APPRENTICE AUTOMATION CHALLENGE 2023

Step Smart

A step in the right direction for walking sticks and home automation.

Team Details

Team Name	It's all under control!
Team Brand	Step Smart
Project	Smart walking stick
Company	Leonardo UK

Team Members

Forename	**Surname**	**Job Title**	**Team Role**
Peter	Metcalfe	Software Degree Apprentice	Team & Software Lead
Melissa	Hobbs	Technical Apprentice	Systems Lead/Scrum Master
Joseph	Grice	Electronics Degree Apprentice	Electrical Lead
Ryan	Rickards	Business Degree Apprentice	Business & Marketing Lead
Tom	Butcher	Manufacturing Apprentice	Manufacturing & Mechanical Lead
George	Richardson	Mechanical Degree Apprentice	Team Mentor

Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Definition
AF	Atrial Fibrillation
BSI	British Standards Institute
BoM	Bill of Materials
CAD	Computer Aided Design
CDR	Critical Design Review
COTS	Commercial Off-The-Shelf
CTQ	Critical to Quality
FEA	Finite Element Analysis
FMEA	Failure Modes and Effects Analysis
GPIO	General Purpose Inputs/Outputs
GUI	Graphical User Interface
IMechE	Institution of Mechanical Engineers
LED	Light Emitting Diode
NA	Not Applicable
NHS	National Health Service
OS	Operating System
PCB	Printed Circuit Board
PDR	Preliminary Design Review
QA	Quality Assurance
S.T.T.E.	Special to Type Test Equipment
SDR	System Design Review
SWOT	Strengths, Weaknesses, Opportunities, Threats
TBC	To Be Confirmed
TBD	To Be Determined
TRR	Test Readiness Review
UI	User Interface
UPC	Unit Production Cost
UX	User experience
R&D	Research & Development

Introduction

In a world driven by technology, where automation has become an essential part of our lives, we, the talented and diverse team of apprentices from the Leonardo Luton site, have embarked on a remarkable journey to revolutionise home automation. Under the banner of "Step Smart," we proudly present our business case for a ground-breaking product that will redefine safety and independence for individuals in need of support. Our entry into the prestigious IMechE Home Automation Challenge aims to showcase the immense potential of our creation, a smart walking stick unlike any other.

Motivated by a deep desire to enhance the lives of individuals requiring assistance, we embarked on this project with unwavering determination. We recognised the challenges faced by both users and caregivers alike and were determined to create a solution that surpasses conventional aids. Our team is composed of apprentices from different areas of expertise, including software development, technical skills, manufacturing, and electrical engineering. By harnessing our collective knowledge, we have created a product that blends technological advancements with genuine care.

Let us introduce the Step Smart walking stick, a device that surpasses traditional aids. Equipped with sensors, it not only provides support but also detects potential falls, sending alerts to caregivers or designated services. This real-time response system acts as a lifeline, ensuring prompt assistance and reducing the risk of injuries. Additionally, the walking stick's unique foot design allows users to effortlessly leverage it back into an upright position if it accidentally falls, eliminating the need for bending or strain.

Figure 1: Walking Stick Render

To enhance user safety and well-being, the Step Smart walking stick features a built-in light source, illuminating the path during evening walks or in low-light environments. Furthermore, a heart rate sensor integrated into the handle provides users with valuable health insights, promoting proactive care.

Our report delves into the details of our problem statement, conceptualisation, design specifications, development journey, and manufacturing processes. Through rigorous research, prototyping, and testing, we have meticulously crafted a business case that highlights the technical prowess, usability, and market viability of the Step Smart walking stick. Our aim is to demonstrate its potential for widespread adoption, commercial success, and most importantly, its profound impact on the lives of those who could rely on it.

Problem and Concept

Idea Selection

The initial stage of any engineering endeavour involves generating a wide range of ideas. Utilising brainstorming techniques, Team: It's all under control, generated a set of ideas aimed at improving home automation. After careful consideration, the team narrowed down the options to the four most promising ideas:

1) Plant Pot/Pet Food Dispenser
2) Mould Reduction System
3) Modular Dog Lead
4) Smart Walking Stick

Pet food dispenser / plant pot (2-in-1)

Idea: automatically feeds pet and waters plant

Features:
- Pet food storage
- Automatic feeding
- Plant watering
- App for configuring/controlling

Other:
- Could do wet and dry food?

Pros:
- Encourages afforestation and planting

Cons:
- Not a very unique idea?
  Lots of food dispensers exist

Mould Reducer

Idea: humidity sensor and automatic window opening.

Features:
- Monitors humidity
- Opens window

Other:
- Monitors weather to know when to open window
- Using UV could clean air reducing mould spores?

Pros:
- Topical; aims to fix a problem in the news right now

Cons:
- Security issues with opening window?

Modular dog lead/bag

Idea: Customisable, different sections of lead or bag used for different things, plus a pedometer

Features:
- Modular/customisable design
- Storage
- Pedometer (for user and dog)

Other:
- Add lights / torch, for night walking

Pros:
- Simple design

Cons:
- Not considered 'home automation'

Smart walking stick

Idea: Monitors/notifies fall detection (if it falls, have a 2min timer for Old person to get up, if not, ALERT).

Features:
- Detects Falls
- Alerts carers of potential emergency

Other:
- Could help pick things up for people with bad back?
- Pedometer
- Could help elderly get back up with 4 legs?
- Add a heart rate sensor for monitoring heart attacks?
- Add lights for easier travel in dark
- Pill storage?
- Collision detection (blind people)?
- Built in voice assistant?

Pros:
- Simple design? Easier to make

Cons:
- Difficult fitting it all in small size
- Needs to be strong enough to help elderly support their weight and resist falls.

Figure 2: Summary of Ideas

To narrow down our options and identify the strongest idea, we sought input from an external reviewer who provided unbiased feedback on each idea. We found this strategy rewarding as the reviewer offered insights into factors to consider. For example, it was highlighted that the Modular Dog Lead may not align with the concept of "home" automation, as its functionality is more suited for outdoor use.

While we valued the input of others, our team also recognised the significance of making informed decisions supported by evidence. We therefore generated a PUGH Matrix, see figure 3, to enable us to see clearly which of our concepts were most suitable.

Criteria	Datum, Plant pot pet food dispenser	Mould Reducer	Modular dog leash	Smart walking Stick	Option 4	Option 5	Option 6	Option 7
Ease of use	0	1	0	1				
Skill required for design/manufacture	0	-1	0	0				
Innovation	0	1	0	1				
Cost	0	1	1	0				
Mechanical complexity	0	0	1	1				
Ability to trial in short timeframe	0	0	1	1				
Risk	0	-1	1	0				
Lead times on components	0	-1	0	0				
Electrical complexity	0	-1	-1	0				
Software complexity	0	-1	1	0				
Part avaliability	0	-1	0	0				
Sustainability	0	-1	-1	-1				
Existing products	0	1	0	1				
Marketability	0	0	1	1				
Feasability	0	-1	-1	1				
Number better: Σ+	-	+4	+6	+7	+0	+0	+0	+0
Number worse: Σ-	-	-8	-3	-1	0	0	0	0
Number same: Σ0	-	3	6	7	0	0	0	0
Sum: Σ All	-	-4	+3	+6	+0	+0	+0	+0

LEONARDO ELECTRONICS

	Mould Reducer	Modular dog leash	Smart walking stick
Ease of use	Once installed, much easier to use, as the user shouldn't need to do anything, all automated.	Should be just as simple to use.	Should more simple to use, especially if designed for older people, with bad eye sight or lacking understanding of the
Skill required for design/manufacture	More complex, dure to the whole system having to communicate. Variety of sensors needed in different locations, makes designing more difficult.	May sound more simple to design, but quite difficult to fit features in small package and function as intended.	Fairly simple to design, depending on the direction taken with idea.
Innovation	Very innovative and topical. Aims to solve a challenging problem.	Similar product exist already, so being innovative may be	Fairly unique idea, with little competition, so lots of room to show innovation.
Cost	Cheaper than complex plant pot pet feeder, due to less mechanical parts and less structual integrity needed.	Cheaper to reduced size of product.	Cost around the same due to similar amount of materials used and structual integrity needed.
Mechanical complexity	The pet food dispensor must open door to dispense food, the mould reducer must open window. Similar mechanical	Less moving parts, so less mechanical complexity.	Depending on direction taken with idea, less mechanical complexity.
Ability to trial in short timeframe	Mould reducer would require tmie to trial, with more setup, to be able to test all the different compnents are calibrated and working together as	Smaller product, with more simple design, so less time needed to trial.	Fairly simple producct to test and trial.
Risk	Mould reducer can cause risk of infection from mould if not working correctly. Also risk of criminal damage if window un-knowingly opened, or wheather damage, or lost	Less rick than pet feeding plant pot, which to miss-fead pets and lead to problems.	Only risk being is being usless in the scenario it was made for, but it is no worse than not having it at all.
Lead times on components	Has more compnonts so may increase lead times	Should be roughly the same.	Uses similar components, so should have similar lead time.
Electrical complexity	A lot of compents to maintane and account for, so more complex.	It would be difficult constraing the electronics to fit in small package.	Same complexity as pot, a few sensors to connect to micor-processor, etc.
Software complexity	Software heavy product. Must be accurate and precise in controlling and commuicating between all the different components.	Not as much software in modular dog leash.	Similar complexity to pet food dispenser. Software needed to run electronics as well as app to act as friendly user interface.
Part avaliability	Product has more parts, so may take longer to acquire everything necessary.	Smaller prodeuct so less parts to account for.	Similar amount of parts needed to plant pot, so simliar part availability.
Sustainability	Less sustainable than plat pot, which encourages users to plant vegetation.	Less sustainable than plat pot, which encourages users to plant vegetation.	Less sustainable than plat pot, which encourages users to plant vegetation.
Existing products	Plant pot has similar existing products, but mould reducer is a unique and challening problem to	Dog leash does have existing competitors.	Fairly unique idea, with limited exisiting products.
Marketability	Harder to market due to complexity, but easier due to the scale and relivancy of the problem it solves.	Easy to sell, due to large existing market of dog walkers.	Possibly life saving features, makes the product easier to sell and interests more customers.
Feasability	Due to more complex design and ambitous system requirements, less	Not considered 'home' automation as used outside on walks.	Slightly less ambitous design and concise construction.

PUGH Option	PUGH Value	
Smart walking Stick	**6**	Most Favourable
Mould Reducer	3	
Modular dog leash	**-4**	Least Favourable Option

Figure 3: PUGH Matrix Diagram (Metcalfe, PUCH Matrix Diagram, 2023)

On review, using both the feedback received from an external reviewer and results from the PUGH Matrix, we found the most suitable product, and therefore a final decision was made.

