostion and customer segments.

The first part examines what a potential customer's tasks are, what pain or frustration is involved. Lastly, in the customer profile, it looks at what benefits and enjoyment the customers can get from the product.

In the second part, the value map, it begins by looking at the products and services on which the value proposition is based. Then it considers how this can help reduce customers' pain and make their lives more enjoyable. Finally, it paints a picture of how this can provide more pleasure and convenience and increase profits. The value proposition of the project can be seen Figure 25.

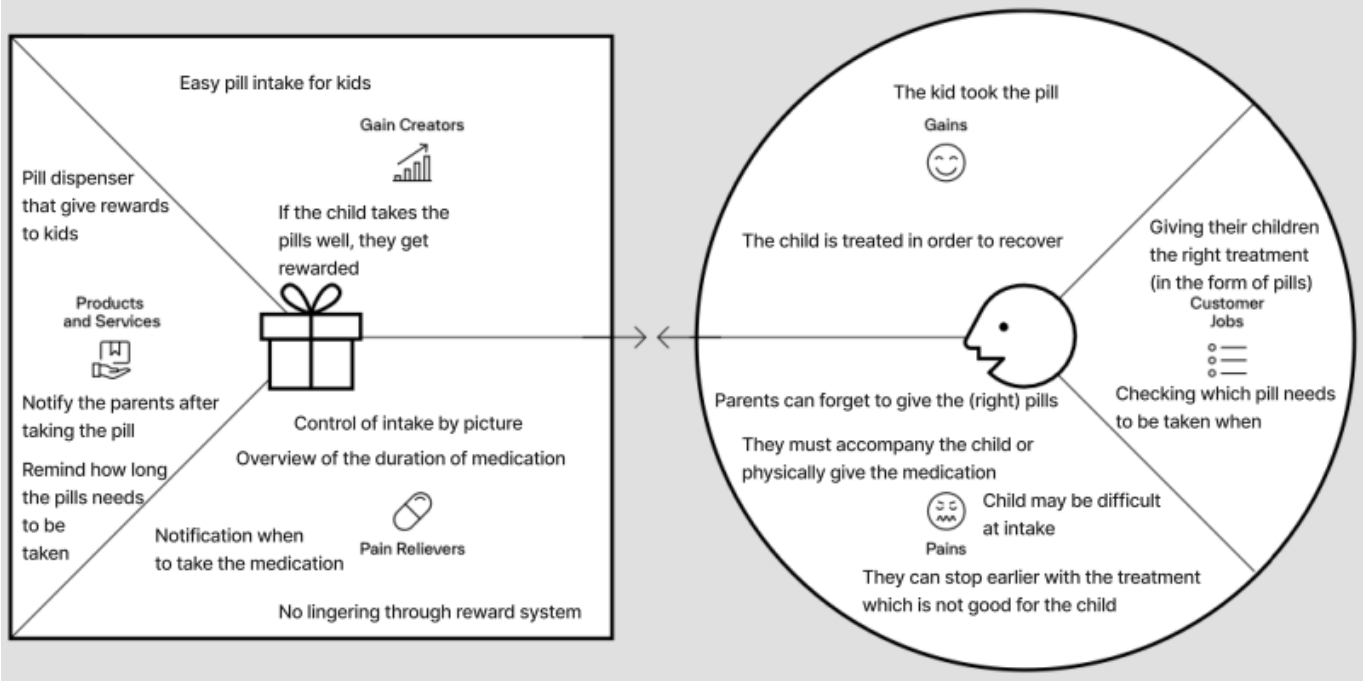



Figure 25: Value proposition

### 4.1.3 PESTEL Analysis

The PESTEL (Political, Economic, Social, Technologies, Environmental and Legal) analysis is a type of model used as marketing research for companies (see Figure 26). It gives a company insight into external factors that may affect their strategy. Usually the PESTEL analysis is used along with the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. Together, these two models help companies recognize and respond to opportunities and pitfalls. Each aspect of the PESTEL analysis says something about a different external factor **[Alayna Wood, 2024]**.

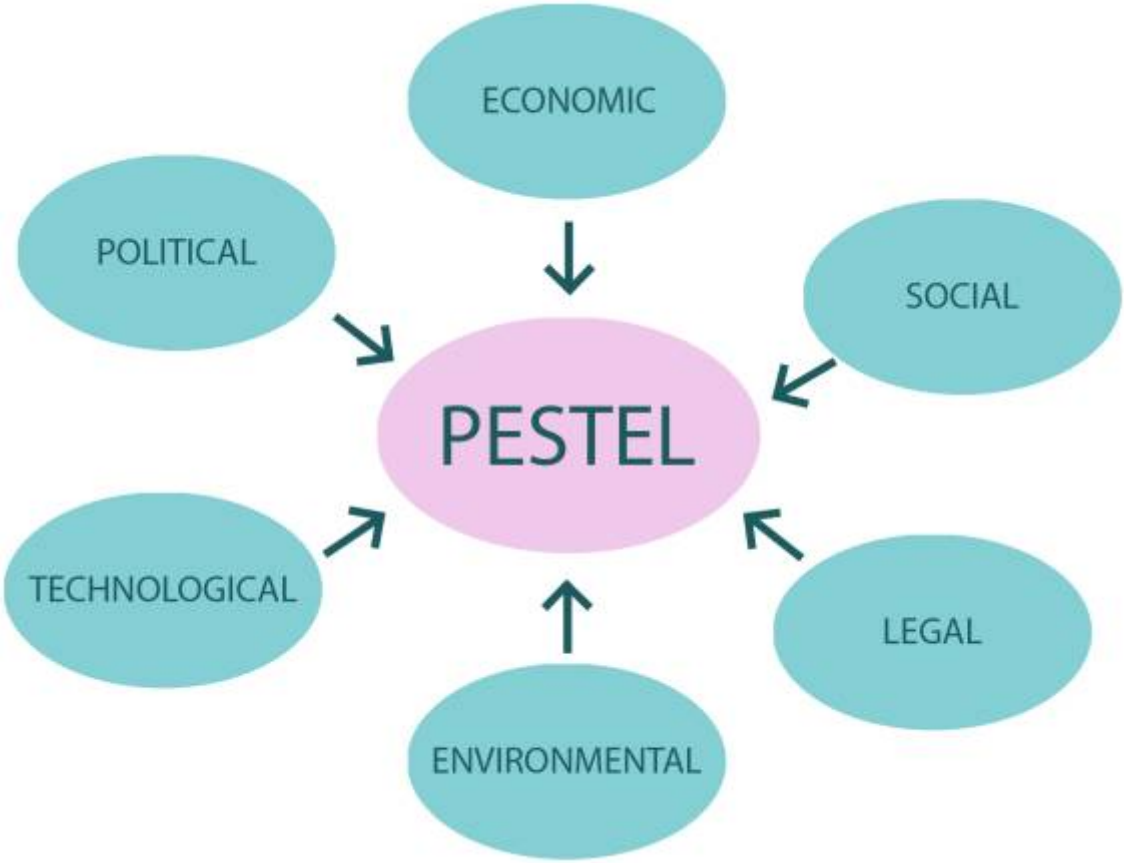



Figure 26: PESTEL Analysis

**Political factors**

Opportunities:

- With Europe's open borders, this facilitates Billy's sales, as well as the import and export of goods.
- European countries are working together on the UN SDG. This means that each country benefits from a strong health system and products that contribute to the health of their citizens.
- Government healthcare policies and funding allocations may influence the adoption of medical devices like pill dispensers, potentially affecting reimbursement rates and market demand.
- Once a product is licensed, in most cases it is valid for the entire European Union.

Threats:

- The direct impact or added value may be limited since the pill dispenser only facilitates tasks of the caregiver and makes the process more pleasant for the child, so the product is not indispensable. It may miss out on grants or reimbursements for that reason.

**Economical factors**

Opportunities:

- Billy is cheaper compared to many competitors.
- The pill dispenser is targeted for children, which makes parents often willing to pay more for their child's health care.
- In the first phase, Billy will be sold only in the European Union, which means that price fluctuations in currencies will not affect production costs or selling price.

Threats:

- The purchase price of 250 € is an additional cost on top of the price of the medication and possibly other treatment costs, for financially less powerful families this may be a cost too much.

### Social factors

Opportunities:

- Children can take pills from the age of 5 years old **[Ashley Rapske, 2018]**. Although they are the exception because usually it starts around age 8 when a doctor will prescribe them pills. To make this process easier, they can use a pill dispenser designed for children.
- This device makes it more fun for the children to swallow the pills and also helps them remember when to take which pill.
- Statistics show that more and more children are becoming allergic to pollen and the like **[Jin Schofield, 2023]**. Therefore, the product can add value to the market.

Threats:

- Not all potential customers will put their trust in this device when it comes to timely and correct dispensing of pills.
- Some cultures have different ways of raising children. It may be that a device to teach pill swallowing in a child-friendly way is therefore inconsistent with the upbringing the parents want to impart.

### Technological factors

Opportunities:

- Technological innovations, such as smart sensors, mobile applications, and connectivity features, enable the development of advanced pill dispensers with enhanced functionalities and user-friendly interfaces.
- Increasing digitalization and adoption of telehealth solutions may create opportunities for integrating pill dispensers into remote monitoring and medication management platforms. This may make it possible to get a more complete record of a patient.
- The price of small electronic components has fallen sharply in recent decades. Also, the components are getting smaller, allowing more freedom in designing a pill dispenser.

Threats:

- Not relevant.

### Environmental factors

Opportunities:

- With the awareness of the environmental impact caused by humans, more and more sustainable alternatives are also entering the market. To minimize Billy's environmental impact, it was chosen to work with bio degradable plastic and the packaging is completely recyclable.

Threats:

- To date, it is not yet possible to produce and transport Billy completely climate-neutral.

**Legal factors**

Opportunities:

- Once a product is allowed to be sold it may be sold throughout Europe.
- Products are subject to European regulations but at the same time they are also protected by these rules.
- Compliance with consumer protection laws ensures transparency, product safety, and fair marketing practices, fostering trust and confidence among consumers in the pill dispenser market.

Threats:

- To market a product, certain approvals and licenses are required. For the medical sector, these requirements are more strict.

### 4.1.4 Macro-environment

- Market Segment: The target market is parents with children who resist taking pills, indicating a need for innovative solutions to ease the medication process.
- Regulations and Standards: Compliance with EU medical device regulations (such as CE marking) is crucial for market entry and ensuring safety and efficacy standards are met.
- Competitive Landscape: While there are several startups in the market, none offer features specifically designed to make pill intake more entertaining for children, offering an opportunity for differentiation and market capture.
- Technological Trends: Emerging technologies like gamification, interactive interfaces, or smart reminders could be use to make the pill dispenser more engaging for children.
- Healthcare Policies and Insurance Coverage: Understanding reimbursement policies and potential incentives for medical devices can impact adoption rates among consumers.
- Certification and Compliance: Obtaining necessary certificates and complying with regulations is essential for market acceptance and building trust among consumers.
- Socio-Economic Factors: Affordability and accessibility may influence purchasing decisions, highlighting the need for cost-effective solutions and distribution strategies.
- Distribution Channels: Direct-to-consumer sales through the company’s website can provide easy access to the product, but partnerships with pharmacies or healthcare providers could increase customer trust and popularity.
- Cultural Attitudes: Cultural perceptions of healthcare and medication management may vary across EU countries, requiring localized marketing strategies and product adaptations.
- Design and Sustainability: Ensuring the pill dispenser is child-friendly, perhaps through colorful designs or interactive elements, aligns with the need to make pill intake more enjoyable. Additionally, considerations for eco-friendly materials and manufacturing processes can appeal to wider group of consumers.

#### 4.1.5 Micro-environment

Customers: Billy aims for specific customer groups for example parents who struggle with their kids taking medications. Such caregivers can not devote all their time to children to take control over medicine intake.

Competitors: Nowadays, on the market are many pill dispensers. They offer several functions such as: a login panel, face recognition, reminder, integrated app and many others. Most of products are the same, so they don’t introduce any innovation.

Suppliers: The pill dispenser can take electronic components from several sources, as they are commonly used in industry. Apart from these parts, the device will have a custom cover and some mechanical which can be 3D printed.

Intermediaries: Pharmacies are the dream middleman. Before the product can be sold here, the proper certificates are needed. Once this is in order, it can be sold in pharmacies. In addition, Billy will also be available for sale through the online webshop.

### 4.2 SWOT Analysis

The SWOT analysis is an abbreviation for strength, weakness, opportunities and threats. In this analysis the team looks at the product through these four points of view. It makes it clear what advantages the product has and what things can still be improved **[Will Kenton, 2023]**.

#### 4.2.1 SWOT for the market/business

**Strengths:**

- When consumers buy products, they buy benefits. The reason to buy products/services is to avoid pain or experience pleasure. This gives a lot of opportunities to develop products because there is a broad market for.

**Weaknesses:**

- High development costs and expensive medical treatments weigh heavily financially on the manufacturer and the patient.
- The medical industry is subject to changing regulations.

**Opportunities:**

- More and more people are having allergic reactions form food and pollen **[Jin Schofield, 2023]**, this can be treated by taking medication, that prevents symptoms. Therefor a pill dispenser can be useful especially for kids to remind them and give them a right amount of pills.

**Threats:**

- The medical market is complex and crowed, start-ups are often sponsored with big budget. The development is done with a team of different experts. Therefor it is difficult to compete as a

group of students and launch a successful product.

An overview of the SWOT analysis can be seen in Figure 27.


Figure 27: SWOT

### 4.2.2 Product SWOT

**Strengths:**

- The device gives the user a reminder when to take the pills and can tell you how long you have to take them.
- The product is designed to be child friendly and playful.
- To make it attractive for kids, there is a reward system if they take their medication.
- To prevent overdoses, there is a system with finger print sensor to only give supervisors access to the pill containers. The computer knows when and how many pills it can release.

**Weaknesses:**

- The device is designed to be installed in a fixed place, that means that it is not portable so if children need to take pills at school for example, they will need to store these pills in an other container.
- As a parent or caregiver you need to manually place the pills in the containers, this can take a few moments to do.
- Despite the device have a camera system to reward and check if the kid has taken their medication, therefore, there can be no guarantee that the pill will be swallowed.
- Some medical treatments can be expensive, the purchase of an extra device can be too much for some parents.

**Opportunities:**

- Most kids will like this game and therefor not hassle when taking their medication.
- Many children take medication in the form of syrup or powder, but pills work more effectively. Helping them with Billy can help them heal faster.
- The reminder function ensures that children do not forget their medication, this ensures faster healing.

**Threats:**

- By the fact that the product uses a digital system that is connected to the internet, that means that the device can be hacked.
- For some situations the product is unsuitable and for that reason it can lack value.
- Some parents may have doubts or don't trust the device.

An overview of the SWOT analysis can be seen in Figure 28.


Figure 28: Product SWOT

## 4.3 Strategy

Strategic objectives are specific and concrete goals that a company sets for itself, taking into account its marketing analysis, in order to achieve its long-term goals. It is in fact a roadmap to turn the predefined vision into reality. These goals have the characteristic of being concrete and explaining in detail what they mean. Strategic objectives has several similarities to SMART (Specific, Measurable, Achievable, Realistic, and Timely) goals. SMART is short for specific, measurable, attainable, relevant and time-bound. Strategic objectives sometimes have slightly different parameters but both methods are very useful and usable to set goal-oriented goals and achieve long-term objectives.

Strategic Objectives:

1. Alignment with vision and mission.
2. Specific and clear
3. Measurable
4. Relevant and realistic
5. Time-bound
6. Hierarchy
7. Flexibility and adaptability

These are just a few guidelines that an objective must meet to be strategic. But in addition, there are different types of strategic objectives, distinguishing between growth, customer and financial strategic objectives, an example of this can be seen in Table 30.

Table 30: Billy's objectives

| Description | Deadline | Status |
|---|---|---|
| Determining the target group | 2024-04-24 | Delivered |
| Finishing the list of materials and the design | 2024-04-24 | Delivered |
| Deliver a working prototype | 2024-05-28 | Ongoing |
| Delivering and presenting the pill dispenser | 2024-06-20 | Upcoming |
| Finding investors to produce Billy | 2024-09-01 | Upcoming |
| Starting marketing campaign | 2024-09-05 | Upcoming |
| Launch online webshop for selling Billy | 2024-09-05 | Upcoming |

### 4.3.1 Segmentation and Targeting

Market segmentation is a business practice that companies use to divide their target market into smaller, more manageable groups of people. They do so on the basis of things common to their target group, to optimize their marketing, advertising, and sales efforts. Simply put, customers of each market segment have similar characteristics that businesses can leverage to advance their efforts **[Hannah Tow, 2024]**. A strong research of market segmentation can yield several benefits. The biggest benefit is probably that a company can better understand their audience and respond to it. As a result, they are able to better reach their customers, which is often accompanied by growth of the company, more efficient use of resources and a better customer experience **[Adobe Business, 2024]**. Not every market segmentation is the same, so there are different types, each for their specific application. This ensures that for each situation there is a tailored research to the target audience and thus can expect better feedback or results.

Information such as age, gender, social class and location are of great value in determining the target audience. The persona and target audience are certainly not the same thing. A persona is a more detailed representation and moreover is of one person, it outlines more of a character and image of an individual. The target audience (see Figure 29) is a more general segment of people with similar similarities.


Figure 29: Target audience children

### 4.3.2 Positioning

The companies have been catalogued by product price and by innovation/functionality, which is defined in 4 categories: product smartification, adjustability, ergonomics and design. In Figure 30 there is an overview that shows similar products such as Medacube and Hero. Those products are highly innovative but also very expensive (over 1000 €), but offer features such as secure drug storage and the ability to dispense 1 dose for 90 days. In the middle of the chart are Pillohealth and Karie, which are less expensive but offer slightly fewer functions, in particular a much smaller number of doses. And finally Gogooda and Livefine offer products with less functionality (simple alarm or nothing at all) but at very economical prices.

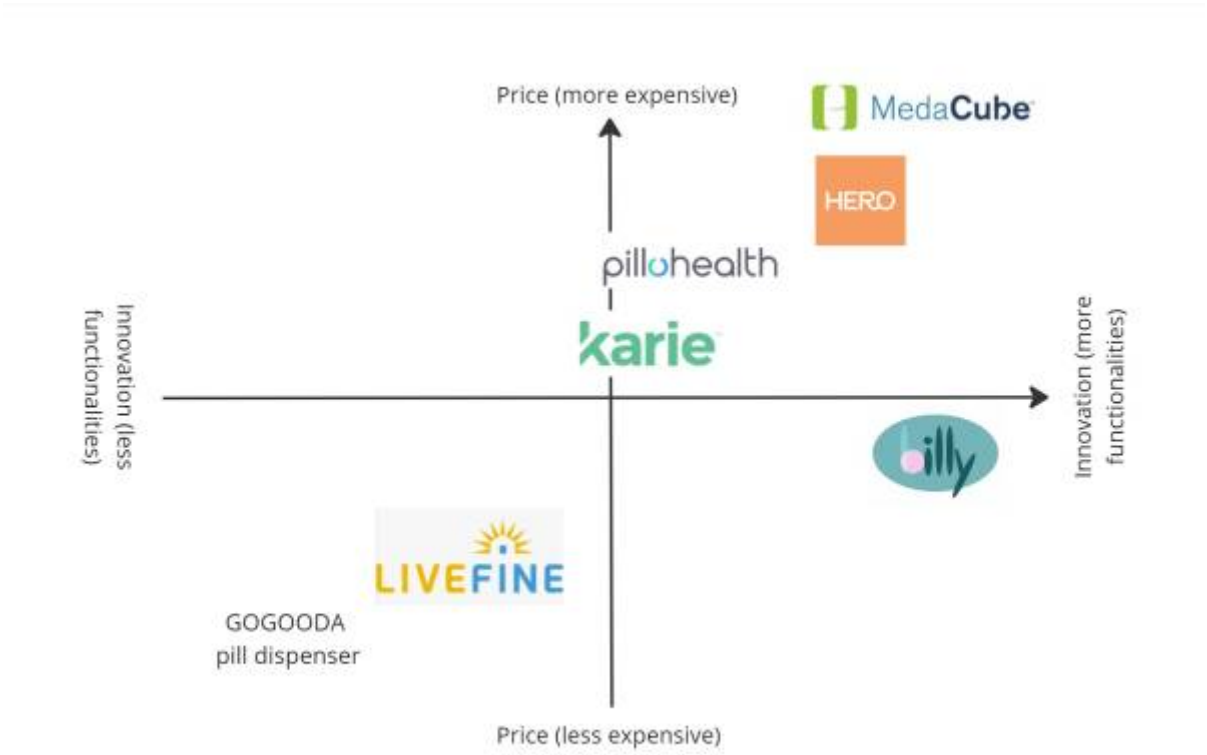



Figure 30: Positioning of Billy compared to the competitors

The comparison that can be made against the product can be difficult, because the product that the team is producing is not on the market. Billy will be more expensive than the average automatic pill dispenser offering many features but slightly fewer doses than the most expensive products. An

overview of this can be seen in Table 31.

Table 31: Billy's objectives

| Products | Functionality | Smart | Ease of use | Appealing to kids | Price |
|---|---|---|---|---|---|
| Gogooda | Just a plastic box | – | ± | Yes | 5-10 € |
| Livefine | Plastic box with an alarm | ± | + | No | 60 € |
| Karie | Alarm system plus face recognition | + | + | No | 200 € + subscription |
| PilloHealth | Alarm system plus face recognition | + | + | Yes | 300 € |
| Hero | Alarm system plus notification of medication taken to relatives | ++ | + | No | 44.99 €/month |
| MedaCube | Alarm system connected to an app to notify that the medication is taken to relatives | ++ | ++ | No | 1700 € |
| Billy | Reward system for kids and notified that the medication is taken to relatives | + | ++ | Yes | 250 € |

### 4.3.3 Marketing-Mix

- Product

The idea of a pill dispenser is not very innovative, although the team believes that the product can make a change in this market. Billy, the name of the product, is a pill dispenser focused on children. It was decided to make a pill dispenser, although there are already a lot of products for elderly people on the market. Most of those devices are smart, have a connection with the customers smartphone and can track which kind and the amount of pills that have been dispensed. But none of these products are designed for kids. Lot of kids have issues with taking medication, especially if they need to swallow a pill. For that reason, there is an opportunity to design a product for children. The main goal was to make the process of taking pills more playful for children. In addition, the idea was to add other features to reward the children when they complete their treatment, a reminder system and a protection against overdoses. It is a strong belief that this product can add value to children and by extension the family. More and more people, especially children, are sensitive to allergies. Often these symptoms are treated with pills. Learning children how to take medication in a playful way can avoid a lot of hassle and Billy is happy to help with that.

- Price

To have a highly competitive price, the product must be priced lower than competitors. Billy will therefore be on sale at a price of 250 €. However, it is the team's goal to offer the product as a purchase option but also give customers the flexibility of being able to rent the device for a certain period of time.

- Place

Billy will be available in healthcare stores and the product will be also sold on the online store of Billy.

- Promotion

The promotion will be done through different methods. No solution fits perfectly for everything. Please refer to the strategy for Billy's promotion to 4.5.1 Marketing Programmes.

### 4.3.4 Brand

#### Name

The name for the pill dispenser is “Billy”. Since it is a product designed for children in order to make their medication intake easier and add some fun to it, the intention was to give it a name that could also be the name of a friend. In some way, Billy kind of does become a child's best friend during the time they have to take their medication. More explanation about the name and the logo is presented in chapter 7.

The company behind Billy would like to apply for European and international rights to protect the brand.

#### Logo

The logo is supposed to match Billy's energy which is why the choice of the logo's colours and shape of it was made to be colourful, intensive and also round, the logo can be seen in Figure 31.


Figure 31: Logo

## 4.4 Marketing Programmes

### 4.4.1 Programmes

It was decided to promote the product through different methods. For example, the team desires to create campaigns that target parents of young children and distribute them through social media. Platforms such as Facebook **[Facebook, 2024]**, Instagram and Google Ads **[Google, 2024]**, it is very effective for targeting individuals to send targeted and customized advertising to. These

individuals are determined through the marketing research. Part of the plan is also to distribute the flyers and leaflets at hospitals and healthcare providers. This is a place where children come together with their parents, which makes it interesting to leave the information here via flyers and the like.

The persona of the product is a young child who needs to take medication for whatever reason. But they are not the ones who actually purchase the product, the parents of the child are the ones that are buying the product. The flyer can be seen in Figure 32.


Figure 32: Flyer

### 4.4.2 Budget

To estimate costs, a financial plan is prepared specifically for marketing purposes. This means that all costs per item, such as flyers, online ads, etc, are noted to obtain an overview. This is important for the team to keep track of the total costs of the project but in addition, it also adds value for the shareholders. This way they can see how much is spent on marketing and make a ratio between this expenditure and the total income of the product. In Table 32, the data is shown with the expenses for marketing.

Table 32: Budget

| **Income** | **Price [€]** |
|---|---|
| Budget | 3000 |
| **Expense** | **Price [€]** |
| Flyers | 150 |
| Posters | 250 |
| Leaflets | 300 |
| Facebook | 1000 |
| Instagram | 1300 |

### 4.4.3 Control

To know and measure exactly what is going on, companies make use of the PDCA (Plan, Do, Check and Act) method **[ProductPlan, 2024]**. This is the abbreviation for Plan, Do, Check and Act. This method allows the team to continuously evaluate and improve the work to achieve the pre-set goals, a diagram of this can be seen in Figure 33.


Figure 33: The PDCA Circle **[ProductPlan, 2024]**

- Plan: The approach starts with an analysis which is called the plan. In this step, existing data is analyzed and a goal is established.
- Do: In the do phase, an idea can be tested or have a small trial.
- Check: Here the results of the do phase are analyzed. If the results are found to be positive, it can be tried on a large scale. If not, it can be returned to the plan phase and the team has to develop a new idea.
- Act: Action is now taken with the knowledge gained from the previous stages.

Before an audit can be conducted, clear objectives must be planned. This is defined in Table 33. Depending on the different platforms, different objectives are set. By keeping track of these parameters, controls can be performed and objectives measured and achieved.

Table 33: Objective controle

| Platform | Objective | Key Performce Indicators | Budget € |
|---|---|---|---|
| Flyers | Reach potential customers in physical stores such as pharmacies and child care centers | The team would like to reach 3000 potential clients | 5-10 |
| Posters | Reach potential customers in physical stores such as pharmacies and child care centers | The team would like to reach 3000 potential clients | 250 |
| Leaflets | Reach potential customers in physical stores such as pharmacies and child care centers | The team would like to reach 3000 potential clients | 300 |
| Facebook | Using social media to publicize Billy to potential customers | The team would like to reach 50 000 potential clients | 1000 |
| Instagram | Using social media to publicize Billy to potential customers | The team would like to reach 50 000 potential clients | 1300 |

### 4.5 Conclusion

In the marketing chapter, the team has learned a lot of insight about the potential that the product, a smart pill dispenser, has. It is clearly known for whom and why this product is being developed as a solution. The team's task is to start implementing the knowledge acquired during these investigations properly. Moreover, it is concluded that in addition to this niche group, children of the age of 8 to 12 years old, there are very limited to no direct competitors for this target group. All these aspects together ensure that the team is determined to bring a successful product to market.

The marketing chapter provided a strategy for Billy to make a reality. The next chapter is going to focus on making this project sustainable and is called Eco-efficiency Measures for Sustainability. In times of sustainable change, minimizing the impact of development, materials, assembling, transportation and use and possible recycling is crucial. In this way, the objectives can be achieved sustainably.

## 5. Eco-efficiency Measures for Sustainability

Over the last few decades, sustainability has gained importance. This chapter will first give an overview of the most important aspects of sustainable development and eco-efficiency. Therefore, it will be focused on the three pillars of sustainability, the set of sustainable development goals, and the Life Cycle Analysis (LCA) of the product, Billy.

*What is sustainability?* Sustainability is a process that attempts to meet its goals continuously over time. Moreover, these goals include preventing the depletion of natural or physical resources. These could, for example, be gas, coal or oil. In the past, they were used intensively and therefore had a big impact on the economy. But over time, it became visible that it had a bad impact on our planet and,

therefore on the living species. So it would be in everyone's will to find a way to make life as sustainable as possible. This should point out that sustainability is not only about environmental aspects, it is also about our health as a society, and has to ensure that no areas suffer as a result of environmental legislation. One impact on that would be environmental engineering and therefore trying to produce Billy as eco-efficiently as possible. To sum up, sustainability means protecting our natural environment, human and ecological health while driving innovation and not compromising our way of life.

*Sustainable development*

The sustainable development engages in keeping the balance between the need to move forward technologically and economically while also protecting the needs of the environment and natural resources (see Figure 34).

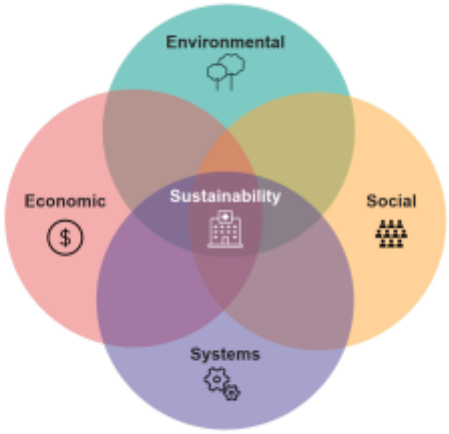



Figure 34: Three Pillars of Sustainability **[Shari Blanch, 2024]**

Due to sustainable development, the World Summit on social development identified three core areas in 2005 called "The three pillars of sustainability". These areas try to provide a philosophy for sustainable development. The three areas include Economic Development, Environmental Development and Social Development.

*The Primary Goals of Sustainability* In 2015 the United Nations invented the Sustainable Development Goals (SDGs), also known as Global Goals, to make a process in the end of poverty and protecting the planet and set the goal, that all people should live in peace and prosperity by the year 2030. There are 17 SDGs, as you can see in Figure 35, which all depend on each other. That means that if changes can be recognized in one SDG it will have an affect on another one **[United Nations Development Programme, 2024]**.


Figure 35: Global Goals for Sustainable Development **[United Nations Development Programme, 2015]**

Every Indicator has its own goal to fulfill. For example, a closer look at number 3, Good Health and Well-being, shows that the goal is to guarantee healthy lives at all ages. Moreover, it is stated why this goal should be achieved and what progress has been made so far. In this example it points out, that the healthy lifestyle and therefore our social development can be distracted trough a lot of different things as for example pandemics as covid-19 which damaged the health system globally. Besides that, it also points out what impact every individual can have **[United Nations Development Programme, 2015]**.

## 5.1 Environmental

Individuals can have a significant impact on sustainability by making changes in their daily lives. This is also true for companies developing products. By adapting to nature, rather than trying to control it, more sustainable practices and products can be created.

The three common ways to reach environmental protection can be seen in Figure 36:


Figure 36: Aspects concerning environmental protection **[UNISAN, 2024]**

The goal is to keep the carbon emissions as low as possible. Moreover, one could help the environment by using renewable power sources or just not overconsuming not-needed goods. Since only local providers get selected for the production of Billy, the transportation ways are the shortest possible and therefore fewer emissions get produced.

*Reduce - Reuse- Recycle*: The renting option also makes it possible to reduce waste, since customers who only need Billy temporarily can give it back. Moreover, broken pieces can be exchanged, so there is no need to throw away the whole product. Furthermore, the used items get recycled the best way possible and get used in other products again.

Some of the Goals of Sustainability (SDGs) try to improve this environmental pillar. One example would be indicator 13 ”Climate Action”. The goal is to take urgent action to tackle climate change and its impacts **[United Nations Development Programme, 2015]**.

One could ask why this is so important. Big changes in climate change can be seen, therefore the warmest decade was 2010–2019. At first, this did not sound very dangerous, but within the warmth came massive wildfires, hurricanes, melting glaciers and much more. But this not only has an effect on nature it also affects humanity and the economy. With the Parisian Agreement in 2015, the United Nations took a significant first step to take action on climate change. The goal to which 195 states committed is to make the global temperature rise to below 1.5 °C at best, but at least below 2 degrees **[United Nations Development Programm, 2015]**.

## 5.2 Economical

Economic Sustainability is the process of taking actions that help a business grow financially or in economic growth while also preserving the environment, society and moreover the culture. Therefore, a general understanding of sustainable business practices is needed. This includes avoiding harmful manufacturing techniques, the production of food waste and burning fossil fuels to help with climate change.

“The goal of economic sustainability is to achieve economic growth without making the negative environmental trade-offs that traditionally go hand in hand with growth. Economic sustainability is a broad collection of decision-making principles and corporate practices” **[Schneider Electric, 2022]**.

Nowadays, sustainable economic development has gained in importance. Rapid industrialization puts more and more pressure on the world's resources, and big companies need to adapt. Even businesses that try to help with economic growth need to take action when it comes to sustainability. It shows that the trend goes to “being sustainable” because it is a good and appealing marketing strategy. Most of the big companies start to advertise sustainable products, but most of the time, this is only used as marketing method to reach a broader target audience.

“When it comes to environmental impact, the truth regarding the damage caused by the global business community is harsh. They are one of the worst contributors to the abuse of natural resources and carbon emissions. By not prioritizing environmental sustainability, businesses around the world are contributing to the negative environmental impact“ **[Schneider Electric, 2022]**.

Most of the time, companies try to make the biggest profit possible therefore, they use the cheapest way to produce and the most inexpensive raw materials possible. One example is the fast fashion industry, which uses single-use plastics. Costs might be more appealing for a business owner because it is usually cheaper to produce environmentally unfriendly products. Fewer costs in production make the pricing for customers lower, resulting in better sales on the market. Rising markets and product variability have a big influence on the competition, which every company tries to keep up with.

As a sustainable company, it is possible to make small changes in production that have an impact, such as:

- Selecting sustainable transport methods
- Choosing a production location that is not too far away from the delivery point to minimize transportation ways
- Using lightweight materials
- Buying from local suppliers
- Using recyclable materials
- Creating coordinated processes to not lose time and resources

Implementing in Billy: by choosing local providers as our first source for materials, transportation becomes easier. In addition to that Billy firstly is only sold in Portugal and near regions which also creates short distances. Since Billy is designed to fit in every household it is not very big. The packaging is also created to be practical while shipping and also easily stackable to make the most use out of the given transportation options. Also, the packaging of Billy should not only have a shipping purpose, by creating a game inside it is possible to give it a new life and not need to throw it

away.

## 5.3 Social

The social aspect of sustainability deals with the community, education, equality, social resources, health, well-being, and quality of life.

Definition: “Social sustainability includes achieving a fair degree of social homogeneity, equitable income distribution, employment that allows the creation of decent livelihoods, and equitable access to resources and social services, a balance between respect of tradition and innovation, and self-reliance, endogeneity and self-confidence (Sachs, 1999, pp. 32–33). A strong definition of social sustainability must rest on the basic values of equity and democracy, the latter meant as the effective appropriation of all human rights – political, civil, economic, social and cultural – by all people” **[Jennifer Mcguinn, et al., 2020]**.

Therefore, the product must not have a big impact on destroying nature by human influence. This can be changed by making the handling a way that is easy to use and understand. Furthermore, Billy must provide information about the right disposal. It would be beneficial to make it possible for customers to send back items they no longer need, allowing these items to be given a new life. In addition, enough information must be provided beforehand about ethical and sustainable issues. Also, Billy will be more affordable than other already existing options on the market, to make it possible for everyone to reach the highest state of well-being. In addition to that the renting option even makes it possible for a bigger target group to afford Billy and limit the expenses, since they can give it back if it is not needed anymore. Moreover, for the sake of Techno-centric-concerns Billy is produced in the most sustainable and resource-efficient way possible. Another way of ensuring social sustainability is trying to find a production place which is not destroying the environment or someone else’s property. The shelter should be placed somewhere next to an urban environment, so it is easy to reach customers and for transport.

However, most importantly Billy tries to make an impact in social well-being by helping parents and their children with a common daily problem, without destroying the environment.

## 5.4 Life Cycle Analysis

A Life Cycle Analysis (LCA), also known as a life cycle assessment is a way of measuring the impact of a product during each stage of its life, from product to waste or recycling. Since for these measurements many parameters play a role in the result, this is not an easy exercise to perform correctly. LCA has therefore been defined as a European standard, the ISO 14040. This standard ensures that all measurements are done according to the same method and rules, thus through the data used a realistic estimate can be made about the total impact on environmental impacts **[European Commision, 2024]**.

Some questions to be asked during this calculation include, for example, what raw materials were used for production and from where do they come? How are these raw materials and the final product transported and how is the product produced. These are some of the questions for which answers must be formulated, supported by data **[Ecochain, 2024]**.

Despite not being a simple and very specific analysis, it can still add value to most departments of a company.

- Product management/R&D
- Supply chain management
- Marketing & Sales
- Executive management

The insights from analysis allow more thoughtful decisions to be made throughout the company. When decisions are made based on data, it is possible to make decisions that not only ensure that the company or product becomes more sustainable but also that other goals such as marketing goals are achieved more quickly and sustainably.

A product life cycle consists of 5 phases **[Ecochain, 2024]**.

1. Raw materials extraction
2. Manufacturing & processing
3. Transportation
4. Usage & retail
5. Waste disposal

A diagram of this can be seen in Figure 37.

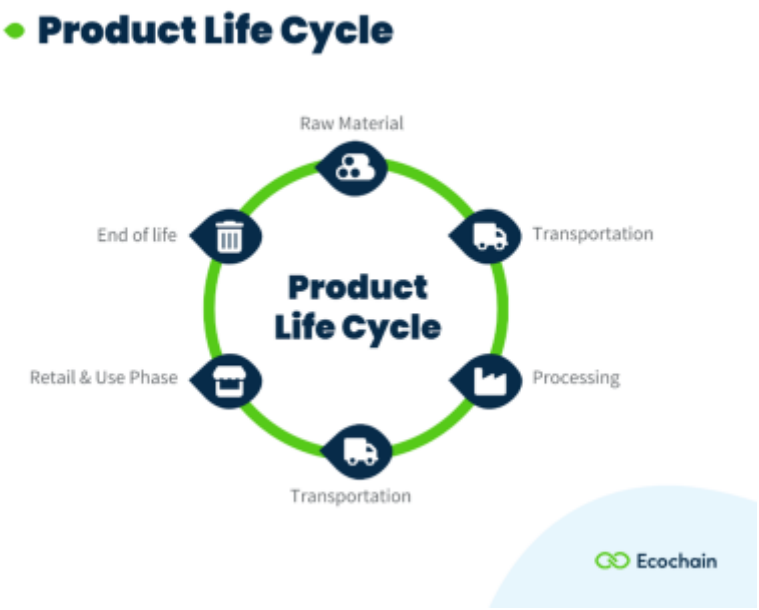



Figure 37: Product life cycle **[Ecochain, 2024]**

There are 4 different methods to analyze the LCA. Depending on the product for which the LCA is being analyzed, the method is determined.

- Cradle to grave

This is an LCA for products that have no further function after use and are then destroyed.

- Cradle to gate

This looks only at the environmental impact of production until it leaves the factory. The impact of consumer use and processing or recycling is not taken into account. Therefore, it does not capture all the stages and the result does not give a complete picture.

- Cradle to cradle

This is the LCA for products in the circular economy. It corresponds to the cradle to grave with the only difference that the waste disposal is replaced by the recycling process. In this process, that product is given a new life, or the raw materials are reused in another product.

- Gate to gate

This LCA is sometimes used by companies to know internally what impact their processes have. This can be added later to another LCA to get a complete result.

These methods are summarized in Figure 38.