The Problem

The team aimed to overcome challenges in the home environment, and our best idea was to develop a smart walking stick. This idea addresses the concern of injuries from trips and falls, which is a significant worry for the NHS, carers, employers, and relatives. These accidents can occur for various reasons, including disability, injury, mobility issues, and old age.

Figure 4: A Demonstration of the Problem, (Warren Duce, 2017)

1 in 7 people in the UK workplace are carers and whilst juggling a complicated work life balance, there is a constant worry that a family member 65+ years old will injure themselves from a fall, this is evidenced through statistics showing 1 in 3 people over 65 will on average have 1 fall per year,

which can lead to a lack of confidence in their own mobility.

The team's aim is to produce a walking stick that can help the user's mobility and allow the carer to monitor the user in real time. This will allow the carer peace of mind and the user the confidence to live a more independent lifestyle.

Potential Concepts

Now that the idea had been confirmed, our team collectively generated concepts for how we were going to make a walking stick that would assist with this problem. The first thing we explored was our target market, along with existing products, to gain a strong idea of what features were desired (see Market Research). On completion, the team came up with some initial designs based on the research.

The first concept was a device that could fit onto any walking stick and enable some 'smart' features, see figure 5.

Positives:

- Compatible with any walking stick
- Its own USP
- Reduced size
- Increase convenience
- Cheaper

Negatives:

- Less features available
- Unbalanced walking stick
- Decreased aesthetics
- Easier to damage

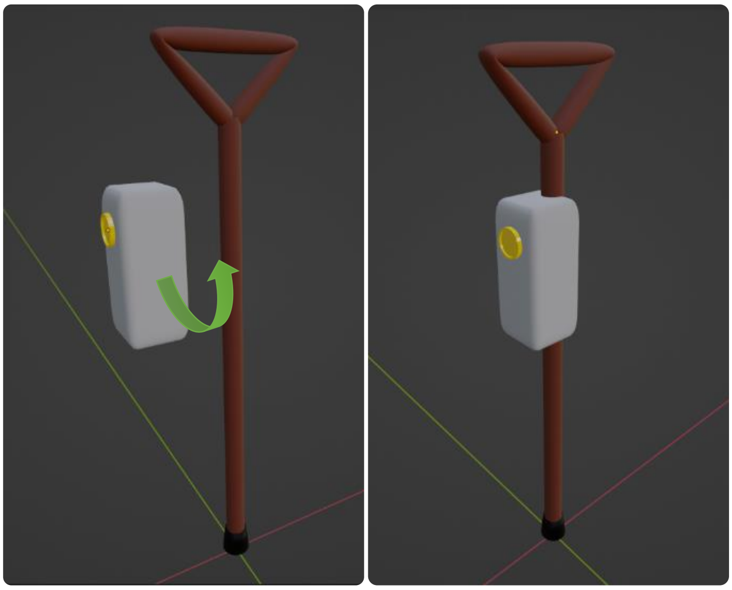


Figure 5: Modular Concept

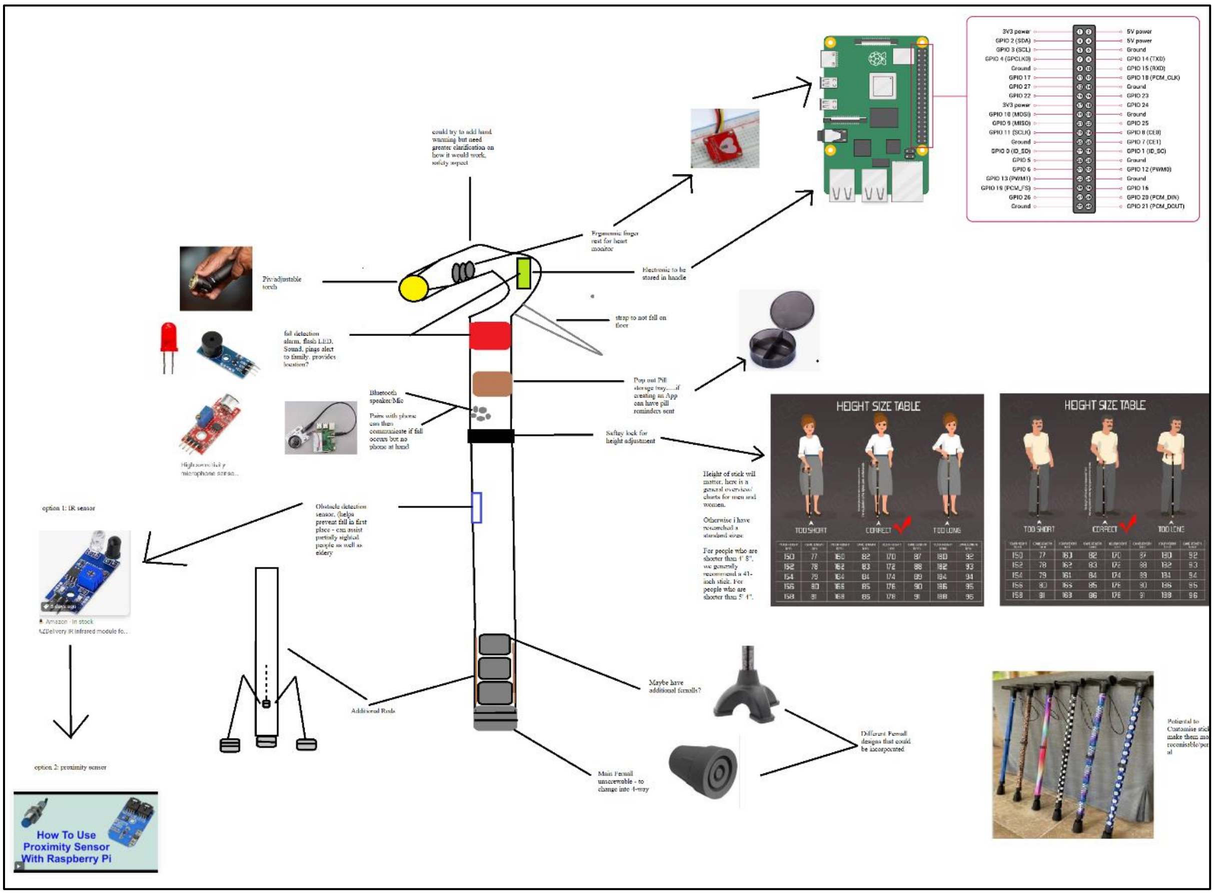


Figure 6: Expanded Concept

Figure 6 depicts an alternative concept for the walking stick, showing more of an overview of the system, designed specifically for more fragile individuals. Here are the features identified in this concept and our thoughts on their relevance to the final prototype.

Main Features:

- Fall detection
- Alert carers in emergency
- App control
- Heart rate monitoring
- Adjustable height
- Torch
- Buzzer/alarm for alerting and locating

Possible features:

- Heated handle
- Storage/pill box in stem
- Self-stand design
- Pop-out legs
- Grabber

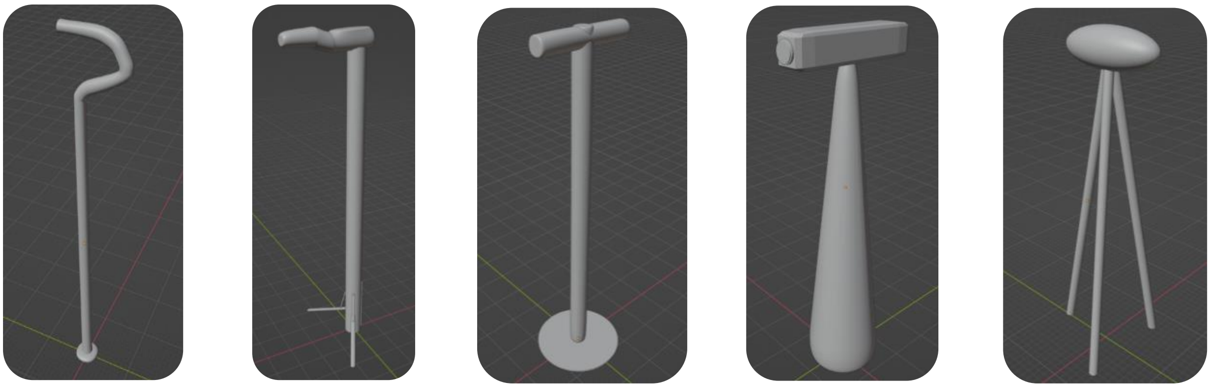


Figure 7: Creative Concepts

The images above show some concepts that took a different approach; instead of focusing on features, these concepts were focusing on the ergonomic design of the walking stick. As we progressed through the project, ergonomics played a vital role, being pivotal to both customer and system requirements.

Every design the team came up with contributed towards establishing our final concept. It was an enjoyable experience to watch our ideas grow and become be more tangible.

Final Concept

Step Smart Walking Stick

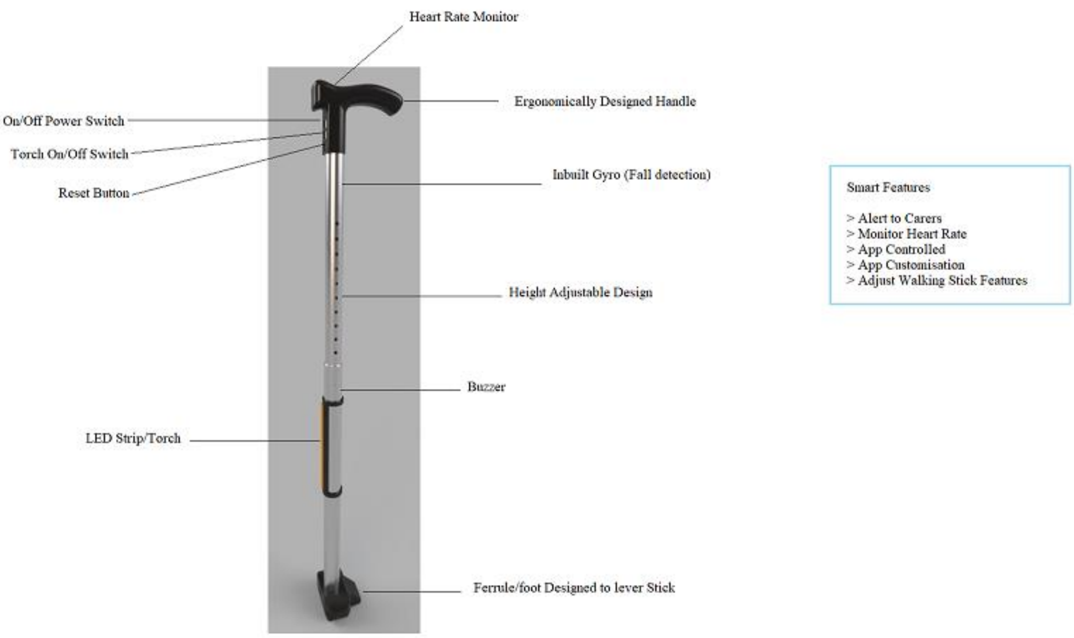


Figure 8: The Final Concept

After considering various concepts and conducting market research, we proceeded with a final concept. Although our team had several ideas to choose from, we agreed that focusing on addressing the core problem would be most beneficial. Other ideas will be incorporated into future iterations of the walking stick. You can refer to figure 8 for a visual representation of our final concept.