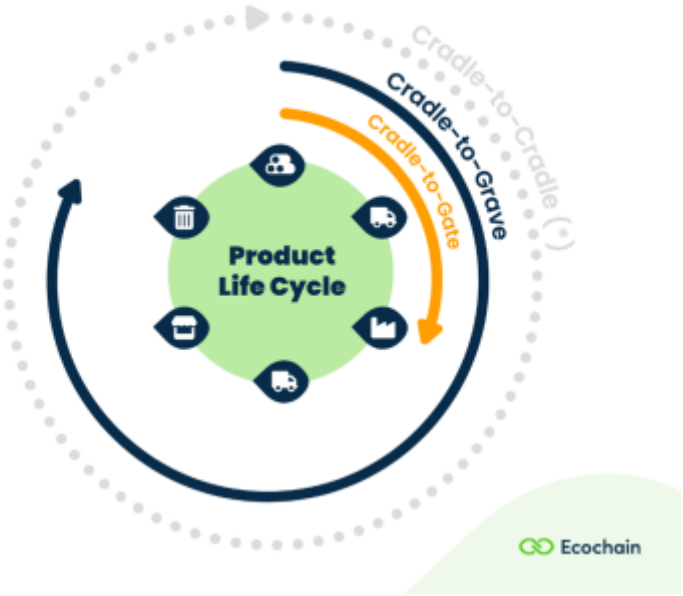



Figure 38: Product life cycle diagram **[Ecochain, 2024]**

There are still some special methods that are only used for specific applications. An example is from “Well to Wheel,” which is an LCA (Life Cycle Analysis) specifically intended for the automotive industry.

Now that we know more about a product life cycle, it is possible to move on to the content of a life cycle assessment, which consists of four phases.

1. Goal and Scope
2. Inventory analysis
3. Impact assessment
4. Interpretation

The first step of the analysis is determining exactly what needs to be analyzed and how comprehensively it should be done. How it will be examined is also important. This is all written out in the first step of the analysis, Goal and Scope. The first step says something about what will be investigated, and the second step will collect and inventory the data. Information must be gathered anyway about the raw materials, production process, transportation and the like. Other parameters needed for the research are established in the first step, what exactly is all being researched. The way of surveying the data currently leads us too far away from this chapter. In the third step, an evaluation is made of the data with the predetermined goals. To process all the data, a software will be used. This software will process all the steps and provide an overview with the necessary results. In the last and fourth stage, an interpretation of the results is done. All phases are reflected in Figure 39. The interpretation is defined in the ISO 14044:2006 standard **[Ecochain, 2024]**.

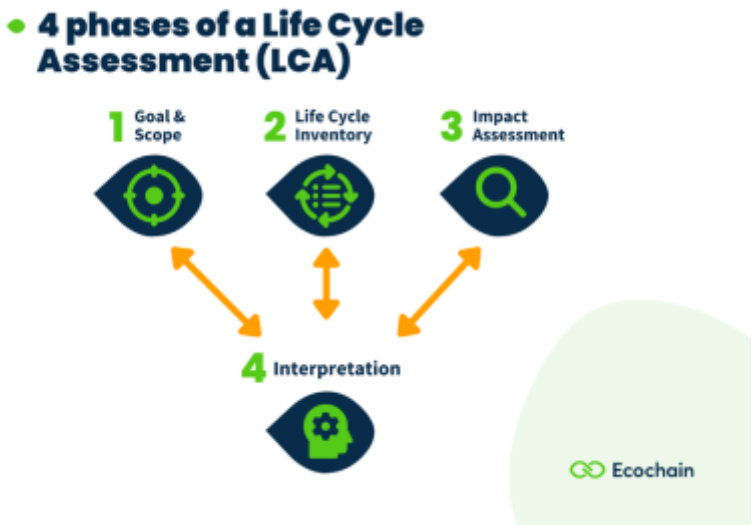



Figure 39: Phases of a LCA **[Ecochain, 2024]**

### 5.5 Conclusion

As a pill dispenser developer, the team aims to improve children's health. To complete the value and mission, this will be done sustainably and ecologically. Although the choice of materials is not yet fixed, there is a strong preference to use mainly plastic for 3D printers. The production of this material requires little energy, resulting in a limited ecological footprint. Moreover, this plastic is fully recyclable.

Additionally, the product contributes to goal 3 of the United Nations “Good Health and Well-being” by helping children take their medication through a sustainable product.

The next chapter deals with ethics in a project such as this one, defines the different types of ethics that exist and how they relate to this project.

## 6. Ethical and Deontological Concerns

Deontology is an ethical theory that helps distinguish right from wrong by using rules. Philosopher Immanuel Kant, who is often associated with deontology, believed that “human beings have a duty to perform or not to perform certain actions, because they are right or wrong in themselves, irrespective of their consequences”, making these concerns a part of every person’s every day lives **[D. M. Daniel, 2013]**.

When developing a product, ethical and deontological concerns are always aspects and concerns that need to be considered. The goal of Billy is, that it gets as much personal information as needed and as little as possible the same time. The aim is to make the product valuable to the children as well as the caretaker by following all ethical and deontological guidelines. In the following chapters, ethical concerns connected to Engineering Ethics, Sales and Marketing Ethics, Environmental Ethics and Liability that may come up will be elaborated on.

## 6.1 Engineering Ethics

Engineering ethics are guidelines adapted for engineers to follow in order to make sure that they make decisions that also match the public's, their client's and the industry's standards **[E. Han, 2023]**. Since engineers play a big role in the development of the world, it is crucial that they uphold ethical and deontological standards.

The National Society of Professional Engineers' code of ethics sets the standard for ethical behavior in engineering. The **fundamental canons** are listed below **[National Society of Professional Engineers, 2019]**:

1. Hold paramount the safety, health, and welfare of the public.

2. Perform services only in areas of their competence.

3. Issue public statements only in an objective and truthful manner.

4. Act for each employer or client as faithful agents or trustees.

5. Avoid deceptive acts.

6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

In addition to the canons, The National Society of Professional Engineers has also defined Rules of Practice as well as Professional Obligations.

**Rules of Practice:**

1. Engineers shall hold paramount the safety, health, and welfare of the public.

2. Engineers shall perform services only in the areas of their competence.

3. Engineers shall issue public statements only in an objective and truthful manner.

4. Engineers shall act for each employer or client as faithful agents or trustees.

5. Engineers shall avoid deceptive acts.

**Professional obligations:**

1. Engineers shall be guided in all their relations by the highest standards of honesty and integrity.

2. Engineers shall at all times strive to serve the public interest.

3. Engineers shall avoid all conduct or practice that deceives the public.

4. Engineers shall not disclose, without consent, confidential information concerning the business affairs or technical processes of any present or former client or employer, or public body on which they serve.

5. Engineers shall not be influenced in their professional duties by conflicting interests.

6. Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by other improper or questionable methods.

7. Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.

8. Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising out of their practice for other than gross negligence, where the engineer’s interests cannot otherwise be protected.

9. Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others.

Of course, as engineers, the team has to and also wants to work according to these rules implemented by The National Society of Professional Engineers. All of the members are aiming to work with a good ethical consciousness and try to avoid every conflict of interest.

## 6.2 Sales and Marketing Ethics

Sales and Marketing are a big part of today’s society since every product or service uses it in order to gain and, in the long term, build long-term relationships with those customers. However, keeping customers requires ethical behavior. In order to achieve that and not to act unethically when it comes to competition or profit, there are certain ethical marketing values that all brands are supposed to strive for **[J. Bradford, 2023]**:

**Honesty**

Being truthful and transparent when it comes to the features of a product. The team will list all of the following features that Billy provides:

- Access only at the right time secured by a Fingerprint sensor
- Dispension of right amount of pills
- Proof by pictures
- App application for the caretaker
- Fun factor
- Reward system

However, the team members will also be honest and transparent about the fact that the pill as well as the reward storage needs to be filled manually after every 21 dosages.

#### Respect for individual rights

Being respectful when it comes to preserving the privacy of costumers and avoiding discrimination. Billy uses pictures as proof in order to make sure that the child actually took the pill. Even though the pictures are going to be stored in the app that is linked to the pill dispenser, only the caretaker has access to those pictures to make sure that the child's privacy is being protected.

#### Respect for Human Dignity

Avoiding tactics that manipulate costumers, like using influencers that in fact do not actually use the product for advertisement. Therefore, the marketing for Billy does not include using influencer's to promote the product. The main distribution channel is going to be a proper advertising placement.

#### Responsibility

Being responsible when it comes to harming people or society which includes advertising an unhealthy product, like colorful vapes for teenagers. Even though promoting Billy requires colorful advertising, it will not deceive the customer since the product itself is colorful because it is designed for children. Responsible advertising for the product will not be an obstacle since the product itself is only a tool for making the pill intake more fun, not promoting to do it more often which is prevented by the fingerprint system anyway.

With selling the product Billy, the team, just like any other company, is also obligated to act according to these values when selling a product or a service. All of the team members aim for a honest, respectful and responsible marketing practice and want to build trust with the costumers, leading to a long-term relationship with them.

## 6.3 Environmental Ethics

Environmental ethics is a part of philosophy that deals with the moral questions of the relationship between human beings and everything not human, including the environment **[Andrew Brennan, Norva Y. S. Lo, 2021]**. Looking at the world, it is impossible not to notice that human beings have altered the world and the environment as they please. Just by looking at the devastation of the rainforest, more than 50 percent of all the rainforest has already been destroyed for human gains, such as attaining mineral resources, livestock farming or building monocultures. Even though

destroying the rainforest is twice as harmful since the CO2-memory function and photosynthesis of the trees get lost, human beings still do not stop **[OroVerde, 2024]**. This might be an extreme example, however, ethical environmental issues can be found nearly everywhere when looking around. Trying to work against that, environmental ethics are supposed to motivate human beings and companies to work ethically and justifiably.

The goal of all the team members is to build a product that has the least environmental impact as possible since no more additional environmental issues are supposed to be added, starting with using components that are as environmentally friendly as possible. In addition, the team is trying to follow sustainable practices throughout the entire value chain, from sourcing materials to manufacturing, packaging, and distribution. Furthermore, the option of borrowing the completed product, making it reusable, so that it does not just end up in the dustbin when it is not used anymore, will be offered. Furthermore, a broken product can be returned, even though the date has passed the guarantee, and reusable parts of it will be recycled.

## 6.4 Liability

The aim of product liability is to encourage product safety **[W. K. Viscusi, M. J. Moore, 1993]**. As with any technology, ethical concerns arise when it comes to the production, the use as well as the disposal of that product. Apart from creating a product that supports sick children and their caretaker, the team's main goal is primarily also to develop a product that is safe for them to use and ethically justifiable. In this chapter, some key ethical and liability concerns will be addressed. In order to avoid product liability issues, the team will work according to the following EU-directives:

**Radio Equipment Directive (RED) (2014/53/EU) [European Commission, 2014]**

This directive has set crucial requirements for safety and health, electromagnetic compatibility and efficient use of radio waves. In addition, it gives the basis for deeper going directives, like technical aspects for protection of privacy, personal data and against fraud as well as for interoperability, access to emergency services and compliance when it comes to the merging of radio equipment and software.

**Low Voltage Directive (LVD) (2014/45/EU) [European Commission, 2014]**

This directive makes sure that a high level protection for European citizens is provided by electrical equipment that is within certain voltage limits.

**Electromagnetic Compatibility (EMC) Directive [European Commission, 2014]**

This directive ensures that side effects that are a result of an interconnection or a close distance between electric devices and installations are kept under reasonable control.

**Protection of Personal and Property Rights:** Protection of Personal and Property Rights

The team will work with personal data, still following the rules of protection of personal data in order not to jeopardize the child's privacy which is the reason why only the caretaker has access to the personal data including the pictures of the child.

### 6.5 Conclusion

In conclusion, ethical concerns and criticism from outside will always arise, however, it is good to work with them and consider them in order to develop a product that is as ethically correct as possible. Since Ethics and Deontology are subjective topics, it is important to stick to the guidelines given by the European Commission. In case of failure, not only ethical problems arise but also potential legal liabilities, such as the violation of privacy laws, discrimination laws or consumer protection laws among others. Therefore, the group aims to work with good consciousness, always considering the above mentioned guidelines. The team will work truthfully and in a transparent way, displaying all of the product's features as well as what has to be done manually by the caretaker, promoting Billy by an official advertising placement which also secures a responsible advertisement.

Based on this ethical and deontological analysis, the team members chose to use PLA plastic which will be used for 3D printing nearly all of the components for the prototype since it is more sustainable than common plastic. Furthermore, in order to prevent unnecessary waist, the team provides the option of renting the product which is a good opportunity, especially for people who “only” deal with a short-term illness and will not need the product afterwards. By offering that service, the product being just put away and not being used anymore will be avoided. In addition, the possibility of a return in case of a defect will be offered. Even if the product guarantee doesn't apply anymore, the team will take it back and reuse all the working parts and components, producing as little waste as somehow possible.

In the next chapter, the progress and the development of the project will be elaborated on. This includes the origin of the name, the development of the logo as well as the design and the prototype.

## 7. Project Development

This chapter clarifies the development of Billy. The entire project development will be explained in several sections, including ideation, concept and design, followed by packaging. In addition, all the more technical elements needed to make the project will be covered through a choice of components, software and hardware. In the end, several tests will be carried out. This chapter traces all the different stages the team went through to complete the project and the prototype.

### 7.1 Ideation

The team started this project by doing a lot of brainstorming about the subject. It took several workshops and discussions before the team was sure they wanted to work on an automatic pill dispenser.

The idea was to create an automatic pill dispenser that would be used by children. The market is full of many different types of pill dispenser for the elderly but none exist for children, so, the team wanted to create one. The idea of making it more fun and less stressful for children to take their pills arose. To achieve this, the team came up with the idea of introducing a reward system to motivate

children to take their medication properly in order to obtain it.

To do this, a design that would be attractive and that would appeal to children needed to be define. The team therefore went through several solutions before finding the one that best suited the project.

**Version 1:** The original idea was to create a dispenser that looked like a robot. The first drawing is visible in Figure 40.

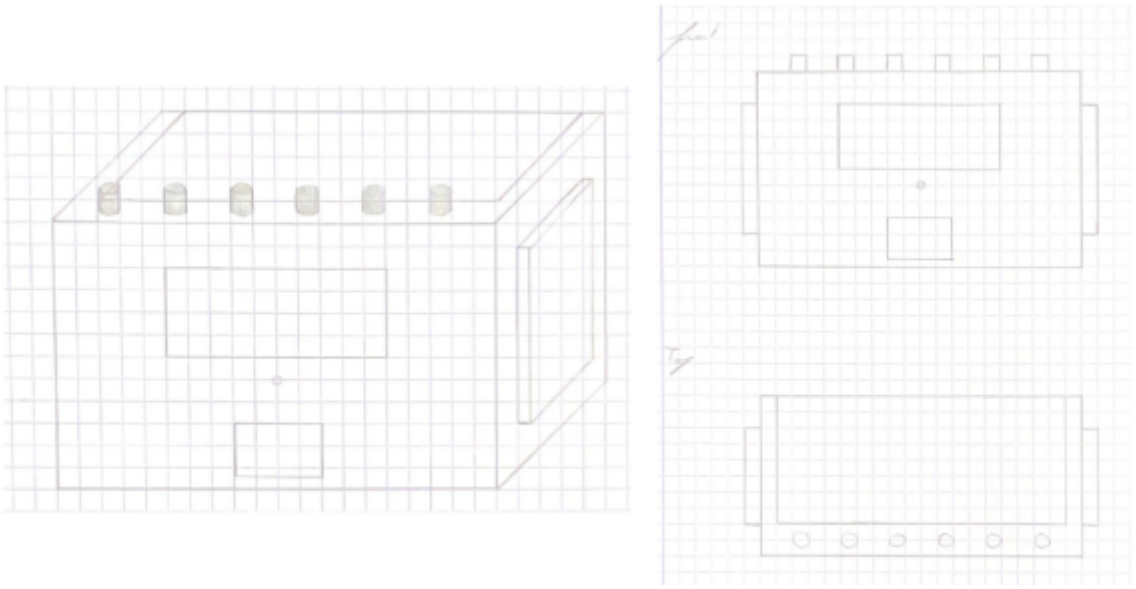


Figure 40: First version

**Version 2:** After negative feedback from teachers on the design, the team decided to modify it and make it look like a children's toy dispenser, an appealing and fun object, with a transparent dome through which children can see their reward. Solution 2 can be seen in Figure 41:

Figure 41: Second version

**Version 3:** The team then decided to modify it one last time by adding a transparent slide, again to

resemble a toy vending machine, so that the child can see the pills falling. The concept is shown in Figure 42:

Figure 42: Third version

## 7.2 Concept

Through the various brainstorming sessions and workshops in which the team participated, the idea of developing a smart pill dispenser for children was born. This would be fun and attractive to them, making it less stressful for them to take their medications. The idea of creating an object that has a direct effect on the health of the people who use it was very appealing to the team.

In response to this problem, an automatic pill dispenser that can be controlled via an application has been created. Billy can dispense up to 21 doses of medication. Once Billy has been refilled with medication by a parent, the latter can configure the day and time at which the doses are to be taken via the app. When it's time to take the dose, a buzzer vibrates and LEDs flash to alert the child. A fingerprint recognition system ensures that the child taking the dose is the one who needs it.

An “admin” profile has also been created for a parent, giving them access to the medication dispensing mechanism and enabling them to refill the dispenser when they place their fingers on the fingerprint reader. The team also wanted the dispenser to be able to store boxes of medicines safely, like a safe box. Only parents have access to this area, always by using their fingerprints.

Finally, a camera allows children to take photos of themselves when they are taking their medication and thus reassure the parent when the child is left alone at home. These photos can be accessed via the application. Billy also features a touchscreen to display information such as the time of the next dose, to help take the photos and, in the future, to add games to make Billy even more fun.

Billy is equipped with a reward system, so the rewards can take several forms - sweets, outings (cinema, water park, etc.), games or activities. For the child to be able to access the reward, the parent must first check via the application that the child has taken all their medication over the

desired period by looking at the photos, then the parent can choose whether or not to open the sphere by unlocking the lock on the application.

As well as allowing you to plan the distribution of medicines and access the photos taken, the application also provides a history of the medication taken and allows you to create several profiles if several children are using the same Billy. Figure 43 below, illustrates the concept of Billy.