Our smart walking stick will be a great product for people with mobility challenges. Going back to our initial problem, we want to help those who are likely to suffer a fall. For this reason we ensured our walking stick would have fall detection. The features selected here are after careful consideration and backed by research. Fall detection will be achieved with the use of a Gyro and Arduino that will be built into the walking stick. Once a fall has been detected, the walking stick will use the built in LED Strip to start flashing and the buzzer to create sound. This will alert anyone in close proximity and get a timely response from those close by. Simultaneously, the walking stick will have inbuilt software that will send an alert to secondary user's (carers, family members, emergency services) phones, via the app.

What if the stick were to simply fall over instead of the primary user falling? Firstly, there is a time delay, to allow for the stick to be picked up before alerts, buzzer and lights are triggered – this is to minimise false alarms being sent to secondary users. The stick has three switches on the handle for, power, torch and resetting – in the event that the stick was to fall and not be picked up within the specified time frame, the user will be able to hit the reset button to stop the buzzers, lights and notification. If the stick were to fall, but not the user, the team has come up with a ferrule design unlike any others. It will allow the primary user to step on the specially designed foot/ferrule to be able to lever the walking stick back to a standing position without the need for bending.

Alongside monitoring falls, we also opted to include heart monitoring using a heart rate sensor. This is partially because the target audience for the walking stick will be those who are elderly and more prone to heart issues such as stroke, heart attack and AF (Atrial Fibrillation). The heart rate sensor will be located in the handle. Whilst the primary user has their finger on the sensor this information can be sent to the app for analysis. This feature is to track the user's heart rate and act as a warning in case a problem. Please note this feature is more of an indicator than a diagnosis, as it is not verified for professional medical use.

Customer market research indicated that ergonomics, stability, durability and height adjustability were huge variables that impacted customer satisfaction. Therefore, our final concept needed to consider what material the stem, ferrule and handle would be made of, as well as ensuring a comfortable and ergonomic design. In order to achieve the strength and durability it was decided that the stem would be made from aluminium tubing (tough but lightweight) and would feature an adjustable height system. The overall ergonomic design of the ferrule and handle were based on research (see Research) and trial and error with rapid prototyping (see Hardware Design). These factors were all important design decisions as it actively impacts the customer satisfaction, ease of use and end user health and safety.

The LED strip attached to the front of the stick was a well-loved feature based on market research. Naturally the LED strip will act like a torch and allow the primary user to make journeys at night, using the stick to illuminate their path. The LED strip will also indicate the battery, by temporally displaying the current battery level using different colours when powering on.

A secondary user's role within our stick is mostly centred on the "Smart" features that the stick provides and this is mainly accessible via the app. The app allows for the secondary user to monitor certain walking stick features, such as heart rate logs and allows them to receive notifications. Additionally, app can also be used to locate a walking stick by triggering a "lost mode" which in turn will flash the LEDs and sound the buzzer. The app is simple and easy to use in consideration for our users'.

Risk and Opportunity Understood

Early on in the project it was clear that we would need to weigh up the risk and opportunities. We therefore created a management plan to capture this information as show below:

Definition	Opportunity	Risk	Risk Likelihood	Risk Severity	Risk Mitigation	Post Mitigation Likelihood	Post Mitigation Severity
£250 material costs budget for project	Lower cost of production means higher profit margins.	Failure of task due to lack of funds	2	5	Conduct suffecient research to ensure getting best price to performance ratio that fits our budget.	1	4
Using Arduino Nano 33 IOT	Simple to use, small form factor, built in gyro and low power consumption	Only 1 MB of flash memory could reduce possible features.	2	4	Using proper coding practice to make sure code is efficient and uses as little memory as possible.	1	3
3D printed handle/electronics casing	Can have custom ergonomic design, allows for use of lattics structures to make interior lightweigh but also strong.	Prints could fail, increasing material cost of project.	3	3	Check design and print material are compatible, consult additive manufacturing expert.	1	2
Using pre-made adjustable stick shaft	Cheap, less time focusing how to construct shaft and more time to focus on electronic and software features.	Less customisability options for possible battery storage in the shaft.	4	2	Conduct analysis on pros and cons between making stick shaft and buying stick shaft to make informed decision.	1	2
Use of optical heartrate sensor	Cheap and simple to implement with arduino, lots of open source code to support it.	Optical sensor would require an opening and an infrared light, making circuit more exposed to surroundings and design less seamless.	4	3	Conduct further research into ECG heartrate sensors, decide on wether or not it can be implemented. Use gasket to seal opening, or use clear acrylic/plastic to prevent opening being needed.	2	2
Small package size and under 2.5kg (TBD)	Design looks more seamless and like a normal walking stick, and lightweight.	Might not have enough room for components, or enough weight allowance for all desired features.	3	4	Researching size and weight of components as well as the features included, to ensure all the desired features are added whilst adhering the size and weight limit.	2	3
Inclusion of 2 year warranty (TBD)	Demonstrates confidence in our product, therefore more saleability and profit.	Product materials may degrade, leading to large amount of customers making warrnty claims, decreasing profits.	3	4	Conduct analysis on materials used as well as the longevity of components used, ensuring proper fixings during manufacturing and design for the components.	1	2
Short development timeframe	Shorter development means less labour costs, therefore more profit.	May not have enough time to fabricate and include everything we want to in the timeframe.	2	3	Use of gantt charts to properly schedule tasks, sharing workload evenly and giving support to each other where needed.	1	2

Table 1: Risk and Opportunity Understood

Key	Likelihood	Severity
1	Rare	Minor
2	Unlikely	Moderate
3	Possible	Serious
4	Likely	Major
5	Highly likely	Catastrophic

Table 2: Risk and Opportunity Understood Key

Development

Design Review Process

For this challenge, our team has followed the same product lifecycle that is used at Leonardo and across industry, which is reflected in the design review process that the team follows. This process is divided into key design review stages, each with a set of criteria which have to be met before the project can move onto the next stage. If successful in meeting said criteria, the team is awarded a certificate to prove they can move on the next stage of the product's development. This development structure ensures the team makes steady progress and that no key elements of development are missed. Each stage is shown below in figure 9.

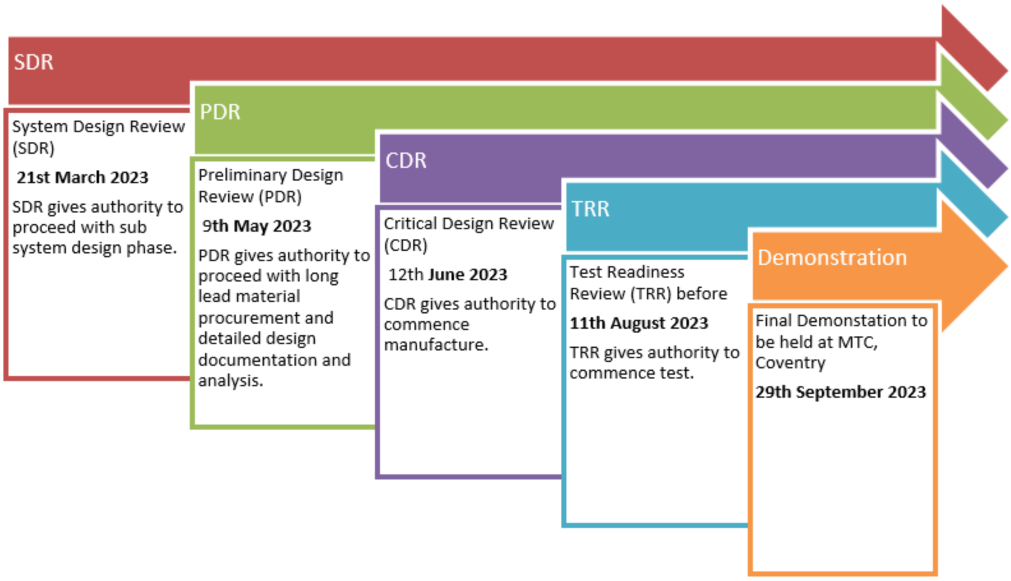


Figure 9: Design Review Process

For each review, the team carried out a presentation to our project mentor, Robert Armstrong, VP UK Mechanical Engineering, as well as other engineers. At this moment in time, we have passed the first three reviews, on our first attempt (The TRR, will be performed on 11th August). We received excellent feedback on these reviews and we tried to go above and beyond for each. The corresponding slideshows and certificates can be found referenced:

- (Team:It'sAllUnderControl, SDR Presentation, 2023)
- *Figure 63: SDR Certificate* - PASS
- (Team:It'sAllUnderControl, PDR Presentation, 2023)
- *Figure 64: PDR Certificate* – PASS
- (Team:It'sAllUnderControl, CDR Presentation, 2023)
- *Figure 65: CDR Certificate* – PASS

Any comments/recommendations left in the team's design certificate was added to the tasks list to be assigned between team members.

Project Planning

In order for any project to be successful, good and concise planning is required. Our team therefore prioritised planning at the early stages of development in order to stay organised and keep track of tasks.

First we implemented a few shared workspaces in the form of a team OneNote and a confluence page. The OneNote proved valuable, as the team was able to share ideas easily – with each member able to view, edit and review any information. It was great for raising concerns and highlighting any areas of importance. The confluence page was used as a storage space for the meeting minutes written at each team meeting. This allowed team members to catch up or refresh their memories on the important issues and topics.