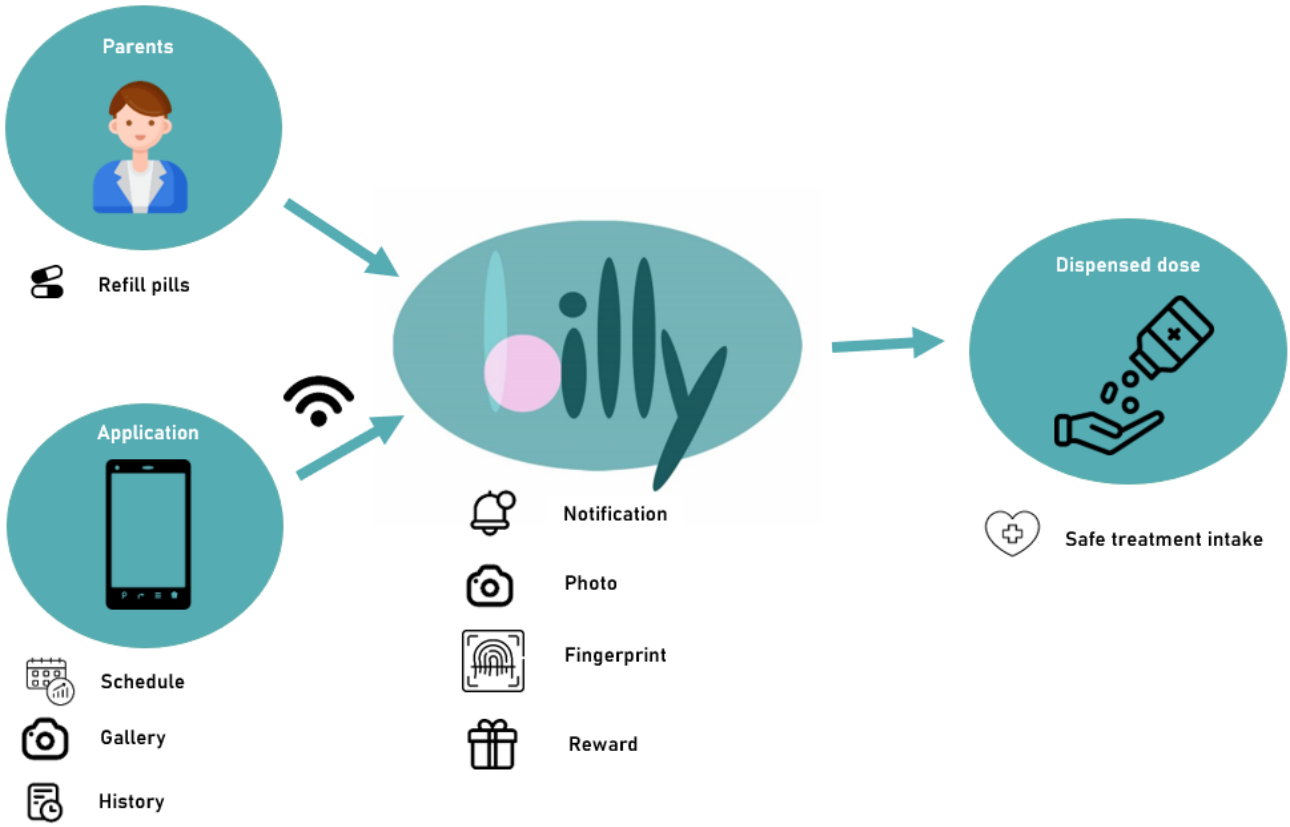



Figure 43: Illustration of the concept of the product

### 7.2.1 Logo

The name for the pill dispenser is “Billy”. Since it is a product designed for children in order to make their medication intake more easy and add some fun to it, the intention was to give it a name that could also be the name of a friend. In some way, Billy kind of does become a child's best friend during the time they have to take their medication. The logo is supposed to match Billy's energy which is why the choice of the logo's colors and shape of it was made to be colorful, intensive and also round.

Figure 44 gives some insights in the creation process of the logo.

Figure 44: Logo creation process

2 main colors have been chosen, a dark turquoise and a light turquoise. The other two colors are a result of negative multiplication with the color of the main shape. The goal was to create positivity and different shades of colors while still harmonizing with each other. The color palette of the logo is shown in Figure 45 below.

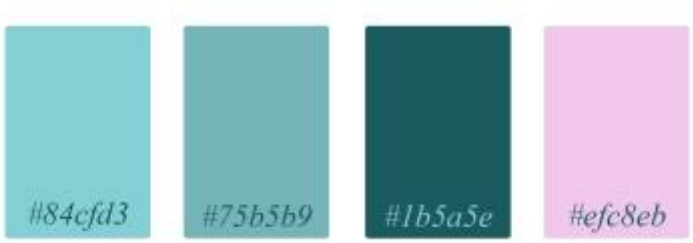



Figure 45: Color palette

When trying to choose the font for the product's logo, it was difficult to find one that matched the team's expectations for Billy completely. The team then decided to create its own font, trying to keep the single characters in a style that reminds one of a pill. That is also what the circle in the background symbolizes. Considering all aspects, the third draft was chosen since it combines everything the team wants the logo to stand for. The final logo is shown in Figure 46.


Figure 46: Final logo

## 7.3 Design

This section describes the solutions and choices made by the team for the production of the physical product of Billy.

### 7.3.1 Structure

After creating initial sketches, the third version, with the transparent dome and slide, was the one that the team chose. The team then brainstormed to define and find a solution to the prototype's

main functions.

Given that the team opted for a round design with as few sharp edges as possible, this presented a challenge in terms of creating the pill dispensing mechanism. The decision to produce a simple system greatly reduced costs, was more environmentally friendly and also avoided the need to develop an over-engineered solution for a problem like this. A 2-part mechanism, with a fixed part and a rotating one (pill selector and pill container) was therefore created.

The team decided to create a product capable of delivering 21 doses of medication, corresponding to one dose per day for 3 weeks. To meet this technical requirement, the pill container was designed with 22 different slots, including a full slot, which was used to configure the product. In order to distribute the medication from the pill container to the child, a slide system has been created, which allows the medication to fall naturally towards the outside of Billy. In addition, the slide created, makes it possible to add a structural support for the pill dispensing mechanism. Figure 47 shows Billy's structure and mechanism.

Another major challenge was safety. To prevent over medication, a lock has been added to the door by using a notch that allows a servo motor to slide in and block the door from opening, which can only be activated by the parents using a fingerprint sensor. Another lock operating on the same principle is used for the sphere.

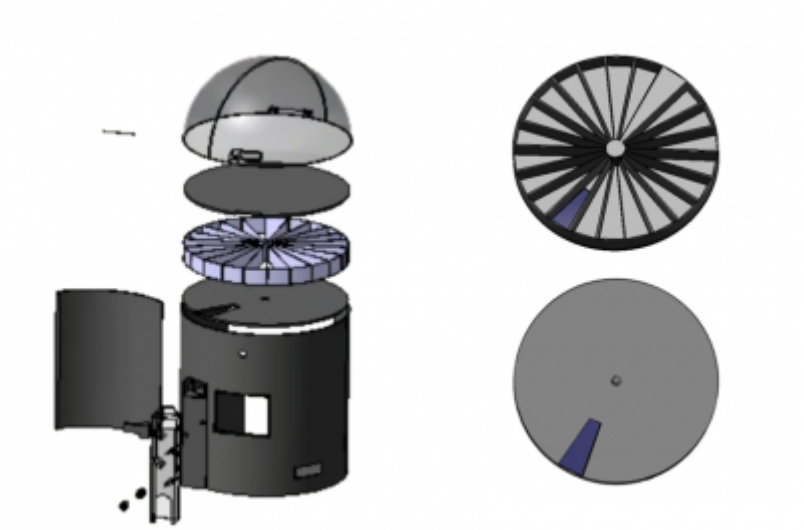


Figure 47: Billy's structure and mechanism

#### 7.3.1.1 Material Selection

For the materials of the project the team chose to 3D print every single part of the prototype except for the dome containing the reward. The team would like to use Polylactic Acid (PLA) plastic to print the parts because it is cheap and it is more sustainable than common plastic. Moreover, PLA is a lightweight plastic with good mechanical strength and is 100 % bio-based and biodegradable. The amount of PLA that is needed for the product will be explained later when the when the dimensions are fixed. It is important for the dome to be transparent so that the kid can see the reward inside which will make him want to have it and therefore want to take his medication correctly to get it. Table 34 below compares the different transparent materials that could be used on the project.

Table 34: Comparison of transparent materials

| Name | Advantages | Disavantages |
|---|---|---|
| Glass | Cheap, very good UV resistance, not flammable | The heaviest in this list, fragile and can break easily on impact |
| Plexiglass | 10 times greater impact resistance than glass | Less expensive than polycarbonate and less difficult to get into shape |
| Polycarbonate | 25 times greater impact resistance than glass, not flammable | Expensive and difficult to get into shape |

The team chose plexiglass for the dome and the slide as it's a good alternative to polycarbonate and much more resistant than glass.Table 35 presents the main materials that will be used for the production of Billy.

Table 35: Materials used in Billy

| Material | Part |
|---|---|
| PLA | Every 3D printed parts (body, pill container, pill selector, plain disk, door) |
| Plexiglass | Sphere and slide |

#### 7.3.1.2 Detailed drawings

Once the design had been defined, the first detailed drawings of the pill dispenser were produced. Its size was defined by calculating the number of doses of medicine that could be stored in the dispenser. The team wanted to store 21 doses which makes it possible to have 1 dose per day for 3 weeks. Having determined this, the design was built around the dispensing mechanism. The detailed drawings are shown in Figure 48 and Figure 49 below.

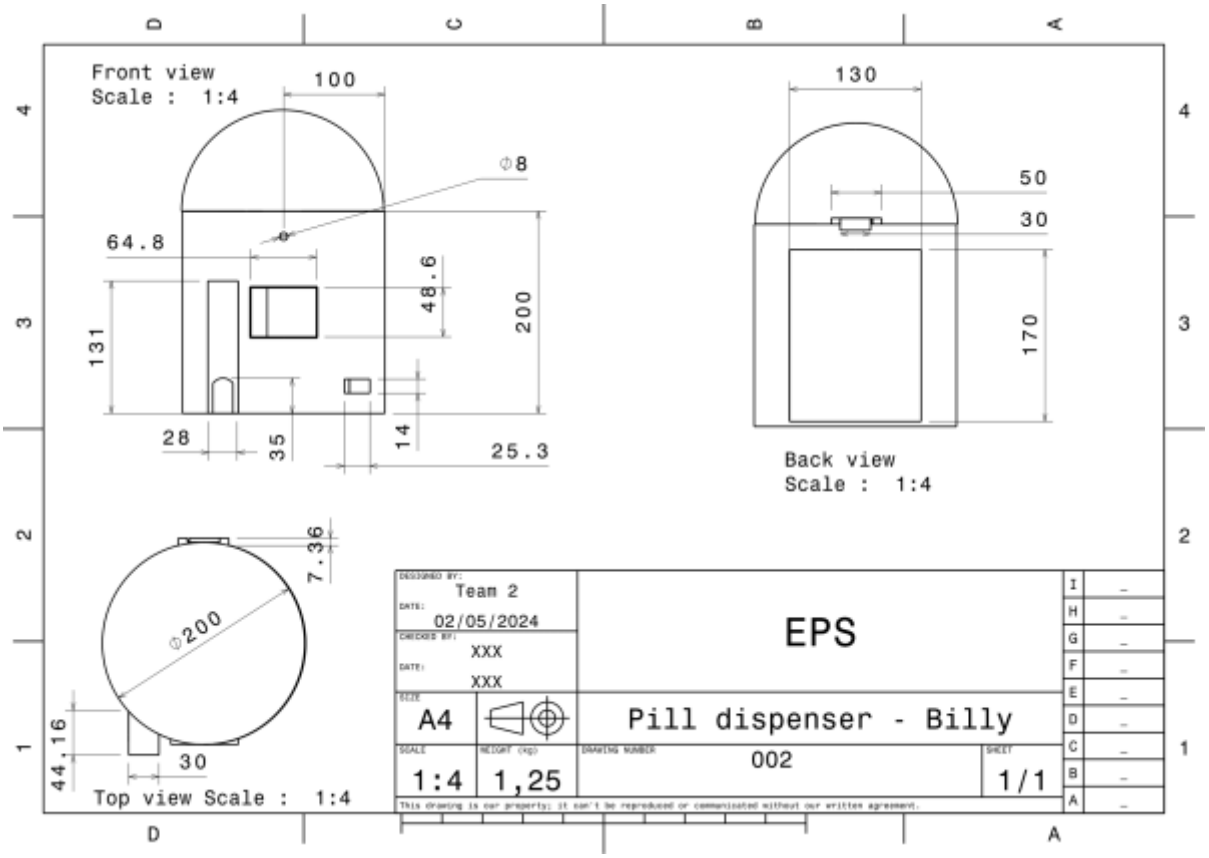



Figure 48: Detailed drawing of the pill dispenser

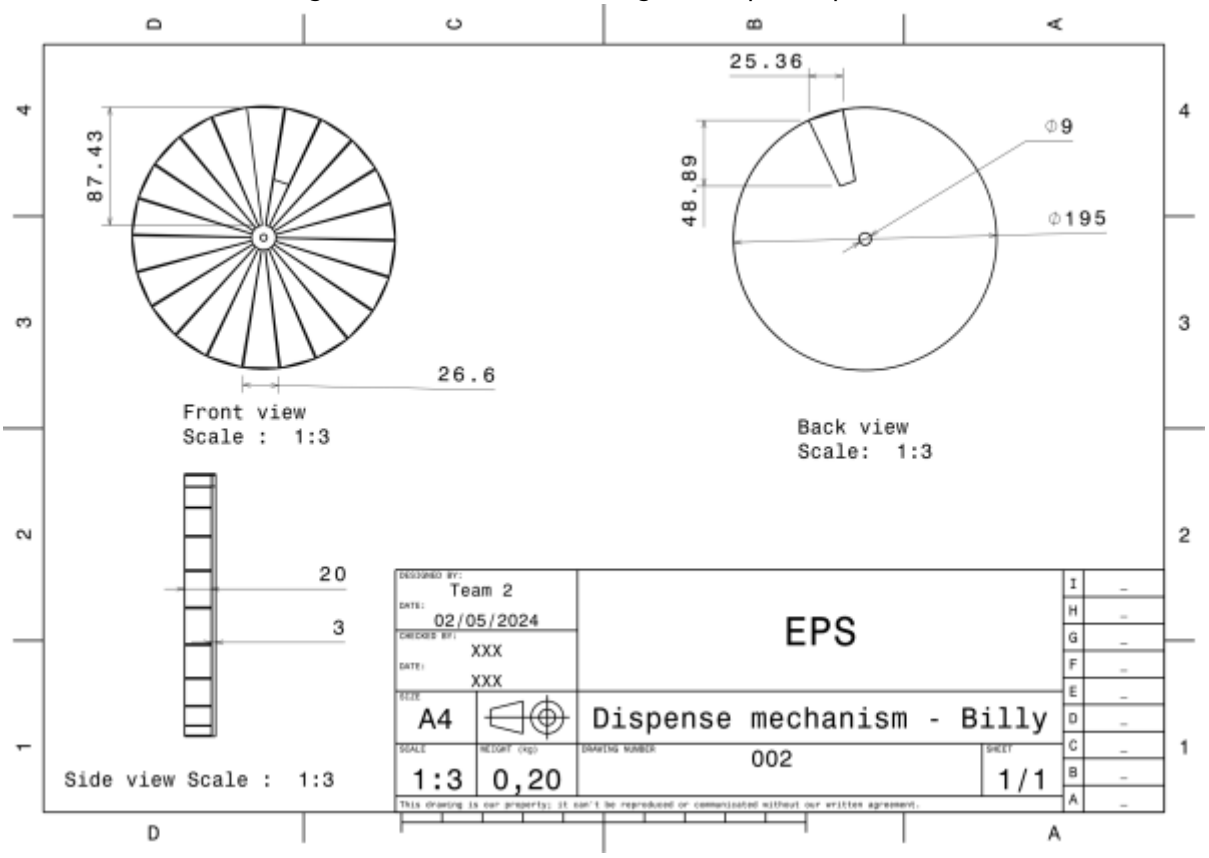
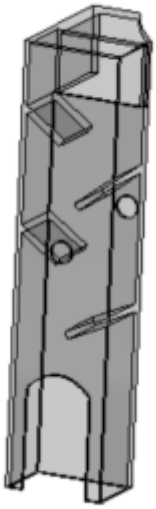
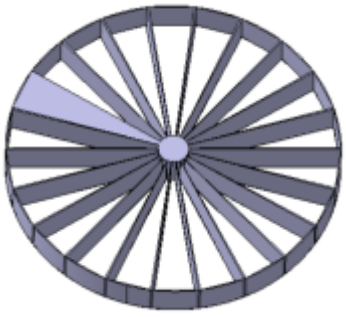
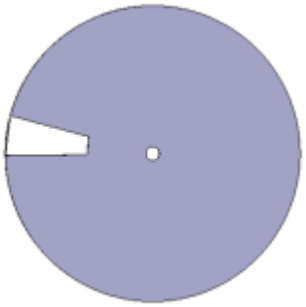
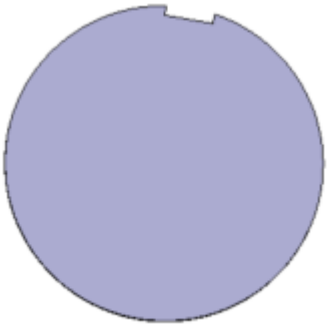



Figure 49: Detailed drawing of the pill dispenser mechanism

Billy is made up of several parts, the main ones being the product body cylinder, the dome above which contains the reward, the slide that allows you to see the pills fall and finally the dispensing mechanism. The various parts of this product are shown in Table 36, and Figure 50 illustrates the assembled product.

Table 36: List of the different parts of Billy

| Name | Picture | Note |
|---|---|---|
| Body |  | The body is a cylinder 20 cm in diameter, 20 cm high and 2.5 mm thick. At the back, a large opening, which will be closed by the door, gives access to the mechanism and electronics. It will therefore be possible to recharge the dispenser from here, as well as storing boxes of medicines in the same way as in a safe. On the front, there is a screen, with the fingerprint sensor on the right and a flat surface on the left for attaching the slide. On the inside of the body, there is an elevation on which the pill selector will rest. This elevation is inclined to allow the medication to slide towards the slide. |
| Slide |  | The slide is made up of multiple small and stiff surfaces so that the pills fall right through to the opening. It is attached to the body using two M4 screws. The slide is also transparent. |
| Pill container |  | The pill container is a wheel containing 21 pill storage sections, running through it, as well as a solid section which is useful when setting up the machine. It will be placed on the pill selector and contains a small slot in its center so that the motor can fit in and therefore turn it. It is 195 mm in diameter and 20 mm high. |

| Name | Picture | Note |
|---|---|---|
| Pill selector |  | The pill selector is a simple disc with an opening the same size as one of the sections of the pill container. Thanks to this, the pill selector allows you to distribute only one dose at a time. It is 195 mm in diameter and 3 mm thick. |
| Plain disk |  | The plain disk is a simple disk with an opening on the side to allow the lock system to close the dome. It allows you to create a separation between the mechanism and the sphere which contains the reward. It is 195 mm in diameter and 3 mm thick. |
| Door |  | The door provides access to the product mechanism. At the bottom, there is a hook to be able to lock access to the mechanism thanks to a servo motor |
| Sphere |  | The sphere is a transparent empty dome so you can see the reward inside. It is equipped with a hook so that it can be locked like the door so that the child does not have access to the reward all the time but only at a desired time. |

Once the final product is assembled, it will measure 300 mm in height and 215 mm in diameter (including the slide). The total weight of Billy would be 1.245 Kg (without electronics) according to the

3D modeling software. An image of Billy assembled can be seen in Figure 50.

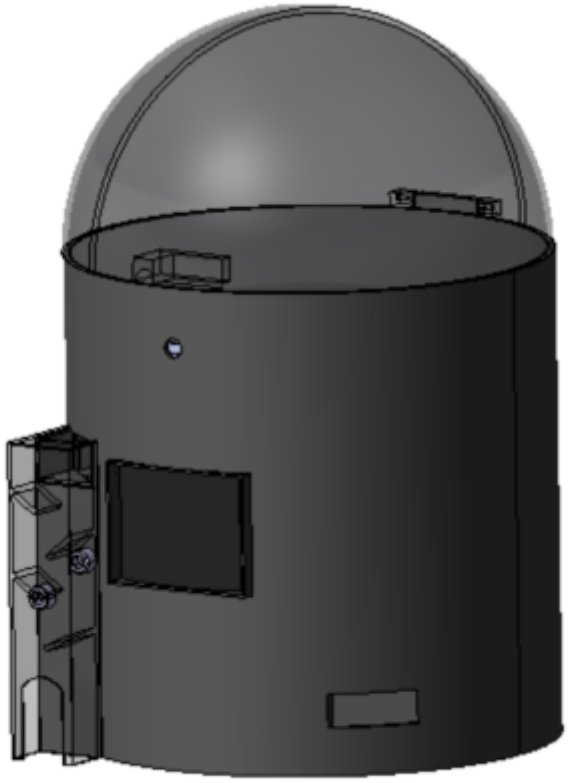


Figure 50: Photo of Billy assembled with all the parts

#### 7.3.1.3 3D model with load and stress analysis

To check that the product was sufficiently resistant and correctly designed, a stress analysis was carried out on a selected part. In the case of Billy, little stress is exerted on it because it doesn't have to move and the pill dispensing mechanism doesn't exert much stress because it doesn't move a large mass. In this section, the team therefore chose to study extreme stress during improper use of the pill dispenser.

It was therefore decided to study the case where a child would want to obtain the reward by force. To determine the effort involved, the team looked at the case where a child would stand on the sphere. Billy is designed for children aged between 8 and 12, and according to the World Health Organization (WHO), the average weight of a 12-year-old child is 42 kg for a girl **[Proxim, 2014]**.

The simulation method used is the Finite Element Method (FEM), which consists of dividing a model into several small interconnected sections to form a mesh. Conditions are then defined (limits, materials, fixations, forces) to configure the simulation. The simulation then shows the effects of the defined conditions on the part being studied.

The objective of the simulation was to evaluate the capacity of the structure and the material to withstand the maximum load in inappropriate use. So a weight of 42 kg corresponds to an effort of 412.02 N, taking into account the gravitational acceleration (9.81 $m/s^2$). To be certain that the sphere was correctly dimensioned, a new analysis was carried out with a safety factor of 2, giving a force of 824.04 N.

Material specification

The material used is polymethyl methacrylate (PMMA), also known as plexiglass. Here are its mechanical properties in Table 37 below:

| Property | Value |
|---|---|
| Density | 1190 kg/m³ |
| Modulus of elasticity | 2770 N/mm² |
| Mass density | 1190 kg/m³ |
| Yield Stress | 70 MPa |
| Specific Heat | 1250 J/(kg.K) |
| Thermal conductivity | 0,21 W/(m.K) |

Table 37: Mechanical properties of PMMA.

Load

The forces applied to the dome are as follows: - Force: 824.04 N

The force, defined earlier, was applied to a defined area and not to the entire surface of the sphere. A circle 8 centimeters in diameter was defined on the top of the sphere. This circle represents the surface area of a person standing on the dome. The forces were then applied perpendicular to the ground and not to the sphere, as shown below in Figure 51:

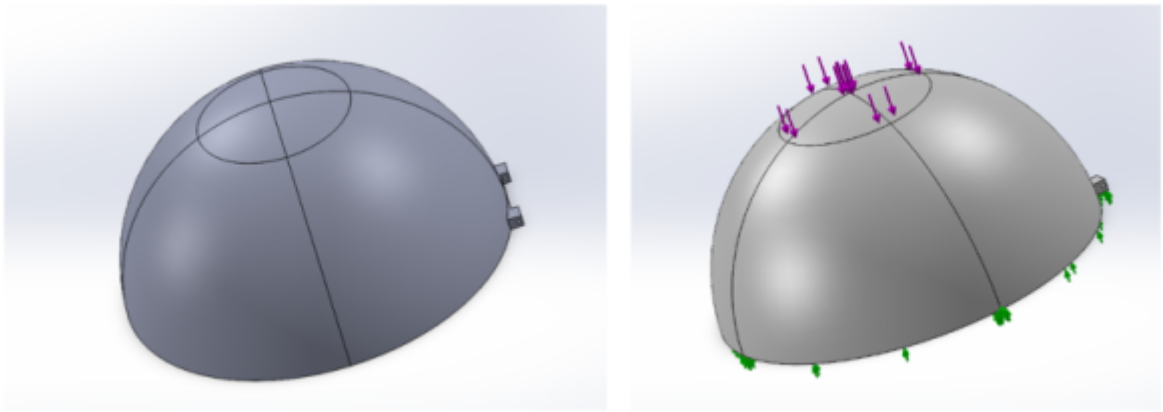


Figure 51: Circle and force applied to the dome

Mechanical connection

Before the simulation can be run, the various connections on the part need to be defined. First of all, a planar link has been defined below the surface of the dome. This will allow the dome to deform in this plane without going through it. Finally, 2 other points have been created to lock the dome in translation. The advantage of using points here is that they will not prevent the dome from deforming at the bottom. The mechanical connections can be seen in Figure 52. This simulation is therefore very close to what would happen in a real-life situation.

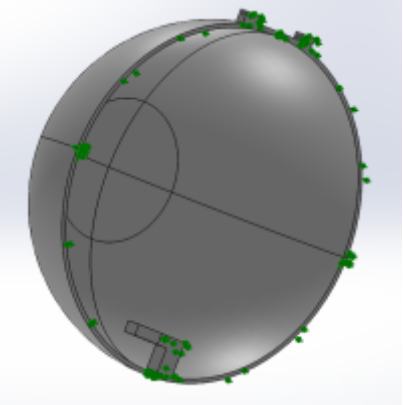


Figure 52: Mechanical connections applied to the sphere

Mesh

The last step before running the simulation is to define the mesh size. The smaller the mesh size, the more accurate the result will be, but the longer the calculation will take. In this analysis, the team ran the simulation several times to see the impact of the mesh size on the simulation result. This will be discussed in the conclusion of the analysis. The following results were obtained with the smallest possible mesh size of 1 mm. The informations corresponding to the mesh used can be seen in Table 38.

Table 38: Mesh informations

| **Mesh informations** | **Quantity** |
|---|---|
| Max element size | 1 mm |
| Min element size | 0.2 mm |
| Total number of nodes | 2110322 |
| Total number of elements | 1367805 |

Results

Von Mises:

The first result obtained by the team is the maximum Von Mises stress that the dome can withstand. This can be seen in the Figure 53 below:

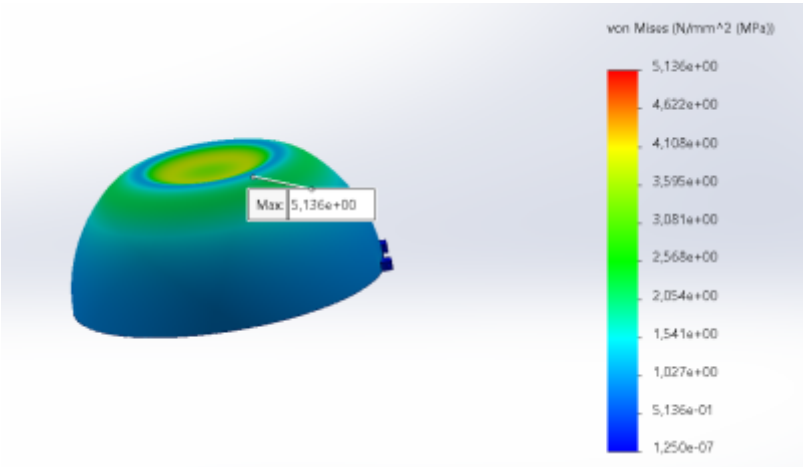



Figure 53: Von Mises results

The maximum stress applied here is 5.136 MPa. As PMMA's yield limit is 70 MPa, this stress is well below what the material can withstand.

Displacement:

Then, the displacement was studied to see how much the dome would be modified by this force. The results can be seen in Figure 54.

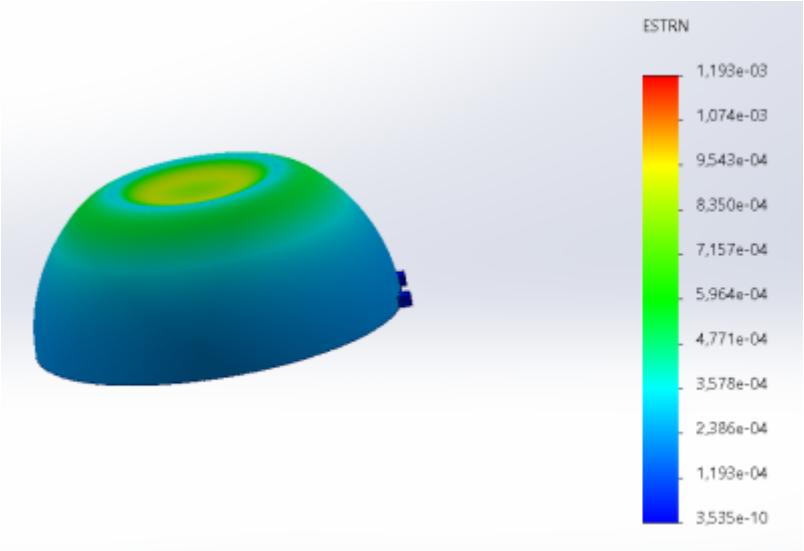



Figure 54: Displacement results

The results above show that the force applied generates a displacement of 0,2785 mm, which is very small, so the consequences of this force on the displacement can be neglected.

The factor of safety:

A final analysis of the safety coefficient was carried out. Although the effort applied is already 2 times greater than the inappropriate case studied, which therefore already corresponds to a safety coefficient of 2, the analysis shown below in Figure 55 defines that the minimum safety coefficient applicable to the sphere is 15, which is well above the needs of the project.

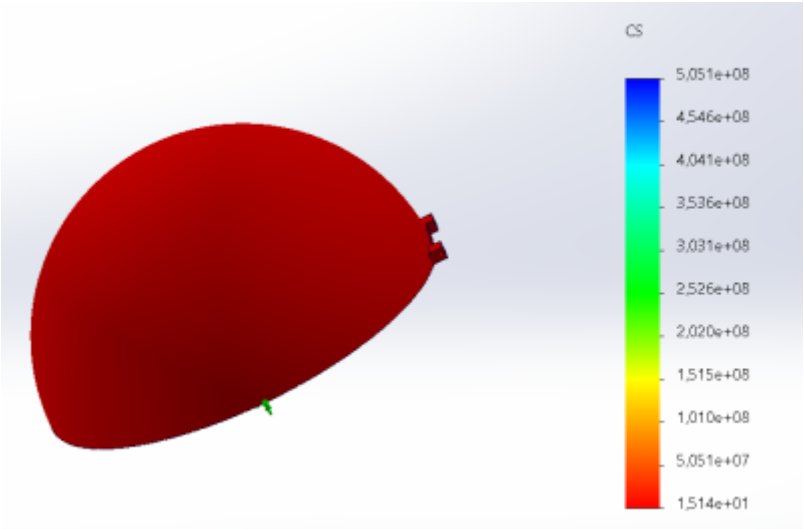



Figure 55: Factor of safety results

Conclusion

After performing a structural simulation using the Finite Element Method (FEM) on the sphere

constructed of plexiglass (PMMA), a solid and conclusive conclusion was obtained. The simulation evaluated the capacity of the structure and material to withstand the maximum load in an inappropriate use. The results obtained are more than satisfactory and show that the material chosen is optimal for the use and for Billy, particularly as the safety coefficient determined during the simulation is 15, which is much higher than the team had hoped for. As explained earlier, the simulation was carried out with a 1 mm mesh. Table 39 below shows the maximum stress results obtained for different mesh sizes.

| Mesh dimension (mm) | Maximum stress (MPa) |
|---|---|
| 30 | 4,248 |
| 20 | 4,636 |
| 14 | 4,887 |
| 8 | 5,098 |
| 5 | 5,116 |
| 3 | 5,126 |
| 1 | 5,136 |

Table 39: Comparison of mesh dimension and effort

Table 39 shows that with a mesh size of 5 mm or less, the result changes only a little bit. Therefore, using a mesh size of less than 5 mm is not really necessary, as the result will be virtually the same and the calculation time will be shorter. Finally, it should be noted that these results were obtained by running virtual simulations and that slight differences may appear when tested on the physical product.

### 7.3.2 Smart System

#### Hardware

*1. Black Box Diagram :*

During brainstorming sessions, the team decided on the features that the team wanted to see in the pill dispenser. The team wants it to alert the patient at the desired time and that the patient, thanks to a digital fingerprint reader, would be the only one able to collect the medication. The dispenser also has a medication storage area that is locked by an adult's fingerprint. The machine is configured using buttons and a screen. The final feature the team would like to have is a camera so photos when the child is taking its medication can be taken and notify the parents. The black box diagram of the project is shown in Figure 56.

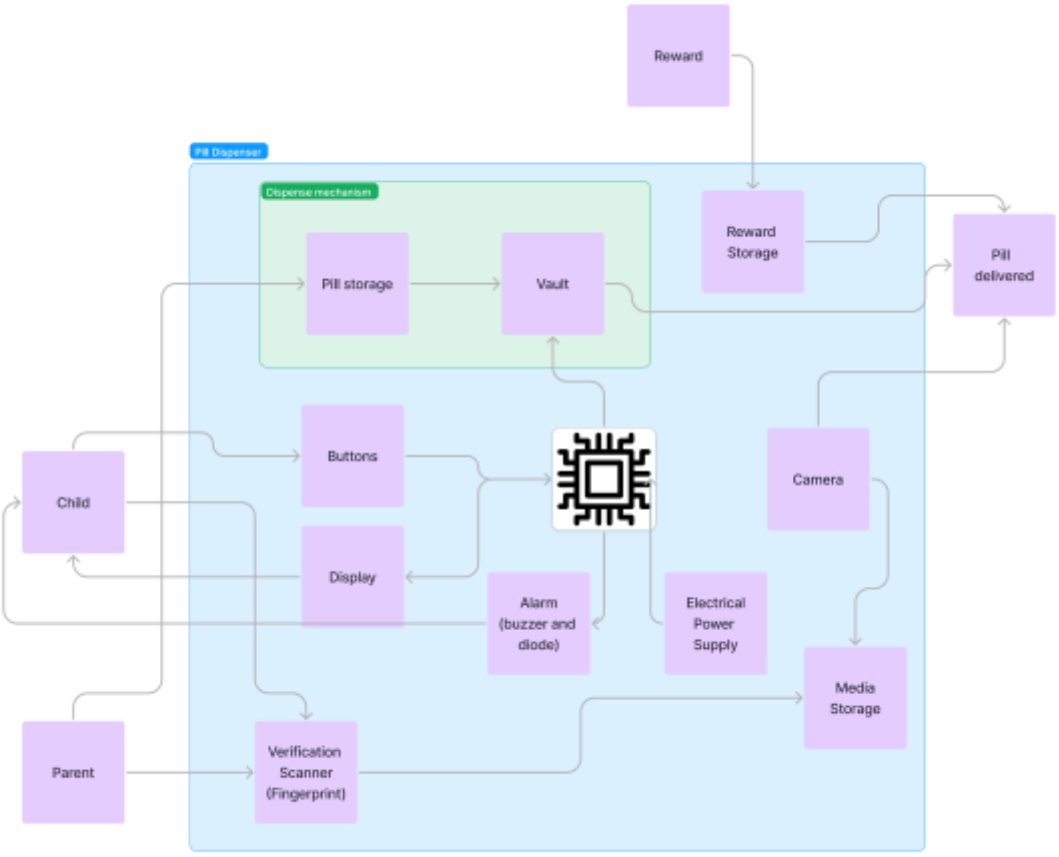



Figure 56: Black Box Diagram

After the first feedback from the teachers on the black box diagram, a new version was needed. The new Black Box Diagram is visible in Figure 57:

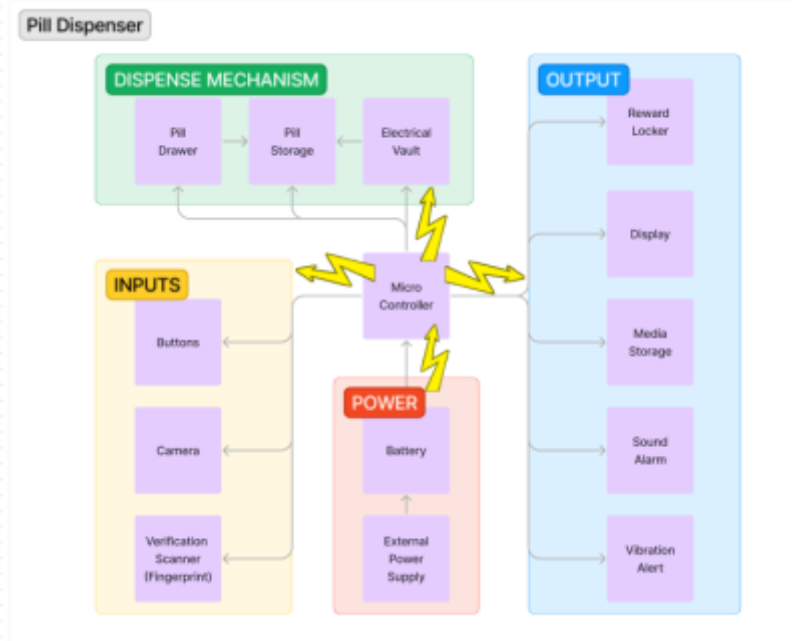



Figure 57: Black Box Diagram 2

*2. Component Selection:*

Electronics are needed to operate the pill dispenser. In the Table 40 below you will find a comparison of the different microcontrollers, screens, motors and fingerprint readers that correspond to the project's requirements, as well as a justification for the choices made.

Table 40: Components comparison

| **Component** | **Options/Description** | **Alternatives** |
|---|---|---|
| ESP32-cam | ESP32-CAM is a development board with a built-in camera module primarily based on the ESP32 chip. It's widely used for Internet of Things (IoT) and camera-related projects. | Raspberry Pi Camera Module |
| | | Arducam ESP32 UNO PSRAM |
| | | AI-Thinker ESP32-CAM |
| | | ArduCAM Mini Module |
| FT232RL | FT232RL is a Universal Serial Bus (USB) to Transistor-Transistor Logic (TTL) Serial Converter chip commonly used for interfacing microcontrollers with computers or other devices via USB. | CH340G |
| | | FT231XS |
| | | PL2303HX |
| ili9341 (touchscreen) | ili9341 is a popular controller chip for small to medium-sized Thin-Film Transistor (TFT) Liquid Crystal Display (LCD), often used in conjunction with touch panels. | 2.8 inch TFT LCD |
| | | 2.8 inch TFT Serial Peripheral Interface (SPI) |
| | | 3.5 inch TFT Touch |
| | | SSD1963 |
| PCF8575 IO Expander | PCF8575 is an Inter-Integrated Circuit (I2C) based Input/Output (IO) expander chip used to increase the number of General Purpose Input/Output (GPIO) pins available to microcontrollers. | MCP23017 |
| | | MCP23008 |
| | | PCF8574 |
| | | MCP23S17 |
| FPM10A | FPM10A is a capacitive fingerprint sensor capable of storing and recognizing multiple fingerprints. It's commonly used in security applications. | GT-511C3 |
| | | R305 |
| A4988 stepper driver | A4988 is a popular stepper motor driver module capable of driving bipolar stepper motors with microstepping capability. | DRV8825 |
| | | TB6600 |
| | | TMC2208 |
| | | LV8729 |
| FIT0278 stepper motor | The FIT0278 is a simple 2 phases hybrid stepper motor. | MIKROE-1530 |

**Component Selection Reasons**

- **ESP32-CAM**: Selected for its integrated camera module and compatibility with the ESP32 chip, offering a cost-effective solution for IoT and camera-related projects. Alternatives considered such as the Raspberry Pi with a camera module were too expensive.
- **FT232RL**: Chosen for its widespread compatibility and reliability in USB to serial conversion, making it suitable for interfacing microcontrollers with computers or other devices. Alternatives like CH340G and FT231XS offer similar functionality but might differ in driver availability and stability.
- **ili9341 (touchscreen)**: Selected for its widespread availability and compatibility with various touchscreen applications. Alternatives like 2.8-inch TFT SPI might offer faster communication through the SPI interface, while options like 3.5 inch TFT Touch provide larger display sizes with touchscreen functionality.
- **PCF8575 IO Expander**: Chosen for its ease of use and compatibility with various microcontroller platforms, providing a cost-effective solution for expanding GPIO pins via the I2C interface. Alternatives like MCP23008 offer similar functionality, suitable for applications with limited GPIO requirements.
- **FPM10A (fingerprint sensor)**: Selected for its reliability and compatibility with various fingerprint recognition projects, offering a cost-effective solution for security applications. Alternatives like R305 provide a budget-friendly option with comparable performance, suitable for less demanding applications.
- **A4988 stepper driver**: Chosen for its widespread usage and reliability in stepper motor control applications, offering a cost-effective solution with micro stepping capability. Alternatives like TB6600 provide higher current handling capability for more demanding stepper motor applications, while options like TMC2208 offer advanced features like stealthChop for quieter operation.