Gantt Chat

We created a Resource Plan in the form of a Gantt chart. The Gantt chart allowed us to break the project down into logical steps and schedule tasks against a timescale. We implemented other contributing factors into the chart, such as member absences and workloads which was created in accordance with our milestones/deadlines both internally and externally. This gave a clear picture to the team, of the overall objectives of the project. The Gantt chart aided planning by:

1. Clear concise communication for the team.
2. Provided clarity on resources and workload to the project.
3. Provided effective tracking of project objectives.
4. Visual representation of tasking and dependencies.
5. Easy to update and manage, giving the team more control.
6. Compliments our agile style of working (discussed below).
7. Allows for effective time management.

The Gantt chart can be seen to be predominantly in line with our company's internal development stage/reviews (SDR, PDR & CDR) and can therefore be broken down to see individual tasks within the milestones. Figure 10 is a snapshot of the Gantt chart, but alternatively see the full Gantt chart referenced (Team:It'sAllUnderControl, Gantt Chart, 2023).

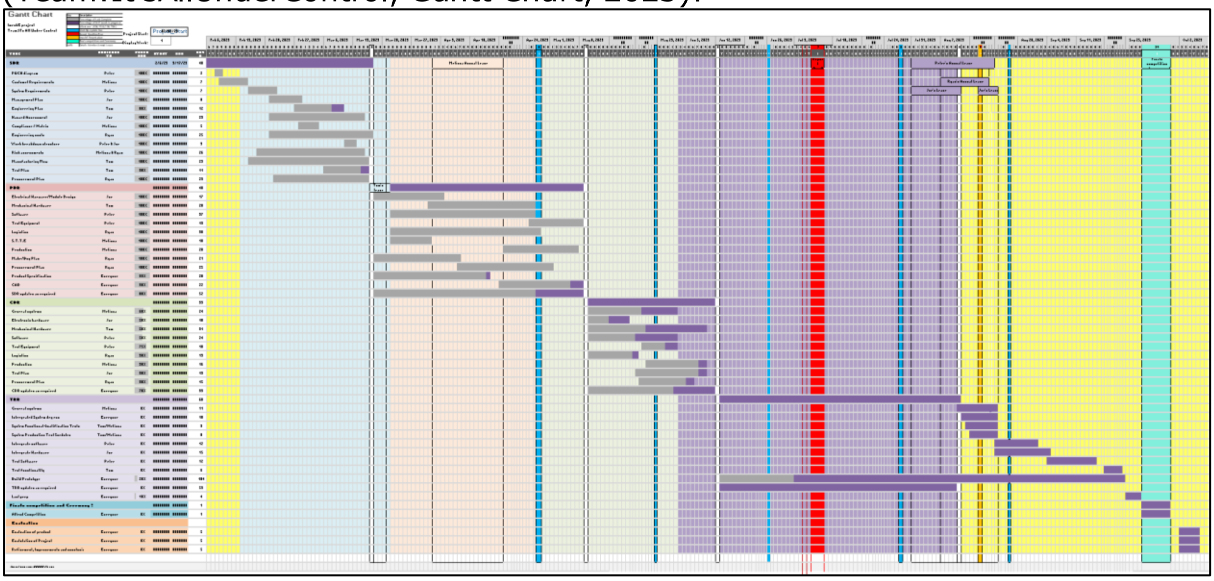


Figure 10: Gantt Chart

Work Breakdown Structure

For an efficient development process we formed this work breakdown structure. This allowed for a more structured approach, see figure 13 below.

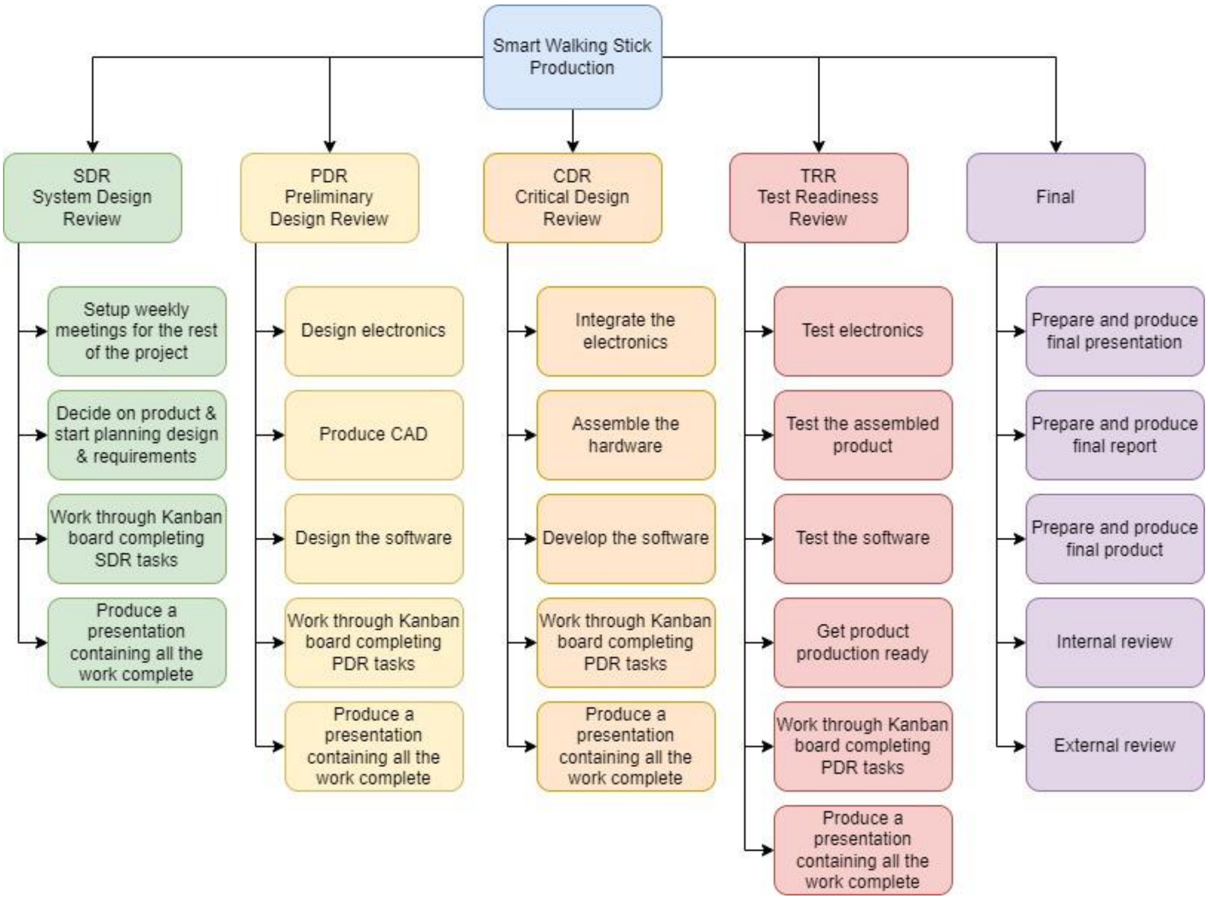


Figure 11: Work Breakdown Structure

Engineering Plan

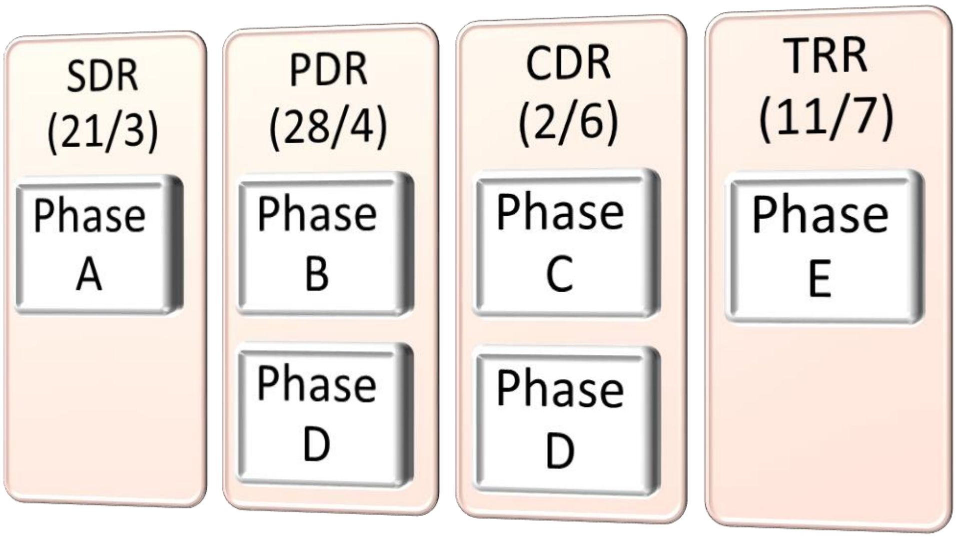


Figure 12: Engineering Plan Timeline

Phase	Description
Phase A - Engineering Requirements	We need to assess the customer's needs and identify the design challenges we must address. It is crucial to determine the requirements necessary to fulfil the customer's needs. Our primary constraints will be the size of the walking stick, the ergonomic design incorporating the electronics, and the budget, considering that smaller electronic components tend to be more expensive.
Phase B - Product Design	We need to choose a design using design tools like CAD, which involves creating initial sketches and then refining them into a model that serves as a set of build instructions. After determining the hardware to be used, we will select the appropriate software to enable its functionality.
Phase C – Software Development	Once we have finalized the software and identified the necessary hardware, we will proceed to code using Arduino to control the functions of the walking stick, such as implementing fall detection using a gyro. Additionally, we need to develop an app that will serve as a user interface for the stick, enabling users to control it and view the stick's statistics.
Phase D - Manufacturing	In order to showcase the functionality, we need to manufacture the product at least at a prototype level. Various manufacturing techniques, including 3D printing, drilling, milling, cutting, and bonding, will be employed. It is important to document the manufacturing process for future replication or design enhancements to simplify production.
Phase E – Product Testing and Refinements	A comprehensive test plan needs to be created to ensure consistent and rigorous testing of all products, establishing a standardized testing procedure. This may involve conducting a PAT test to ensure electrical safety during charging and testing the fall detection capabilities to verify functionality and prevent false alarms. Additionally, strength testing will be necessary to ensure the walking stick can support the user without breaking, and repeated drop and vibration tests will be performed to assess its durability against multiple impacts.

Table 3: Engineering Plan

Agile Methodology

To further support the team we decided to work with an agile methodology approach. This approach was selected due to the range of benefits it brought:

1. Allows for fluid communication and collaboration between team members.
2. Emphasises on flexibility and adaptability.
3. Better customer satisfaction.
4. Improved team synergy.
5. Continuous feedback and team engagement as project develops.
6. Allow team to change direction rapidly if necessary.
7. Promotes rapid prototyping.
8. Identifies errors quickly, reducing the risk of failure.