*3. List of components for Billy*

Using the component comparison tables detailed earlier, the team was able to draw up a list of all the components needed to complete the project. This list can be seen in the Table 41 below.

Table 41: Cost of the components for Billy

| Component | Quantity | Price (with VAT) | Supplier | Shopping link |
|---|---|---|---|---|
| ESP32 CAM | 1 | 14.70 € | PT Robotics | Shopping link |
| FT232RL (USB to TTL Serial Converter) | 1 | 15.40 € | Farnell | Shopping link |
| ili9341 (touchscreen) | 1 | 29.47 € | RS | Shopping link |
| MCP23016 - i2c 16bit Expander | 1 | 3.14 € | PT Robotics | Shopping link |
| Passive buzzer | 1 | 0.66 € | DigiKey | Shopping link |
| FPM10A (fingerprint sensor) | 1 | 22.65 € | DigiKey | Shopping link |
| A4988 stepper driver | 1 | 3.87 € | PT Robotics | Shopping link |
| Stepper motor | 1 | 13.20 € | Farnell | Shopping link |
| Servo Motor | 2 | 13.50 € | DigiKey | Shopping link |
| 2×40 Pin Bar for PCB | 1 | 1.23 € | PT Robotics | Shopping link |
| AC/DC CONVERTER 12V 15W | 1 | 10.68 € | DigiKey | Shopping link |

| Component | Quantity | Price (with VAT) | Supplier | Shopping link |
|---|---|---|---|---|
| Voltage Regulator 5v | 1 | 0.66 € | DigiKey | Shopping link |
| 220 Ohm Resistor | 1 | 0.11 € | DigiKey | Shopping link |
| MULTICOLOR BUTTONS (kit) | 1 | 1.99 € | DigiKey | Shopping link |
| LED RED | 4 | 1.28 € | DigiKey | Shopping link |
| Capacitor Ceramic 100µF | 1 | 0.34 € | DigiKey | Shopping link |
| BreadBoard | 1 | 8.17 € | DigiKey | Shopping link |
| Jumper Wires Pack - M/M | 1 | 2.38 € | DigiKey | Shopping link |
| Jumper Wires Pack - M/F | 1 | 2.38 € | DigiKey | Shopping link |
| USB micro-B Cable - 6 Foot | 1 | 4.19 € | DigiKey | Shopping link |
| Screws M4*25 | 1 | 0.63 € | Leroy Merlin | Shopping link |
| Washer D6 | 1 | 2.59 € | Leroy Merlin | Shopping link |
| PLA plastic for all the 3D printed parts (1 Kg) | 1 | 16 € | - | Provided by the teachers |
| Acrylic sheet/plank 500*500*4 mm | 1 | 15.99 € | Leroy Merlin | Shopping link |
| Snap ring 3 mm | 1 | 0.58 € | Leroy Merlin | Shopping link |
| Total | | 185.79 € | | |

*4. Detailed Schematics:*

Figure 58 is the detailed schematic for the pill dispenser. The brain of the dispenser is an ESP32-CAM, which is located at the top left of the schematic. This microcontroller is directly connected to the display (ili9341). This allows for fast and reliable communication. To flash the software to the microcontroller, an adaptor is needed. This connection is shown with dotted lines because it is not needed once the board is flashed. As shown, the connection to the display takes up many pins on the microcontroller. Therefore, an IO pin expander is used to control the other components, such as the fingerprint sensor, the stepper motor controller, the servo motors, some buttons, and Light Emitting Diodes (LED).

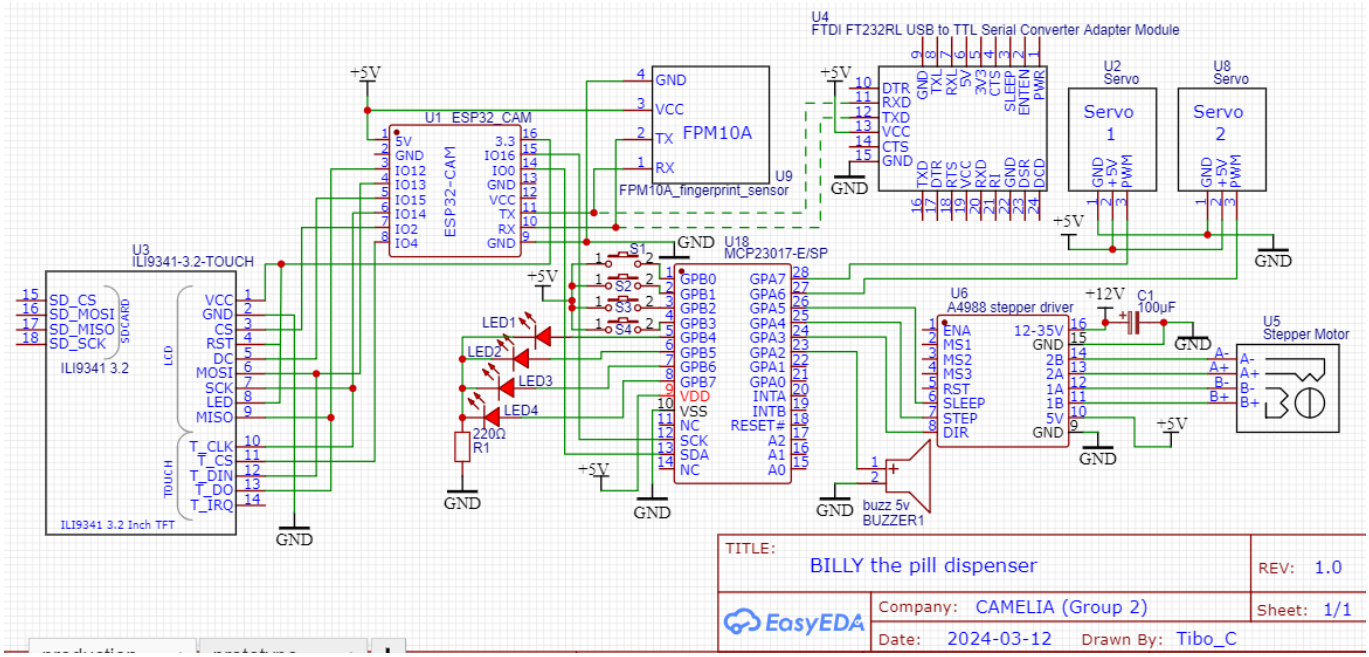


Figure 58: Detailed Schematics

*5. Power budget:*

The power budget, in Table 42 below, lists the power consumption of each component in the project. The voltage and current ratings are provided along with additional notes where applicable. The theoretical maximum power consumption is 8.95 W. The closest standard power supply is 10 W. This is good because it allows for some overhead.

Table 42: Power budget

| **Component** | **Power (W)** | **Voltage (V)** | **Current (A)** | **Additional Notes** |
|---|---|---|---|---|
| ESP32-CAM | 1.55 | 5.00 | 0.31 | 2 A recommended |
| FT232RL (USB to TTL Serial Converter) | 0.35 | 5.00 | 0.07 | |
| ili9341 (touchscreen) | 0.12 | 3.30 | 0.06 | 10 mA module + 50 mA backlight |
| MCP23016 - I2C 16bit Expander | 2.00 | 5.00 | 0.40 | |
| Passive Buzzer | 0.25 | 5.00 | 0.05 | |
| FPM10A (fingerprint sensor) | 0.25 | 5.00 | 0.12 | |
| Stepper Motor | 2.00 | 5.00 | 0.40 | |
| Servo Motor | 2.00 | 5.00 | 0.20 | 2 motors |
| **Total** | **8.95** | | | |
| | **~10** | | | |

*6. Software*

User stories for the smart device:

- As a parent of a child with long-term illnesses, I want a pill dispenser like Billy that is fun and engaging, so that my child is encouraged to take their medication regularly and on time.
- As a parent, I want to personalize the reward system based on my child’s preferences, so that they are more motivated to take their medication regularly.
- As a parent, I want to be alerted when it is time to take my medicine.

User stories for the app:

- As a caregiver, I want to monitor that my child is actually taking their pills, so that I can ensure they are adhering to their medication schedule.
- As a parent, I want an app, on which I can register and log in, to configure the product.
- As a parent, I want an app, on which I can see the previous dosages taken.
- As a parent, I want to schedule my child’s medication, so that I can reduce the daily hassle and ensure consistency in their medication routine.

Selection of development platforms and software components:

For this project, several development platforms could be used to create Billy. The following Tables 43, 44 and 45 compare the various possible options and the solution chosen for the firmware, frontend and backend.

**Firmware development**

Table 43: Comparison of ESP32 Firmware Development Options

| Feature / Aspect | ESP-IDF | Arduino Core for ESP32 | PlatformIO | Micropython |
|---|---|---|---|---|
| **Description** | Official development framework by Espressif | Simplified C/C++ framework based on Arduino | Integrated development environment supporting multiple frameworks | Python-based firmware for rapid development |
| **Programming Language** | C, C++ | C, C++ | C, C++, Python, others | Python |
| **Complexity Level** | High | Low to Medium | Medium | Low |
| **Ease of Use** | Moderate to difficult | Easy | Moderate | Very easy |
| **Library Availability** | Extensive, many official libraries | Extensive, many community libraries | Extensive, supports multiple platforms | Moderate, growing community libraries |
| **Community Support** | Strong, official forums and GitHub | Very strong, large community | Strong, diverse community | Growing community |
| **Debugging Support** | Advanced, JTAG debugging | Basic Serial debugging | Advanced, supports multiple debuggers | Basic, REPL based |
| **IDE Support** | VS Code, Eclipse, CLion | Arduino IDE, VS Code | VS Code, CLion, Atom | uPyCraft, Thonny, VS Code |
| **Build System** | CMake | Arduino build system | Custom build system (SCons) | N/A (interpreted) |
| **Deployment** | Firmware flashing via esptool | Firmware flashing via Arduino IDE | Firmware flashing via esptool, custom options | Direct upload of scripts |
| **OTA Support** | Yes | Yes | Yes | Yes |
| **File System Support** | SPIFFS, FAT | SPIFFS, FAT | SPIFFS, FAT | LittleFS, FAT |
| **Real-Time Operating System (RTOS) Support** | FreeRTOS included | No (requires manual integration) | FreeRTOS (via ESP-IDF) | No |
| **Power Management** | Advanced | Basic | Advanced (via ESP-IDF) | Basic |
| **Best Suited For** | Professional development, complex projects | Beginners, hobbyists, quick prototyping | Intermediate developers, complex projects | Rapid prototyping, educational purposes |

PlatformIO emerges as the best option for ESP32 firmware development due to its comprehensive support for multiple frameworks, advanced debugging capabilities, and robust community support. It is well-suited for both intermediate and professional developers working on complex projects that require flexibility, powerful features, and efficient development workflows.

### Frontend development

Table 44: Frontend frameworks comparison

| Name | Language | Performance | Ease of use | User Experience |
|---|---|---|---|---|
| Angular | TypeScript, HTML, CSS | Fast and efficient, with a virtual DOM for optimized rendering | Relatively easy to use for basic tasks, but may require more advanced skills for complex interactions and optimization | Can provide a highly responsive and interactive user experience, with a focus on component-based architecture |
| React | JavaScript, JSX | Fast rendering with a virtual DOM; great for complex applications | Easy to learn with a large community and extensive documentation, but advanced features may require deeper understanding | Can deliver a dynamic and high-performing user interface, with a component-based architecture that promotes reusability |
| VueJs | JavaScript, HTML, CSS | High performance with virtual DOM and efficient reactivity system | Very easy to learn and use, with a gentle learning curve and flexibility for complex applications | Provides a smooth and highly interactive user experience, focusing on simplicity and ease of integration |

### Backend development

Table 45: Technology Comparison for Backend Frameworks

| Name | Language | Performance | Ease of use | Scalability | Security | Integrations |
|---|---|---|---|---|---|---|
| Spring Boot | Java | High performance with asynchronous processing and non-blocking I/O | Moderate ease of use, extensive documentation, and a large community | Highly scalable with microservices architecture support | Strong security features with built-in support for authentication and authorization | Integrates well with other Java-based tools and libraries, and supports RESTful APIs |
| Express | JavaScript (Node.js) | Fast, especially for I/O-bound tasks, due to non-blocking I/O | Easy to use, minimalistic, with a large number of middleware options | Scales well with Node.js clustering and microservices | Moderate security, relies heavily on third-party middleware for comprehensive security | Strong integration capabilities with Node.js ecosystem, supports REST APIs and middleware |

| Name | Language | Performance | Ease of use | Scalability | Security | Integrations |
|---|---|---|---|---|---|---|
| Flask | Python | Moderate performance, suitable for smaller applications | Very easy to use and lightweight, with minimal boilerplate code | Scalable with additional components, suitable for small to medium applications | Moderate security, requires third-party extensions for comprehensive security | Good integration with Python libraries, suitable for RESTful APIs and web services |
| ASP.NET Core | C# | High performance with asynchronous processing and optimized runtime | Moderate ease of use, extensive documentation, and strong tooling support | Highly scalable, suitable for enterprise-grade applications | Strong security with built-in authentication and authorization mechanisms | Excellent integration with Microsoft ecosystem, supports RESTful APIs, gRPC, and more |
| Django | Python | High performance for database-driven applications, efficient ORM | Easy to use with a focus on rapid development and convention over configuration | Highly scalable with built-in features for handling large applications | Strong security features built-in, including protection against common vulnerabilities | Integrates well with Python ecosystem, supports REST APIs and web services |

All the proposed solutions in these tables would work and correspond to the needs of the project. The choice was therefore made based on the framework's ease of use and the fact that the team members had already used it. For the frontend, Angular is used due to its many useful modules that improve the UX of the website. Additionally, it is highly recommended among IT communities. For the backend, the team chose Express with Node.js because it seemed quite simple, intuitive, and well-optimized. For the same reasons, AWS was chosen for the server. An illustration of the chosen development platforms is shown in Figure 59.

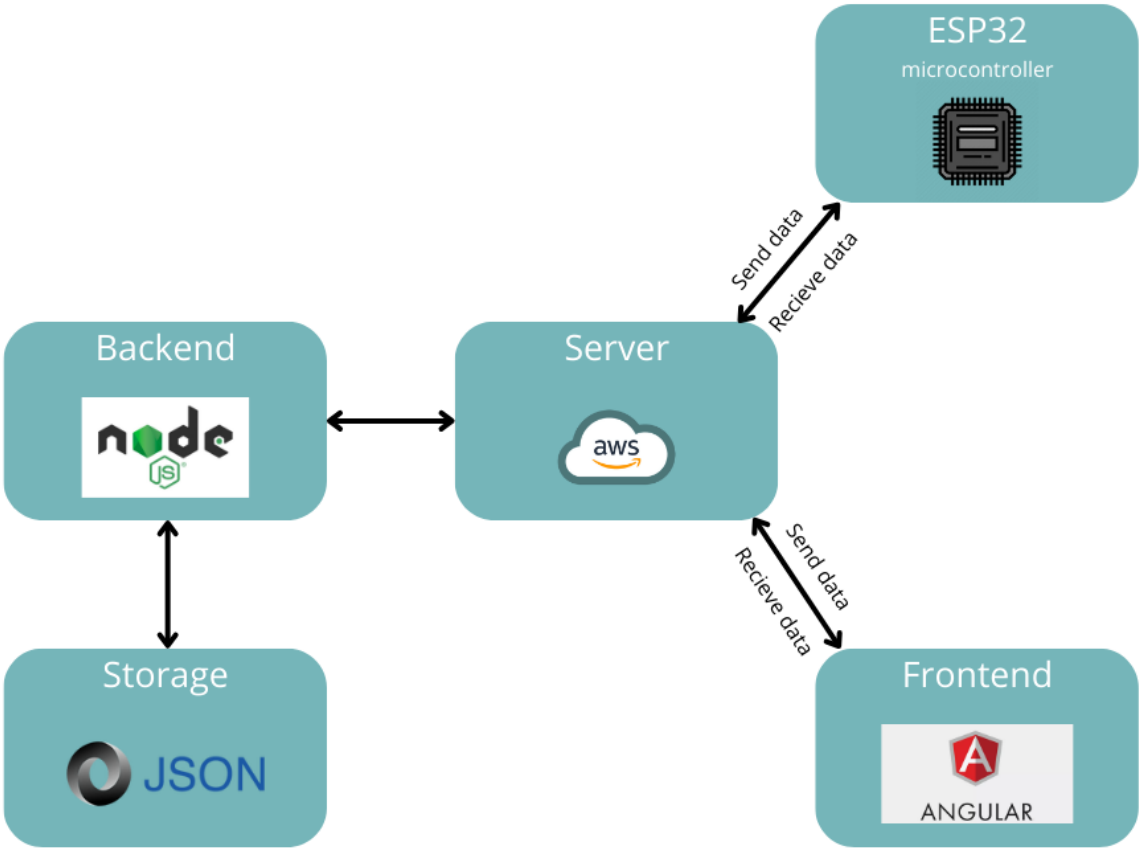



Figure 59: Webserver system

The component diagram consists of 3 systems: the controller, web app and data storage, see Figure 60. In the application, users can create an account and log in. They can plan future doses, view the history of doses already taken, and see photos stored on a server. The application also communicates with the microcontroller by sending an HTTP request to activate the distribution of pills as planned in the application.

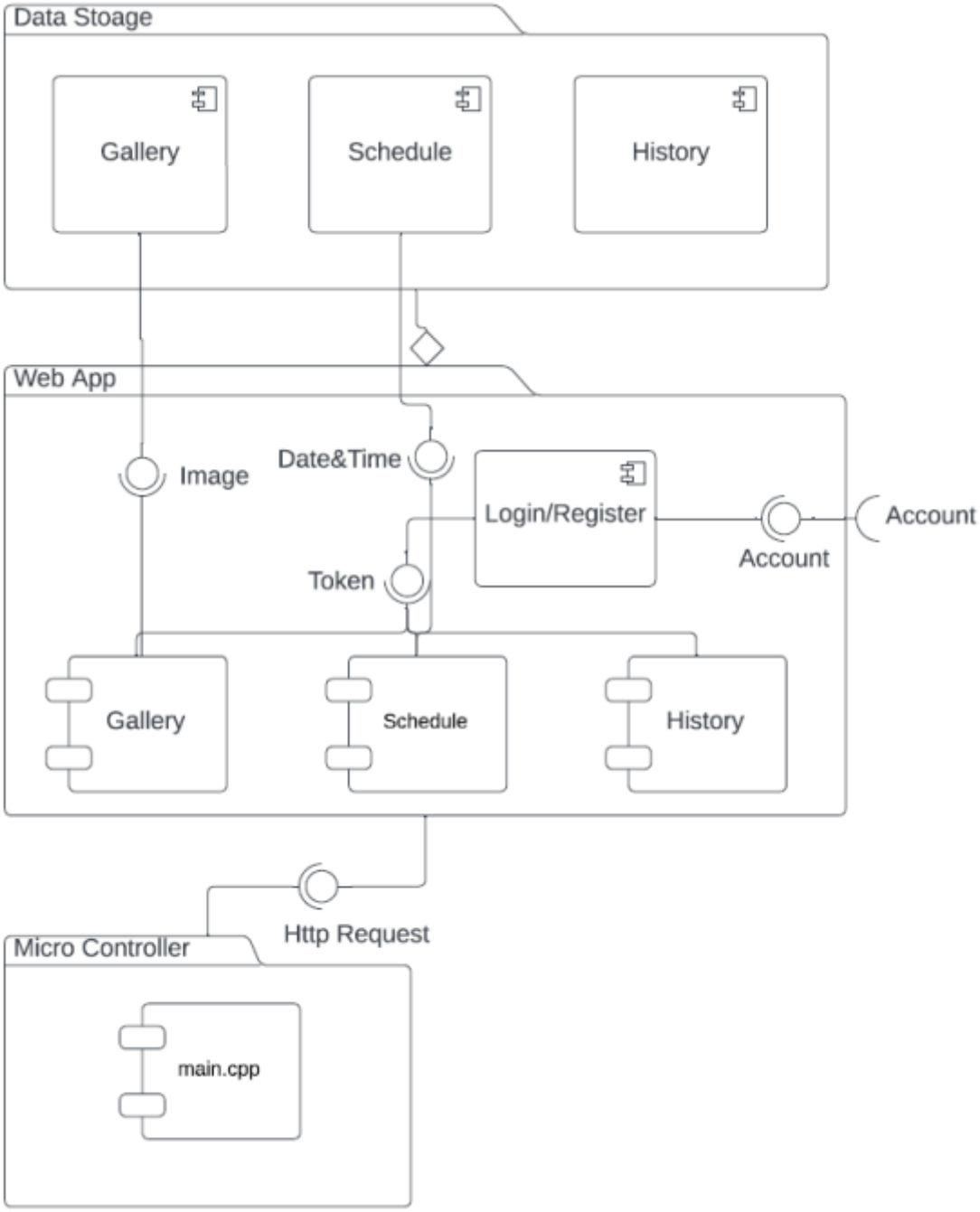



Figure 60: Component diagram of the system

The component diagram offers a visual representation of how the various components of a system interact. It illustrates how the components are connected and how they collaborate to deliver the necessary functionality. This diagram aids in comprehending the system's overall architecture and the interactions between different components.