In order to enhance the agile methodology the team assigned Melissa as Scrum Master, who overlooked team activities, metrics and synergy. The team would also participate in:

- Team sprint planning sessions (to gauge sprint work scope).
- Weekly stand-ups (updates on progression of allocated tasks and appreciation of any tasks blocked or on hold).
- Retrospectives (to look back on our performance within the milestone and identify any improvements that could be made.

Additional toolsets were used to help with the agile methodology, in the form of a Kanban board and a retrospective board, see figures 13-15 below.

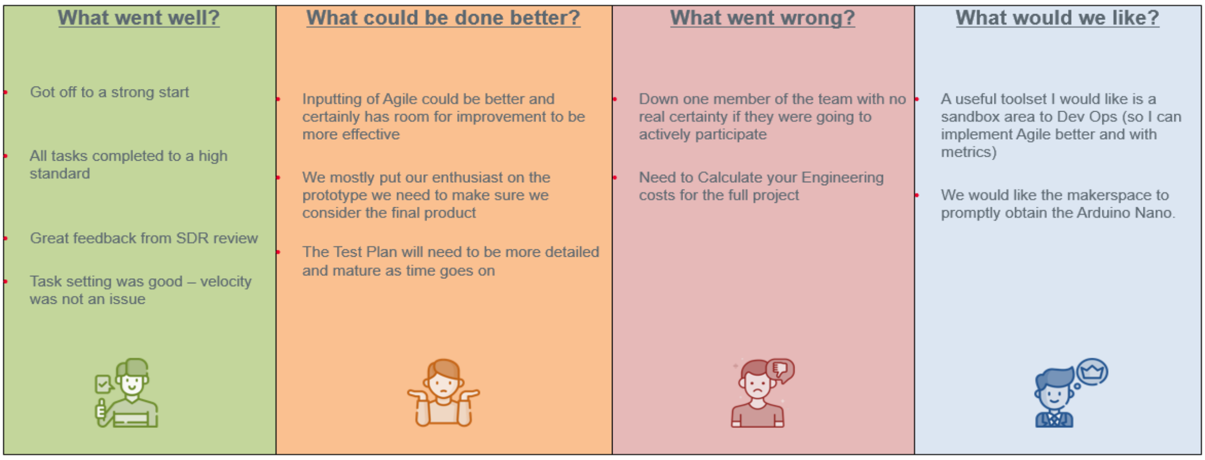


Figure 13: Example Retrospective Board

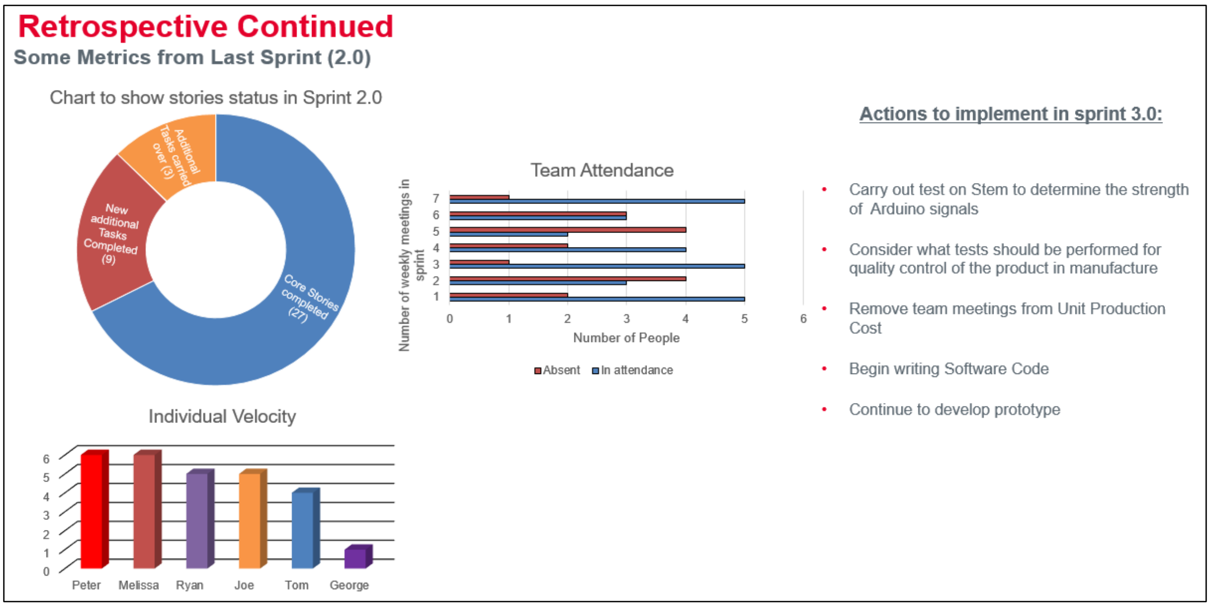


Figure 14: Team Metrics and Actions from Retrospective

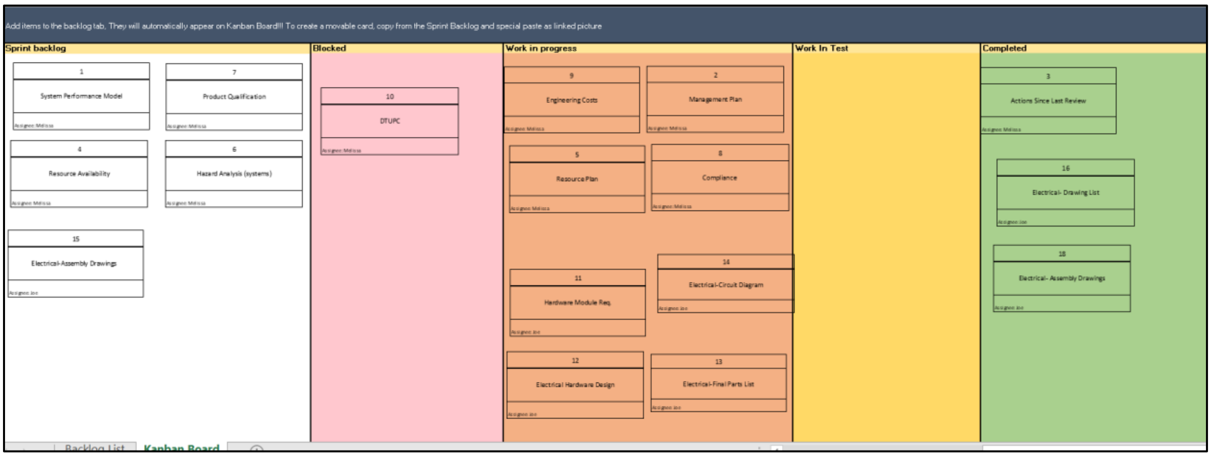


Figure 15: Kanban Board

SWOT Analysis

Strengths:

- Competitive pricing
- Unique product

Weaknesses:

- No current brand reputation/image
- Only £250 development budget
- Small market

Opportunities:

- Expand brand image through social media
- Improve brand image through recommendations from organisations such as the NHS
- Lack of similar products available in the UK
- Have external (BSI) and internal connections (SHE department)

Threats:

- Similar product in US branching out to UK market
- Failure of smart stick can lead to negative media coverage
- Customer could misinterpret heart rate monitor as entirely accurate rather than a general indicator

Regulations & Legislations

When creating any product, there are always regulations and legislation to adhere to, ensuring customer/employee safety is not compromised. Therefore, we conducted research to learn what our product was classed as and explore what requirements would align with our design.

We found that walking sticks can be considered a "medical device", "aid for daily living" and even "PPE", with the rules for each varying considerably. The final findings disclosed that our walking stick would be considered more of a medical device and therefore is subject to the UK Medical Devices Regulations 2002 Great Britain (EUROPEAN UNION, 2020). Medical device legislation contains Annex I showing requirements and Annex II stating information on conformity (COUNCIL OF THE EUROPEAN COMMUNITIES, 1993). It is essential to comply with these requirements to obtain certification (UKCA marking), in order to sell such a product on the market. Failure to comply in accordance to this regulation leads to problems with the trading standards office.

Researching uncovered a list of problems often encountered. This helped us understand where issues can occur in products similar to ours, see figure 16 below.

6.1 What can go wrong

Problems with an assistive technology device may include:

- inadequate repair or maintenance instructions from the manufacturer
- poor or lack of training in how to use/repair/maintain the device
- inappropriate local modifications/adjustments
- inadequate maintenance process
- inadequate or inappropriate repairs/replacement parts
- problems from storage/use conditions
- inadequate end-of-life/scrapping information from the manufacturer or provider
- incompatibility or the lack of compatibility information with other devices
- problems with the device itself:
  - failure of the device, e.g. cracks, leaks, detachments
  - design
  - production
  - packaging
- device documentation (e.g. instructions for use, technical/operation manual etc.):
  - not complete
  - confusing
  - not with the device
- medical devices that are not appropriately conformity marked being supplied to the UK
- aids for daily living that are marked as medical devices in the UK

Figure 16: Common Problems Research

As a team, we also want to champion health and safety within our engineering environment. Understanding health and safety regulations and legislations that effect the team and those around our working areas is paramount. In order to ensure safety here are some regulations and legislation we will work in accordance with:

- The Management of Health and Safety at Work Regulations 1999
- Workplace Health and Safety and Welfare Regulations 1992
- Personal Protective Equipment at Work Regulations 2022
- Manual Handling Operations Regulations 1992
- Provision and Use of Work Equipment Regulations (PUWER) 1998
- Display Screen Equipment Regulations 1992
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
- Control of Hazardous Substances Hazardous to health COSHH 2002
- Electricity at Work regulations 1989

BSI Standards

We contacted the Technical & Compliance Manager at BSI to find out more about the standards our walking stick would have to comply with and tests that it would undergo if we were to get our product BSI certified. Our contact at BSI reached out to their electrical and medical labs in Loughborough to find out more on our behalf. As a result, we have gained valuable knowledge on which British Standards we have to comply with and what tests we would have to pass.

Aspect of the Stick	Standard(s)	Tests performed
The stick as a whole (a 'walking aid')	BS EN 1985:1999 EN 1441, EN ISO 9999:1998 prEN 12182:1997	Mechanical testing with a 250N force and 825,000 cycles and a temperature test of -25°C.
Material used	EN 1441 prEN 12182:1997 cl 5.2	Subjecting the stick to repeated usage of load-bearing conditions. Test maximum weight it can support.
Ergonomics	prEN 12182:1997 cl 22	Stability testing: ensuring it remains secure during regular use and involves subjecting it to various forces and movements to simulate real-life conditions. Also, load-bearing capacity & durability testing here too.
Construction & moving parts	prEN 12182:1997 cl 17 prEN 12182:1997 cl 11 & 12	Testing the stick on different materials or uneven terrain as well as tilting or tipping forces. Plus, durability tests with impacts or stress conditions.
Marking / Instructions	prEN 12182:1997 cl 23	Labelling: visible labels that provide important information like warnings and part number.
"smart" part of it considering it to be Information Technology, considering the electronics	BS EN IEC 62368-1:2020+A11:2020	Testing insulation resistance, leakage currents, adequate shock protection. Thermal tests. Energy source tests: check batteries, short circuits, overheating.
Close proximity to users, (i.e. Bluetooth/Wi-Fi etc, Radio Equipment Directive)	EMC 61000	Testing electromagnetic radiation emitted. Testing the sticks ability to withstand radiation from external sources. Electrostatic discharge tests. Surge immunity tests. RF immunity tests.

Table 4: BSI Standards

Please note that the tests listed in table 4 might vary and are only an indication based on information provided by our contact at BSI and information found within the associated standards.

Research

Please see the attached ergonomics research. An incredible amount of detail has been covered, considering every aspect (Hobbs, Ergonomics Research, 2023).

Failure Models and Effects Analysis

FMEA (failure mode and effects analysis) has been carried out in conjunction with the parts list document and seeks to look at the components on the walking stick and foresee any possible failures, see Table 20: Failure Models and Effects Analysis.

Hazard Assessment

We completed a hazard assessment in order to identify potential hazards to the customer, as well as control measures we can implement in order to mitigate the likelihood and severity of the hazard. See hazard assessment in figure 17 below.

	Before control			After control	
HAZARD TO CUSTOMER	LIKELIHOOD	SEVERITY	CONTROL MEASURES	LIKELIHOOD2	SEVERITY2
Electric shock from loose cabling/Electrostatic build up	2	3	ESD proof casing sourrounding electrical circuit and components, during production ensure proper soldering and secure connections.	1	3
Sharp edges hurting customer	2	3	Sanding down burrs, make design ergonomic and include no sharp edges, ensure tolerancing is correct so that radius of rounds are correct.	1	3
Battery rupture/explosion	2	5	Include in manual instruction to turn off walking stick when not in use, smart charging feature to stop charging when battery is full, sleep function where no movement for set time goes into sleep mode.	1	5
Board/alarm failure, leading to no alarm if user falls over	3	5	Include disclaimer in manual advising carer not to rely purely on stick alarm.	1	5
Stick snapping	2	4	Stick must be stay intact under maximum load of 250N (Refer to BSI standard)	1	4
Stick ferrule slipping	3	4	Include TPU ferrule to increase friction	2	4
Stick falling on someone	3	3	Stick handle must not contain more than 50% of the weight of the entire stick so reduce falling force.	3	2
Lack of understanding of how to use the stick	4	2	Include in depth instruction manual, as well as keeping app and stick design as intuitive and simple as possible.	2	1

No.	Likelihood Key	Severity Key
1	Rare	Minor
2	Unlikely	Moderate
3	Possible	Serious
4	Likely	Major
5	Highy Likely	Catastrophic

Figure 17: Hazard Assessment

Design Specification

Requirements

To ensure the successful realisation of our vision, we have established a set of requirements that guide the development of the Step Smart walking stick. These requirements encompass both the needs of our customers and the technical specifications that enable us to create a product of exceptional quality. By aligning these requirements, we aim to meet the expectations of our target market and deliver a solution that excels in functionality and usability.

Customer Requirements

At the core of our design process lies the commitment to meet the expectations of our valued customers. We recognise the significance of creating a product that not only performs efficiently but also provides an exceptional user experience. To achieve this, our customer requirements (Hobbs, Customer Requirements, 2023) encompass a range of essential factors. We have carefully considered the ergonomics of the handle to provide comfortable usage. Height adjustability ensures a personalised fit for each user. The buzzer is designed to emit a loud and distinct alert for effective communication. The light source is bright enough to enhance visibility in various environments. Additionally, we have ensured that the walking stick is lightweight for effortless manoeuvrability. By incorporating these features, along with accurate fall detection, ambient lighting, and customisable settings, we aim to fulfil the diverse needs and preferences of our valued customers.

Figure 18 below shows our CTQ tree diagram we designed to clarify our customer needs and understand fully, the specific measureable performance requirements needed to fulfil our customer requirements.

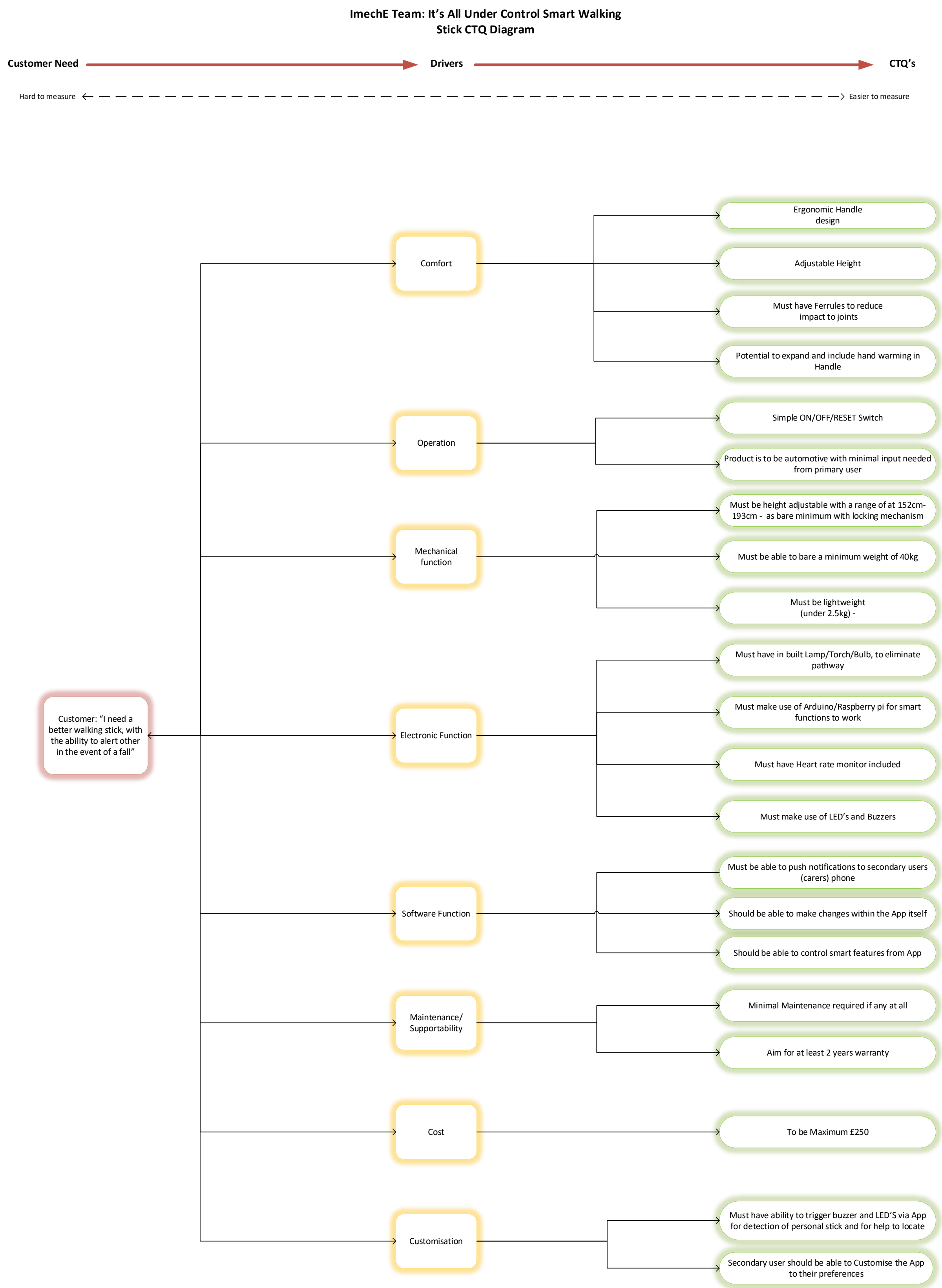


Figure 18: CTQ Tree Diagram

System Requirements

To transform the customer requirements into actionable design elements, we have established a set of system requirements that serve as the foundation of the Step Smart walking stick. These requirements focus on the technical aspects necessary for optimal functionality and user safety. Our system requirements prioritise precise fall detection capabilities, allowing for the timely notification of caregivers or services. We also emphasise the integration of a reliable heart rate monitoring system to provide users with valuable health insights. Durability is of utmost importance, and our system requirements ensure that the walking stick withstands the rigors of everyday use. Furthermore, we adhere to stringent safety standards, guaranteeing compliance with relevant regulations. These system requirements form the bedrock of our design, empowering us to create a trustworthy and user-friendly walking stick.

See figure 19 below. Notice we included tests alongside each requirement to ensure we had a way of verifying our final design.