#### 7.3.2.1 Web Application

For the project, it was decided to create a web application for caretakers to configure Billy easily. The app allows caretakers to plan doses, schedule intake times and access historical records of photos, medication, and rewards. Caretakers can also create and manage different profiles (names, roles, and fingerprints). Users can register and log in. The team aimed for the application to be user-friendly, with a design consistent with Billy's image and intuitive. The same colors as the logo were used in the

application's design. The application will have a login screen and, once logged in, users will have access to 5 main interfaces: history, schedule, photo gallery, profiles and parameters. These menus are designed to provide a clear understanding of the user's treatment and better manage Billy in the application. The design of the application is shown in Figure 61.

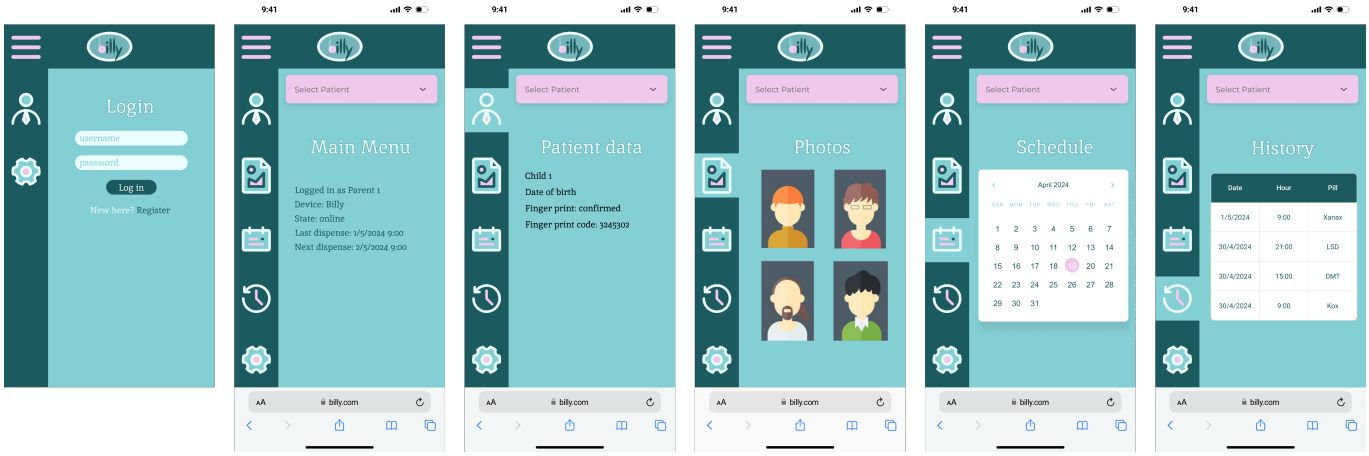



Figure 61: Web application interface

### 7.3.3 Packaging

When it comes to packaging, the packaging material has to fulfill some important tasks, to make sure the product arrives in the required conditions from deliverer to customer. These tasks are:

- Protection: the most important function, packaging needs to keep the product safe and secure from outside influences.

- Storage: packaging needs to safe the product from dust, environmental influence such as for example rain and the time it will be stored.

- Transport: designed so that it can be handled and stacked easily

- Sales & Promotion: the outside design must be appealing for the customer to make a pleasing unpacking experience.

- Disposal: making the packaging most sustainable possible by providing ways to recycle or disposing it.

- Assurance: making sure Billy arrives in the promised conditions **[Aleksandra Owczarek, 2023]**.

As Billy tries to be as sustainable as possible, the company wants to create a way to make the packaging not only useful for transport, moreover, also make it possible to give it a second life after its original use. Therefore, the first idea was to create an origami which led to some problems. Since origami need to be folded a lot of times to be made, the cardboard had to be quite thin, which would be a big risk to take when it comes to delivering the product safely.

After some more brainstorming, the idea became to give the packaging a new life by making it a creative handicraft out of it. Children and their parents can use the cardboard and the already prepared drawings/printings on the inside to build their own treasure chest. The only things that are required will be glue, scissors, and some colorful pencils to make it their own masterpiece. The treasure chest can be used for the storage of the medication, or to store the received rewards, or even just for decoration purposes. Examples of treasure chests made from boxes can be seen in

Figure 62 and Figure 63.

Figure 62: Treasure box example 1 **[KleineGeschichten, 2024]**

Figure 63: Treasure box example 2 **[CreateintheChaos, 2024]**

The treasure box for Billy will follow the following guidelines:

- The Cardboard for the transportation will be 3.0 mm thick and formed with a simple e-wave, to protect Billy from outside influences.
- The size of the cardboard needs to measure 245 mm x 245 mm x 305 mm to fit Billy and still have enough room for some fillers to protect Billy from moving around during transportation.
- All in all, Billy, together with its packaging, will weigh around 2 Kg.

An illustration of Billy's packaging is shown in Figure 64.

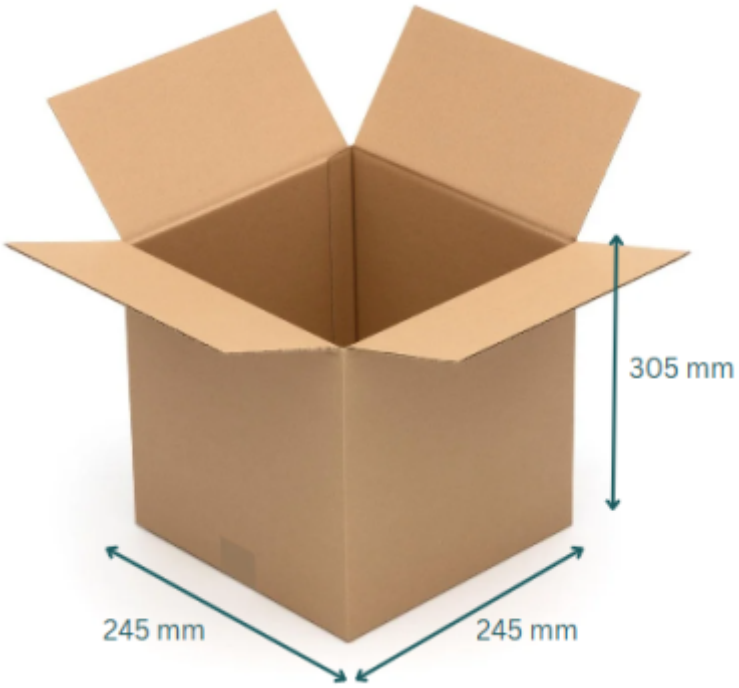



Figure 64: Packaging Dimension

As with all parts and components of “Billy”, the team also wants the packaging to be as sustainable as possible, taking the precautions below:

- Cardboard will be used as the main packaging material since it is the most sustainable option. 96 % of corrugated cardboard is recovered through recycling programs which makes it the most recovered material. Furthermore, even if cardboard landed in the trash, it is extremely biodegradable and will break down in 3 months in beneficial conditions. Finally, cardboard packaging is manufactured by using a renewable resource. Considering that other packaging materials such as plastic are neither biodegradable nor do they have a high recovery rate, cardboard is by far the best option **[BuyBoxes, 2023]**.
- The fillings will be Spiral tissue paper or something similar to quickly create sustainable volume. Tissue paper can be recycled from 95 up to 100 % **[ECOENCLOSE, 2024]**.
- Finally, as mentioned above a treasure box can be built from cardboard, making it reusable.

To create the treasure box, the pre-cut cardboard needs to be folded according to the instructions in Figure 65:

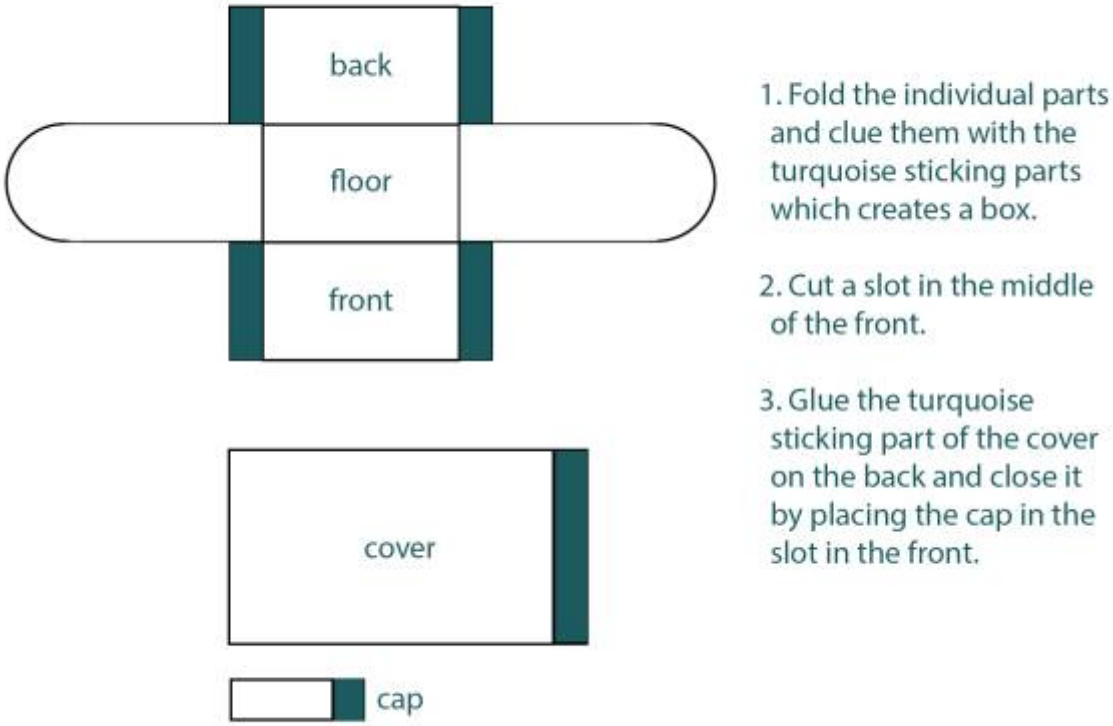



Figure 65: Folding Instructions

Once the treasure box is folded, the children get their first reward: a sticker of the logo that they can put on the treasure box. The team chose not to print the logo onto the cardboard in order to work more sustainably. Furthermore, giving the children something to put onto the box again adds to the fun factor. The logo as a sticker can be seen in Figure 66:

Figure 66: Sticker of logo

### 7.3.4 Cardboard Model

An initial prototype was made out of cardboard in order to get a better idea of how the final product is

going to look like. By physically seeing and touching this “prototype”, the team gets a better feeling of the product and whether or not the form and size of this pill dispenser are suitable for children. The initial prototype is shown in Figure 67.

Figure 67: Cardboard Model

## 7.4 Prototype

This section will deal with the main changes and choices made to create the prototype of the designed solution, particularly the changes made to the structure and hardware, the software used, and the tests carried out.

### 7.4.1 Structure

In order to produce a prototype, certain modifications had to be made to the structure of Billy to fit for 3D printing. The team wanted to print it in 3D. Given that the prototype should only be presented as a proof of concept for the project, it was decided to produce a downscaled version of Billy. The prototype was therefore halved compared to the final product. To have something solid and 3D printable, the shapes of the parts have also been revised. Reinforcements had to be added to the plain disk and pill selector to prevent the parts from wrapping. On the body, chamfers had to be added in certain places to create a support for 3D printing. On the pill container part, the thickness of the slot walls had to be increased to prevent them from breaking.

Moreover, margins needed to be added on various parts because 3D printers are not very accurate. An additional box had to be created to house the screen and the fingerprint reader. This decision was taken because these components could not be integrated into the smaller version of Billy due to size

constraints. For the sphere containing the reward, the team used a simple transparent plastic Christmas ball to demonstrate the principle of reward. Figure 68 below, illustrates all those modifications.

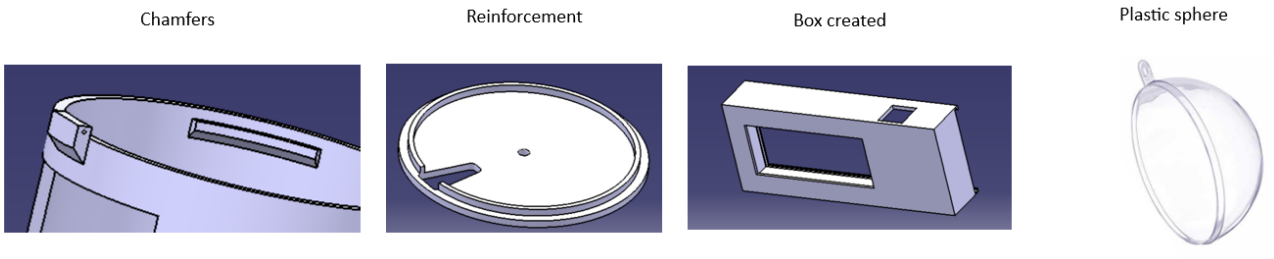



Figure 68: Illustration of the changes made

After printing the parts, the prototype has been assembled using glue and metallic pins. Figure 69 shows the model assembled.

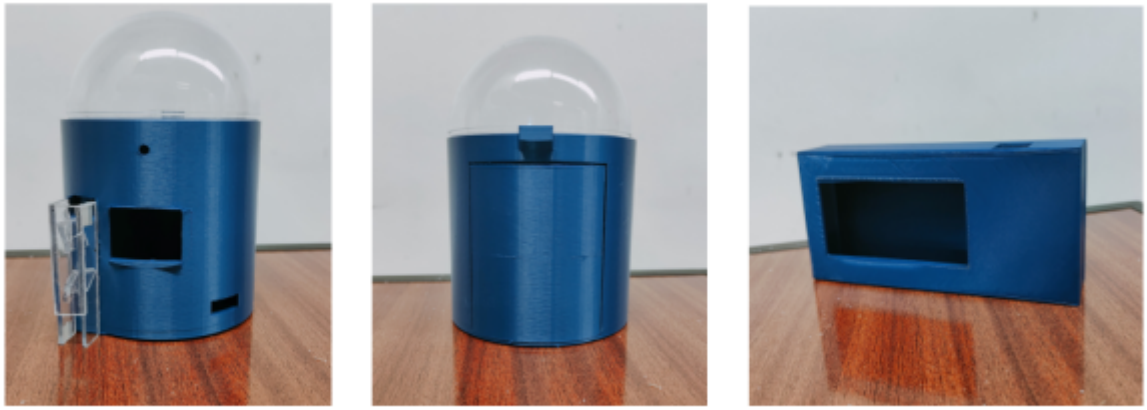


Figure 69: 3D printed prototype and box

The electronic components were then put into the 3D printed model and wired up. The Figure 70 shows the fully completed prototype of Billy.

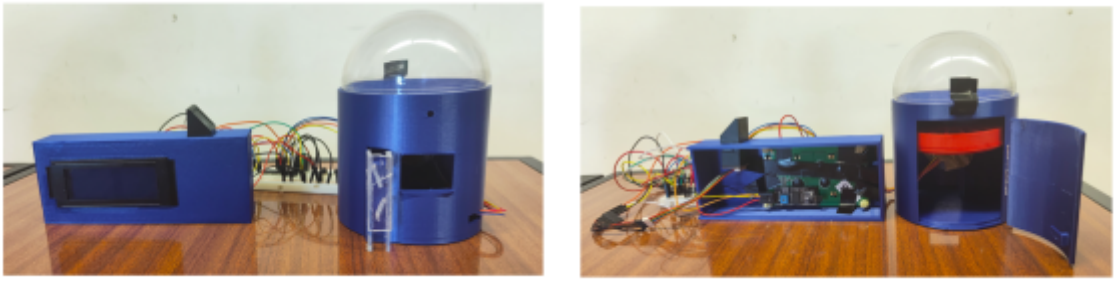


Figure 70: Completed prototype of Billy

### 7.4.2 Hardware

*1. List of components and Materials*

In order to respect the budget of 100 € that was given for this project. Choices had to be made about the components used to reduce the overall cost of the prototype. To do this, the team concentrated on components with important functions that should not be modified. Obviously, security was the

most important function for the team, so security components, such as the fingerprint reader, were retained, despite their high cost. To fit within the budget, the changes were made using a lower-performance, non-touch screen display, to display only the main information. The stepper motor and servo motor have also been changed for less powerful and less precise models. Finally, the main supplier has also changed, from DigiKey to Mouser, which turned out to be cheaper. In the Table 46 below you will find the list of components used for the prototype.

Table 46: Cost of the components for the prototype

| Component | Quantity | Price (with VAT) | Supplier | Shopping link |
|---|---|---|---|---|
| ESP32 CAM | 1 | 13.24 € | Mouser Portugal | Shopping link |
| FT232RL (USB to TTL Serial Converter) | 1 | 6.77 € | PT Robotics | Shopping link |
| DFRobot I2C LCD Screen | 1 | 9.21 € | Mouser Portugal | Shopping link |
| MCP23017 - i2c 16bit Expander | 1 | 2.58 € | PT Robotics | Shopping link |
| Passive buzzer | 1 | 0.56 € | Mouser Portugal | Shopping link |
| FPM10A (fingerprint sensor) | 1 | 18.55 € | Mouser Portugal | Shopping link |
| ULN2003 (moter driver) | 1 | 1.23 € | PT Robotics | Shopping link |
| Stepper motor | 1 | 7.44 € | Mouser Portugal | Shopping link |
| Servo Motor | 2 | 7.00 € | Mouser Portugal | Shopping link |
| 2×40 Pin Bar for PCB | 1 | 1.23 € | PT Robotics | Shopping link |
| AC/DC WALL MOUNT power supply 5V 15W | 1 | 4.67 € | PT Robotics | Shopping link |
| 220 Ohm Resistor | 1 | 0.22 € | Mouser Portugal | Shopping link |
| MULTICOLOR BUTTONS (10 pack) | 1 | 0.82 € | Mouser Portugal | Shopping link |
| LED RED | 4 | 1.00 € | PT Robotics | Shopping link |
| Capacitor Ceramic 100µF | 1 | 0.28 € | Mouser Portugal | Shopping link |
| BreadBoard | 1 | 2.99 € | Mouser Portugal | Shopping link |
| Jumper Wires Pack - M/M | 1 | 3.08 € | PT Robotics | Shopping link |
| USB micro-B Cable - 6 Foot | 1 | 0.00 € | Personal cable | |
| Screws M4*25 | 1 | 0.63 € | Leroy Merlin | Shopping link |
| PLA plastic for all the 3D printed parts (500 g because 1/2 scale prototype) | 1 | 8.00 € | - | Provided by the teachers |
| Vidro sintético TRANSPARENTE plank 500*500*2mm | 1 | 5.19 € | Leroy Merlin | Shopping link |
| Total | | 96.69 € | | |

Despite this new list of components, some have been replaced by similar components already present at the school. Like the screen, which has been replaced by an LCD HD44780 20×4 I2C.