	Refernce #	Requirement	Explanation / Justification	Implementation	Test	Test Pass Condition	Category	Completed
Critical	1	Product must detect falls accurately	Main feature	Use accelerometer and gyro unit compatible with microprocessor	Drop stick 100 times	It detects at least 99 falls	Software, Electrical	✖ 0
	2	Product must measure heart rate accurately	For heart attack monitoring. Cannot give false alarms	Use heart rate sensor compatable with microprocessor, and software to process data	Take 10 different heart rate readings	Compare results with tested smart watch. Passes if resaults are within +/- 10%	Software, Electrical	✖ 0
	3	Product must not break under average humnan weight (80kg)	Being a walking stuck, its main function is supporting peoples weight	Use sturdy materials and joints	Compress the stick with 80kg weight	Bust not break or bend in any way	Mechanical	✖ 0
	4	Product must cost less than £250					System	✖ 0
	5	Product must be controlled via app	No other GUI, so must be an app. Also enables communication to external carers	Software and network connection	Connect the app to the stick	App must connect successfully	Software	✖ 0
	6	Product must commuicate with external devices	This feature enables the stick to contact carers in potential emergency	Software and network connection	Send data between devices	Data is reveived, un-corrupted and usable	Software	✖ 0
	7	Product must have light(s)	For aiding with walking in dark and easier locating	LED(s)			Software, Electrical	✖ 0
	8	Product must make noise (15dB)	For locating easier and alerting nearby people for assisstance	Use of a buzzer	Use microphone to measure sound volume	Must be >15dB	Software, Electrical	✖ 0
	9	Must have a unique serial number	This will be used for signing into the app	Sticker	Check serial number with database	Must be unique	Manufacturin	✖ 0
	10	Must be strong enough to resist repetely falling while in use	Cannot break when detecting falls	Use of strong matertials and joints	Drop 100 times	Must not break	Mechanical	✖ 0
Aspirational	11	Should be light (less than 1kg)		Use of light or less materials	Weight the final product	Must be less than 1kg	Mechanical	✖ 0
	12	Product should have ergenomic handle	Better user experience	Could 3D scan hand, or use existing model, or trial and error	Perform survey	75% of people must rate the comfort greater than 6/10	Mechanical	✖ 0
	13	Product should be height adjustable	E.g. For pills. Either in handle/stem of as hooks/clips for post for example	Use linear actuator or a manual pin-and-hole system	Change the height of the stick and measure	Measurement should be different, and stick should still pass all tests	Mechanical	✖ 0
	14	Product could have pop-out legs	For help with getting up	Use of a linear actuator or springs	Pop legs out 100 times	Legs should not jam or break for at least 99 attempts	Mechanical	✖ 0
	15	Product could have grabber	For picking low objcets up	Simple wire from grip to foot to control grabber jaw, or done elctronically with solenoid	Grab a variety of objects, up to 8kg weight	Grabber should hold item securely	Mechanical	✖ 0
	16	Product could have Storage		Leave space in handle or steam			Mechanical	✖ 0
	17	Could have hand warmer (30°C)		Resitive elements	Use digital thermometer to accuratley read tempertaure	Must read greater than 30°C	Mechanical, Electrical	✖ 0
	18	Could have different and customisable aesthetic	Better user experience	Artwork			Mechanical	✖ 0
	19	Could automatically contrtol lights	Could sense dark environment or fall to trigger lights	Use software to control based in time, or LDR to sense dark environment.	Put stick in dark environment	Lights must turn on with in 10 seconds	Software, Electrical	
	20	Could be modular	Better user experience				Mechanical	✖ 0
Extra	21	Could have (Bluetooth) speaker and microphone	Used for communicating directly from the stick with external carers				Software, Electrical	✖ 0
	22	Could have obstacle detection	Help prevent falls and better for people with worse vision	Use infrared sensor to detect distance to near by objects			Software, Electrical	✖ 0
	23	Could have voice assisstent	Help with simple tasks and prevent unnecessary walking, e.g. "Hey stick, turn the	Software implementation, along side speaker and microphone.			Software	✖ 0

Key

Completed	Problem	Not completed
✔ 2	! 1	✖ 0

Figure 19: System Requirements (Metcalfe, System Requirements, 2023)

By aligning our customer requirements with our system requirements, we strive to exceed expectations and deliver a smart walking stick that offers a safe, intuitive, and enhanced user experience.

Hardware Requirements

Below are the hardware requirements for all the electronic components of our design. This is where we set our requirements for each component, which they must meet in order for our product to meet specification.

Component	Component Purpose	Component Requirement(s)	How this will be achieved
Power Bank	Delivering power to all components	Power bank MUST supply 5V to Arduino Nano for reasonable usage time. Power bank MUST supply 5V to LED's.	5V from power bank will be connected to rail that supplies both LED's and Arduino Nano, circuit will be designed to have minimum idle current flow to reduce energy waste.
Arduino Nano	Delivering power to other components	Arduino Nano MUST be able to deliver power to the buzzer and heart rate sensor.	Arduino has multiple digital pins and a 3V3 pin for power.
	Running software for stick	Arduino Nano MUST be able to execute all stick functions and not thermal throttle.	Software will be designed to work with Arduino, and be written to run efficiently.
Buzzer	Alarm in event of fall	Buzzer MUST create easily audible sound for nearby people to hear in the event of a fall.	Choosing the highest dB for a 3V buzzer.
RGB LED Strip	Turn on when light switch is pressed.	LED's MUST work as a functional torch when light switch is pressed.	Ensuring LED's get enough power from power bank and NOT being supplied by Arduino pin.
Heartrate Sensor	Read user heart rate	MUST read heart rate through finger accurately.	Ensuring code designed to read heartrate waveforms works, cut out allowing sensor to get proper reading.
Power Switch	Power on/off	MUST disconnect/reconnect components from power bank.	Connecting power switch in series between components and power bank.
Reset Button	Reset alarm in event of fall	MUST turn off alarm when pressed in the event of a fall.	Reset button gives logical input to GPIO pin which is used in code to reset the alarm.
Light Button	Activates LEDs	MUST activate LED's when pressed.	Using both a button as logical input and an NPN transistor connected to a logical output from Arduino so it is possible to also flash LEDs in the event of fall and be used as a torch on button press.

Table 5: Hardware Requirements

Software Requirements

Below are the software requirements for both the Arduino and the app. Here we set out clear objectives that the software must meet to ensure a fully functioning product. These sit in parallel with the customer requirements to make certain the product meets the needs of the user. In Table 10: Software Test Plan, tests associated with each requirement are discussed.

Arduino requirements		
Category	**Ref. No.**	**Requirement**
Must	1a	Detect falls accurately using a gyro
	2a	Measure heart rate accurately
	3a	Communicate to external devices (e.g. carer)
	4a	Accept input from physical buttons to control lights and IoT communication
	5a	Run on an Arduino
	6a	Alert external device (carer) when it detects a fall
Should	7a	Run on start-up
	8a	Connect to the Wi-Fi network
Could	9a	Turn torch on automatically at specific time, possibly learnt from users behaviour
	10a	Alert user when running low on battery
	11a	Load customised buzzing patterns, inputted by user, to be played in an emergency or when lost
	12a	Change colour of light when in different states/modes
	13a	Measure step count based on stick movements

Table 6: Arduino Software Requirements

App requirements		
Category	**Ref. No.**	**Requirement**
Must	1b	Run on iPhone
	2b	Connect to walking stick Arduino via cloud based database
	3b	Allow user to sign in using unique code
	4b	Display status of walking stick
	5b	Display statistics from walking stick; such as heart rates, falls, etc..
	6b	Display notification for falls
Should	7b	Have a simple and clear user interface to make it easier for impaired vision
	8b	Only communicate/control one walking stick - using unique code
	9b	Allow user to activate 'lost mode' where app communicates with stick and activates light & buzzer
Could	10b	Have customisable themes; light, dark, colourful, colour blind, etc…
	11b	Be compatible for Androids too
	12b	Have haptic feedback
	13b	Have sound effects

Table 7: App Software Requirements

Hardware Design

To finalise the design of the walking stick’s foot and handle we went through a process of rapid prototyping. This involved designing and modelling an idea, 3D printing the part and then testing it thoroughly. This process was repeated using the lessons learned from previous iterations.

Walking Stick Foot

As part of our initial brainstorming session, we had come up with a unique design for the walking stick foot that, in theory, would allow the user to right the stick without straining to pick it up. As we were unsure if this design would work, we began by making prototypes before going ahead with the idea.

Our first design did work, but there were some obvious improvements to be made. For example, we found it was difficult to lever the stick upright due to the steep angle of the foot pedal we had initially designed. So we iterated, learning from each design. Figure 20 below shows this process and how we ended up at our final design (from left to right).

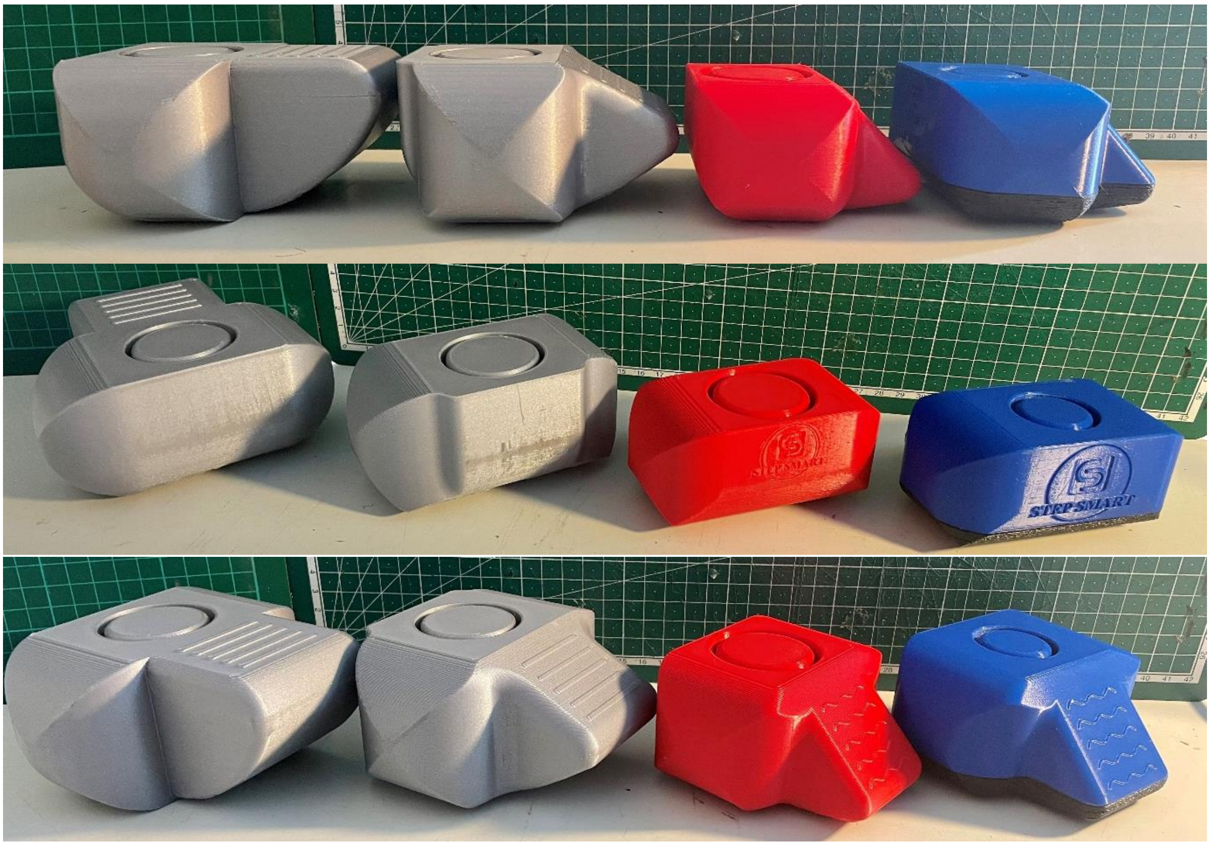


Figure 20: Walking Stick Foot Prototypes

The final result has a more ergonomic foot pedal angle, branding, a smaller form factor, better foot grip and makes use of multiple materials for more friction with the ground to mitigate the risk of slipping. Once we were happy with the design we were able to finalise it and generate the required part drawings for the design specification.