*2. Detailed schematic for the prototype*

As can be seen in Figure 71 the detailed schematic has changed a bit. The main difference is the use of a different display. The prototype does not require a full-on touch display to work. A simpler and cheaper LCD is used to display the most imported information. This change freed up a lot of GPIO pins

of the microcontroller. This allows for a component rearrangement. More components are now directly connected to the microcontroller.

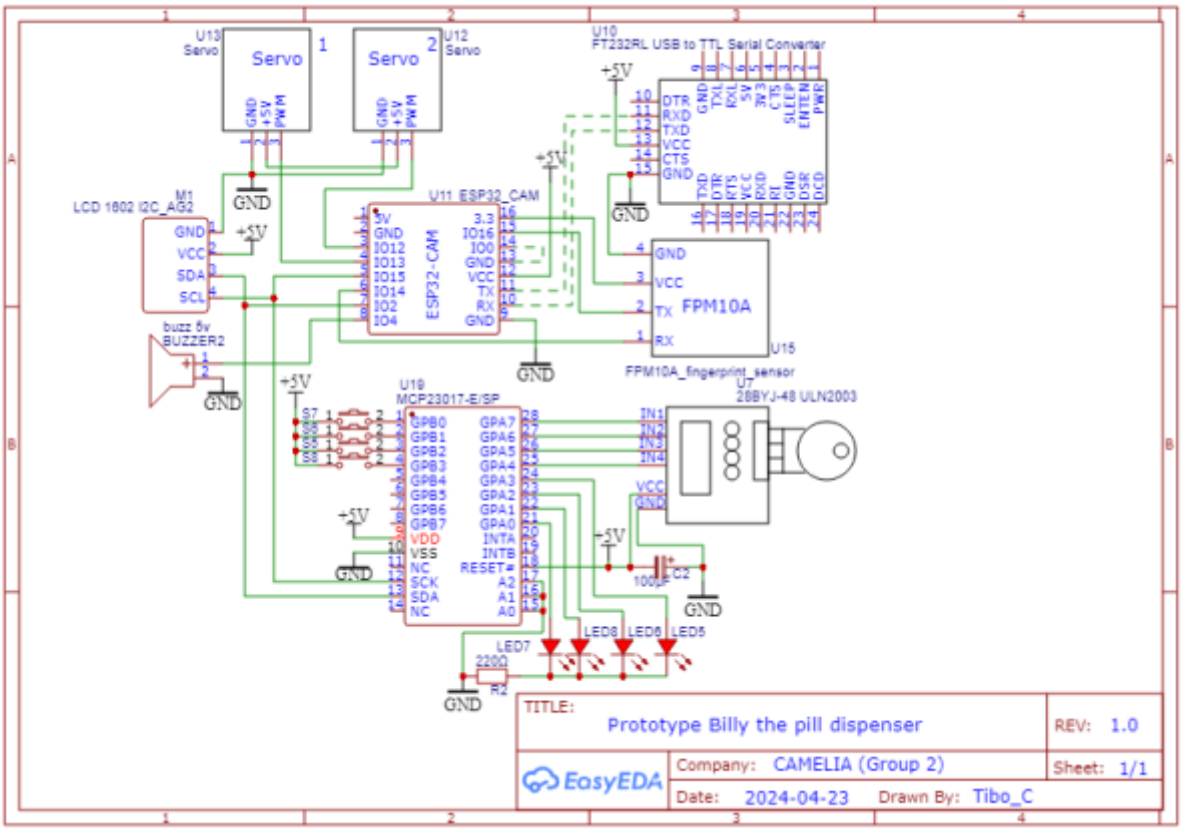



Figure 71: Detailed schematic for the prototype

*3. Power Budget for the prototype*

When designing a prototype, understanding the power consumption of individual components is crucial for proper power management and system stability. The following table presents the power budget for the prototype, detailing the power consumption of each component at their respective voltages. This budget helps ensure that the power supply can adequately support all components and avoids overloading.

In this case, the team chose a 10 W power supply based on the total power consumption of the components. Selecting a power supply with a higher capacity than the total power consumption, allows for some margin and ensures stable operation under various conditions.

For more detailed information, refer to the Table 47 below:

Table 47: Power Budget for Prototype

| Component | Power (W) | Voltage (V) | Current (A) | Additional Notes |
|---|---|---|---|---|
| ESP32-CAM | 1.55 | 5.00 | 0.31 | 2 A recommended |
| FT232RL (USB to TTL Serial Converter) | 0.35 | 5.00 | 0.07 | |
| J204A 20×4 LCD | 0.07 | 3.30 | 0.02 | |
| MCP23017 - I2C 16bit Expander | 0.01 | 5.00 | 0.00 | |

| Component | Power (W) | Voltage (V) | Current (A) | Additional Notes |
|---|---|---|---|---|
| Passive Buzzer | 0.25 | 5.00 | 0.05 | |
| FPM10A (Fingerprint Sensor) | 0.60 | 5.00 | 0.12 | |
| SBT0811 Stepper Driver | - | 5.00 | - | |
| 28BYJ-48 Stepper Motor | 2.40 | 5.00 | 0.48 | |
| SG90 Servo Motor | 2.00 | 5.00 | 0.20 | 2 motors |
| **Total** | **7.23** | | | |
| | **~10 W** | | | |

### 7.4.3 Software

A flowchart, in Figure 72, is used to explain the process of the system. The system retrieves the current time from a time-server and contacts an API to obtain the medicine dispensing schedule. The system continuously checks if the current time matches a scheduled dispensing time. If the scheduled time is not yet reached, it keeps checking until it does. When the scheduled time is reached, the system initiates alerts by playing a sound and blinking a light. It then proceeds to verify the presence of a child's fingerprint. If the child's fingerprint is not detected, the system keeps checking until it is. Once the child's fingerprint is detected, the system dispenses the medicine. After dispensing the medicine, the system takes a picture and sends it to the server.

If the system finds the parent's fingerprint to open the doors. If the parent's fingerprint is not detected, it continues to check until it is. Upon detection, the system opens the doors. Next, the system again checks for the parent's fingerprint to close the doors. If the parent's fingerprint is not detected, it continues to check until it is. Once detected, the system closes the doors.

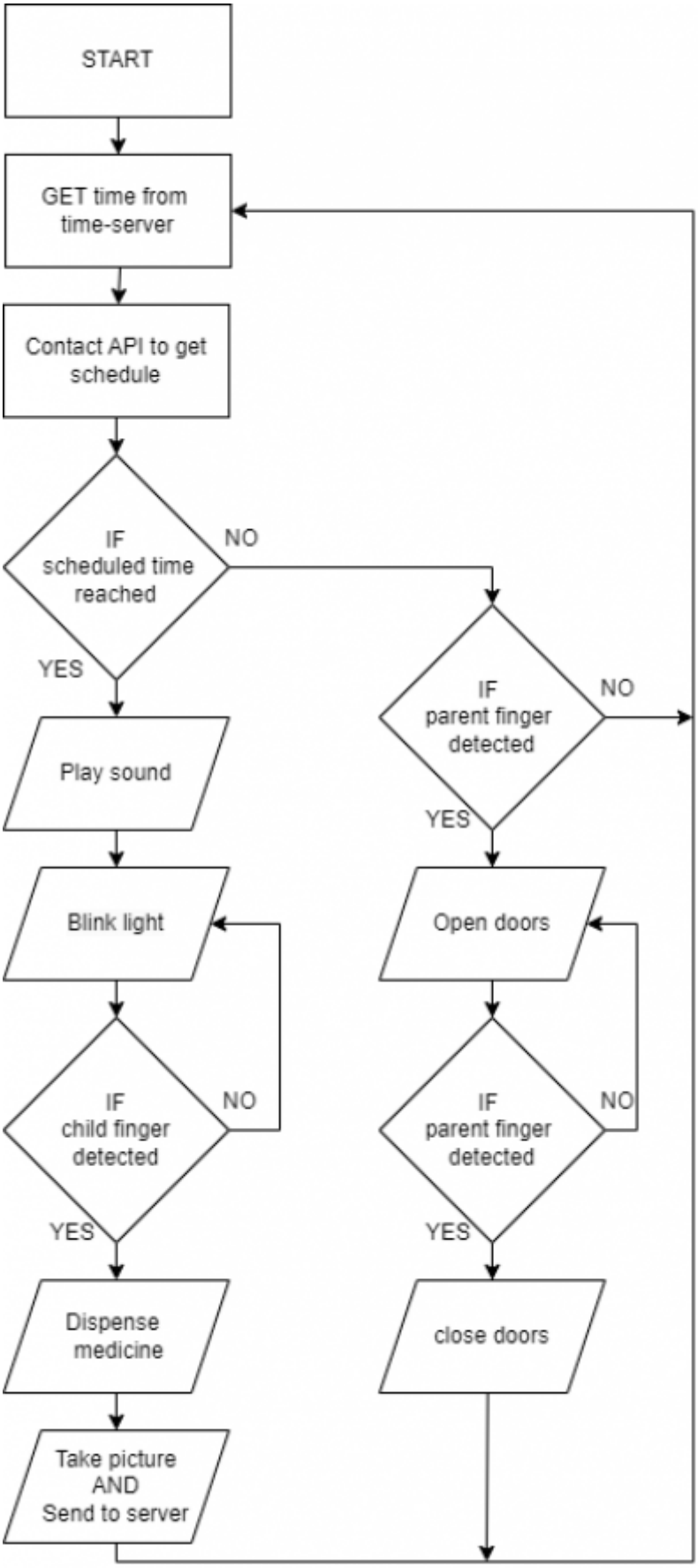



Figure 72: Code flowchart

For the project, it was decided to program only Billy's main functions: the screen, the stepper motor, the locks, the fingerprint reader and the camera. The other elements, such as the LEDs and buttons, have not been programmed as they are not necessary for the prototype.

The application has been programmed, but the design differs slightly from the initial one. It was developed on a computer rather than a smartphone because it was easier to program. Here too, the main functions work, such as the gallery and the schedule. The development of the application for smartphones is therefore the next step. Figure 73 shows the design of the final application and Figure 74 shows how it works.

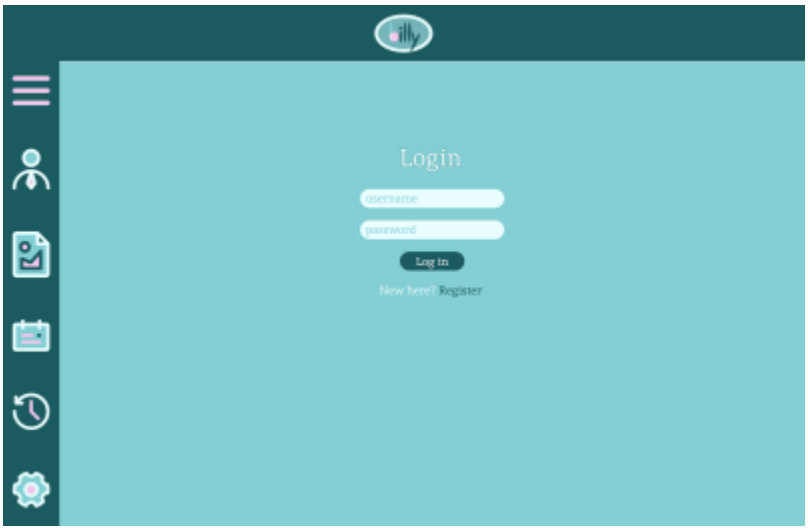



Figure 73: Final application design

app_features.mp4

Figure 74: Interactive screen

All the software was written in Visual Studio Code, making use of the Platform-Io and the Wokwi simulation plugin while the team waited for the components to arrive. The code for the microcontroller is mostly C++. The web application has been programmed in HTML and CSS and JavaScript (Node.js) has been used for the backend. All the code can be found in this GitLab repository

The connection between the application and the hardware was the next stage in the programming. At the moment, the next medication distributions can be planned from the application. Sending photos from Billy to the application/server remains to be done.

### 7.4.4 Tests & Results

Hardware tests

Tests were carried out to ensure that the prototype worked correctly. In the case of the hardware, the tests are described in section **1.6 Functional Tests**, and consisted mainly of ensuring that the various components functioned correctly when required. The following Table 48 shows the type of tests carried out and the results.

Table 48: Hardware test

| Functionality | Test results |
|---|---|
| When the buzzer vibrates and the child places their finger on the fingerprint sensor, a dose of medicine is dispensed | Pass |
| When the parent selects parent mode and places their finger on the fingerprint sensor, the various doors open | Pass |
| A picture of the child is taken while he is swallowing his medicine | Pass |
| The screen shows when the next dose will be available | Pass |

These results indicate that the prototype successfully implements Billy's main functions.

Software tests

The functionalities to be obtained were achieved concerning the use cases defined in the previous sections. The user can log in, plan the net dosage, see the photos taken and see the history of the previous dosage. For the performance execution of the application, each API call was run multiple times. Table 49 contains the test results of the API. It provides an in-depth analysis of the performance and responsiveness of the API.

Table 49: Functional tests for the software

| | | | | | Latency (ms) | |
|---|---|---|---|---|---|---|
| **User story** | **Endpoint** | **Method** | **Result** | **Size (B)** | **μ** | **σ** |
| As a user I want to be able to register | /api/user/register | POST | OK | 377 | 191 | 73 |
| As a user I want to be able to log in | /api/user/login | POST | OK | 536 | 220 | 45 |
| As a user I want to see the schedule of dispences | /api/schedule | GET | OK | 938 | 89 | 64 |
| As a user I want to plan the dose in a schedule | /api/schedule | PATCH | OK | 469 | 73 | 56 |
| As a user I want to see the photos taken by the device on the app | api/gallery | GET | OK | 533 | 91 | 40 |
| As a user I want to see a specific photo on the app | api/gallery/portrait1.png | GET | OK | 46600 | 125 | 65 |

These results confirm that the web application implements the main functions with success, and presents data exchange and latency values compatible with this type of application.

Table 50 contains new testing on a specific endpoint with a high latency.

Table 50: Functional tests with multiple requests

| | | | | | Latency (ms) | |
|---|---|---|---|---|---|---|
| **Number of requests** | **Endpoint** | **Method** | **Result** | **Size ( B )** | **μ** | **σ** |
| 10 | /api/user/login | POST | OK | 535 | 216 | 40 |
| 100 | /api/user/login | POST | OK | 535 | 212 | 56 |
| 1000 | /api/user/login | POST | OK | 535 | 210 | 60 |

A counterintuitive result of multiple requests having lower latency (Table 50) than single request latency (Table 49) is caused by several reasons. First of all, when multiple requests are sent at the same time, the HTTP client often reuses existing connections rather than opening a new one for each request. This is called Connection Pooling and Keep-Alive. The second possibility is a warm-up effect. The first request to an API endpoint may involve some initial setup, such as loading configurations, initializing caches, or compiling code. Subsequent requests benefit from this initial setup, leading to lower latency. In general, modern servers are well optimized for high traffic and load.

## 7.5 Conclusion

The chapter meticulously dissects the various stages of Billy's development, from the initial spark of ideation to the final, functional prototype. The team began by revisiting the problem statement: the alarming number of children who do not like to take medicines, often due to anxiety and forgetfulness. Existing solutions, primarily designed for adults, failed to capture the imagination and address the unique challenges faced by young patients. This realization sparked an idea within the team to create a product that would not only dispense medication but also transform the experience into an engaging and even rewarding activity.

The reward system gamifies the process, encourages children to take their medication consistently. The playful design, complete with a transparent dome showcasing the reward, replaces apprehension with a sense of anticipation. Parental control features, including fingerprint recognition and a monitoring app, empower parents while ensuring medication safety. The integrated camera provides visual confirmation of medication intake, offering peace of mind to caregivers.

The design phase involved meticulous attention to detail, from detailed sketches and material selection to stress analysis that ensured the product's functionality and durability. The chosen round design with a transparent dome prioritizes both ease of use and child safety. The selection of PLA plastic for 3D-printed parts and plexiglass for the dome and slide reflects a commitment to cost-effectiveness, sustainability, and strength. The stress analysis adds an important layer of scientific validation, ensuring users of the product's integrity.

The component selection explained the process of choosing electronic parts based on compatibility, functionality, and cost-efficiency. A detailed list of components with suppliers ensures transparency and replicability. For those with a technical background, the schematics outline the connections between various components, serving as a blueprint for assembly. A power budget table calculates the theoretical power consumption of each component, guaranteeing that a suitable power supply is chosen to keep Billy running smoothly.

All these steps led to the production of a prototype and the results of the tests proved to be positive for the project. The next chapter will conclude on the work done, the differences between the original idea and the prototype created and will also look at possible future improvements.

# 8. Conclusions

## 8.1 Discussion

At the start of this project, the team chose the topic of Smart Health and Well-Being. This was due to the personal affinity some team members had with this topic. It was soon decided to create a pill dispenser for elderly people because it could add value to the health care of family members. After an initial weekly meeting, the team was strongly encouraged to brainstorm about this again. With many pill dispensers already available on the market, it was difficult to develop a product that would be innovative. After further research, the team got a better overview of what was already available on the market as well as what products existed, who they are made for and their functions. So the team's conclusion was quickly made, moving away from the idea of making a pill dispenser for older people. To make this product innovative and to market it competitively, the students did not have the necessary skills and budget. Even before the start of the next weekly meeting (3rd weekly meeting),

the team already had a solution in mind. During research, it became clear that just about all pill dispensers on the market are aimed at adults and older people. No product focuses on children, something the team felt offered potential. After asking around pediatricians, doing online research and our own experiences with the students of this team, the team knew that children often have a hard time taking pills. As a result, the decision was made to develop a pill dispenser aimed at children between the ages of 8 and 12.

Because of the diversity in the team, there were struggles and disagreements. Many topics were new territory for the group, so much time was often spent on preliminary research. Despite this, the team managed to deliver the required deliverables within the deadline each time. Probably the greatest challenge was in developing the software. This took more time than initially estimated and presented challenges. Now that the project is over, the team can look back on a effective project. The pill dispenser has been successfully developed and is called Billy.

Billy will help children take their medication by doing so in a playful and child-friendly way. This is how to motivate the children. A reward system is also provided in which the parents can choose a reward that their children gets after taking their medication/treatment. In addition, the children can take their pills independently. As a parent, you will get a notification through the software with a picture of your child taking the medication. Additionally, as a caregiver, you can put the pills in Billy at the start of treatment and enter into the software when the doses need to be released. You get a notification at the time medication needs to be taken, a buzzer provides attention, and you, as a caregiver, also don't have to think about when the treatment stops. If the treatment takes longer than the number of doses the device can store, you'll be notified when they need to be refilled.

The team is therefore extremely satisfied with the achievements of the last few months and is convinced that Billy can add value to many households.

## 8.2 Future Development

The prototype has been successful, and its main functions have been well realized. However, the production of the prototype has highlighted possible improvements to be made for the final version.

Currently, the screen on Billy is only used to display basic information such as the date and time of the next dose. It is suggested that games could be added to the screen, with virtual rewards to make Billy more engaging for children. Currently, Billy prevents the dose from being administered outside of the scheduled time, creating a problem when the child is not at home. It could be solved by allowing caregivers to override this restriction, making it possible to administer doses at anytime. The pill dispensing mechanism could allow the dispenser to be filled by selecting the day in the app, reducing errors and making the process more efficient. To do this, it would be necessary to develop a solution to prevent pills from falling into the hole of the pill selector.

One possible improvement is to add support for the plain disk and the pill selector. Currently, the disks are not stable enough and may capsize when pressure is applied far from the center. This would require the addition of a third support to make the assembly more stable.

New features for the application could also be implemented, such as the ability to connect the application to multiple devices simultaneously. Currently, the photo taken when taking medication is stored on a server. It would be beneficial to receive the photo directly on the application without going through the server.

Finally, another potential improvement would be to add a chamfer to the pill container to prevent pills

from slipping under the mechanism.

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