Walking Stick Handle

The ergonomics of the handle are an incredibly important factor to get right, so we used a similar process to finalise its design.

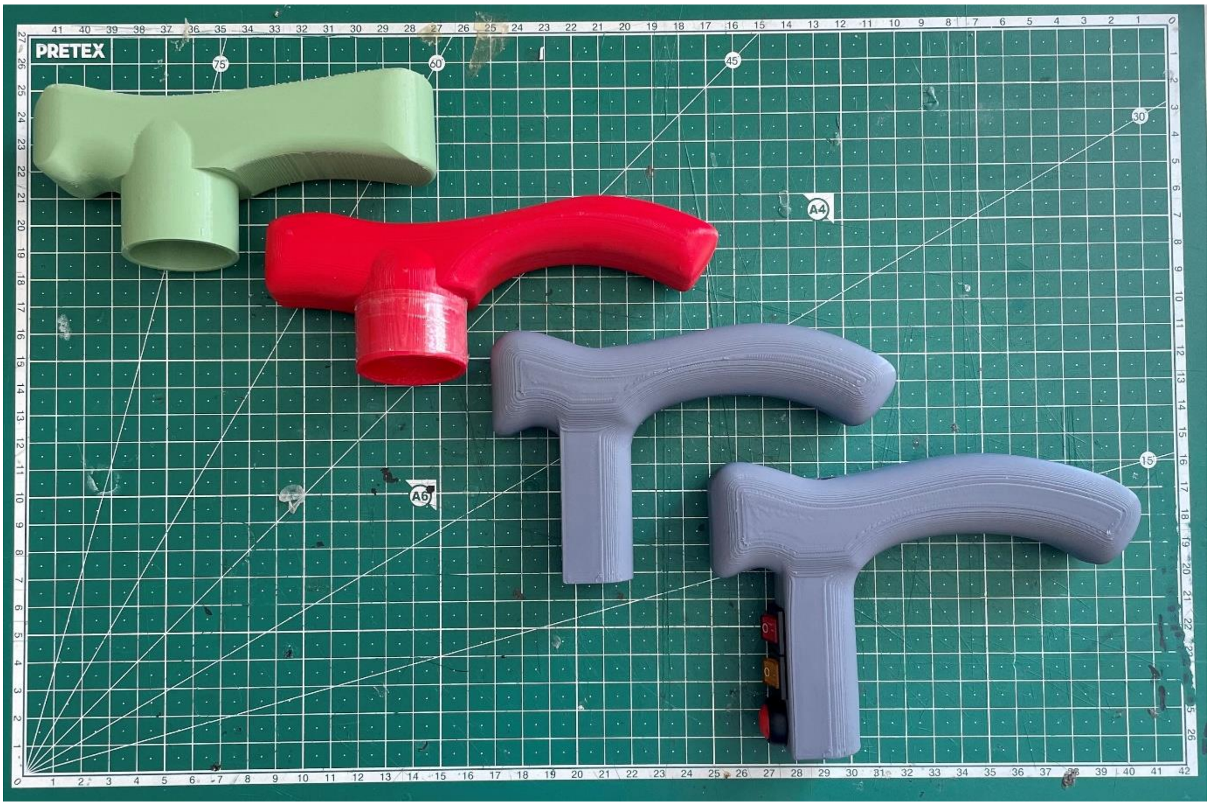


Figure 21: Walking Stick Handle Prototypes

Figure 21 shows our journey to the handle's final design. Notice the different size and shapes of the handle as time progressed. We made subtle changes each time based on our opinions and external reviewers. As the handle is very much opinion based we had to take an average to satisfy the largest majority of people, but for the final product we may offer a selection to choose from at purchasing, discussed more in market research.

Some important lessons were learnt during this process. For example, on our first design, we 3D printed it as one piece, which lead to the use of support material. This ended up being uncomfortable after printing due to the rough surface that was left after removing the support (even after sanding). So from that model onwards, we printed them in 2 halves to avoid the use of support. An example of this is shown in figure 22, where you will also see the high percentage of infill we used to strengthen the handle. This is necessary due to the levering effect a user has when applying their load on the 3D printed part.

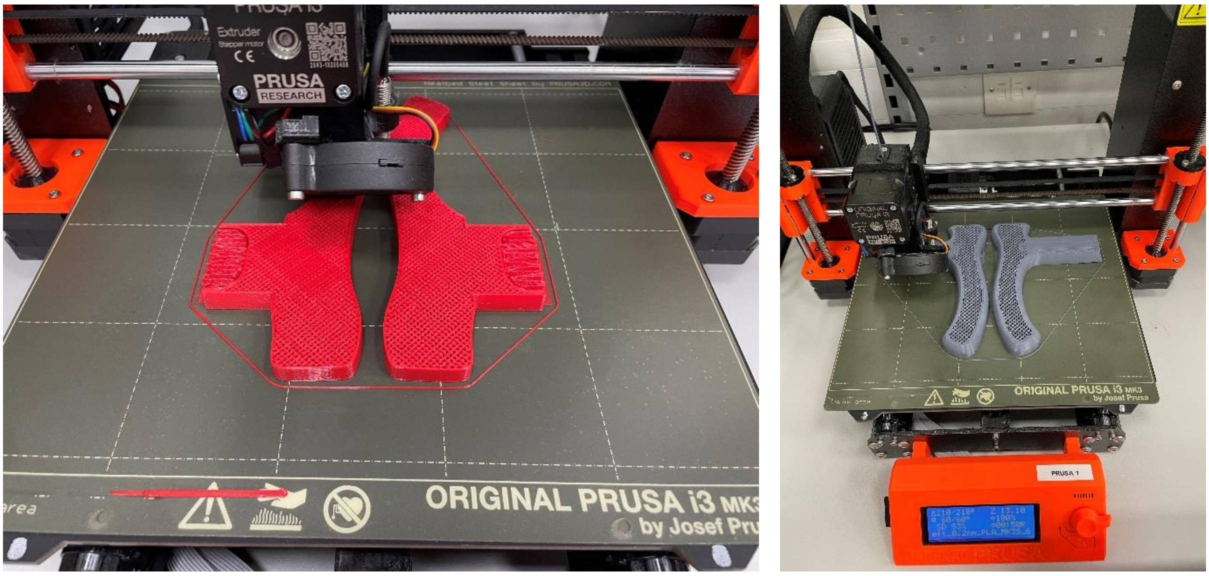


Figure 22: Handle Prototypes Being Printed

Figure 23 shows our final prototype and the design we plan to move forward with. We have accounted for the position of the necessary switches and heart rate sensor (although the sensor had not arrived at this point).

Figure 23: Final Handle Prototype

There are three buttons; the top switch is for the whole walking stick's power, the second switch is for the light/torch and the red button is to be pressed in an emergency, or to reset the stick after it has fallen, to disable the alarm.

Part Drawings

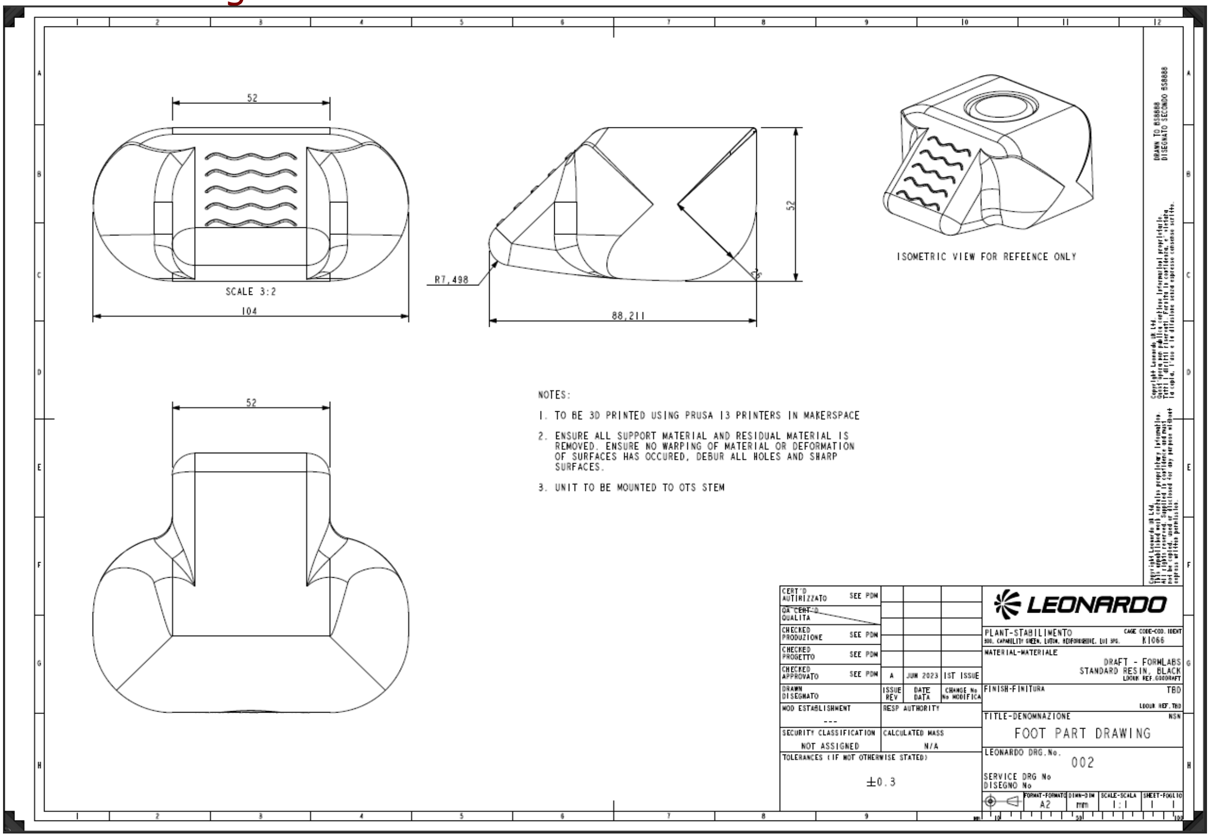


Figure 24: Walking Stick Foot Part Drawing

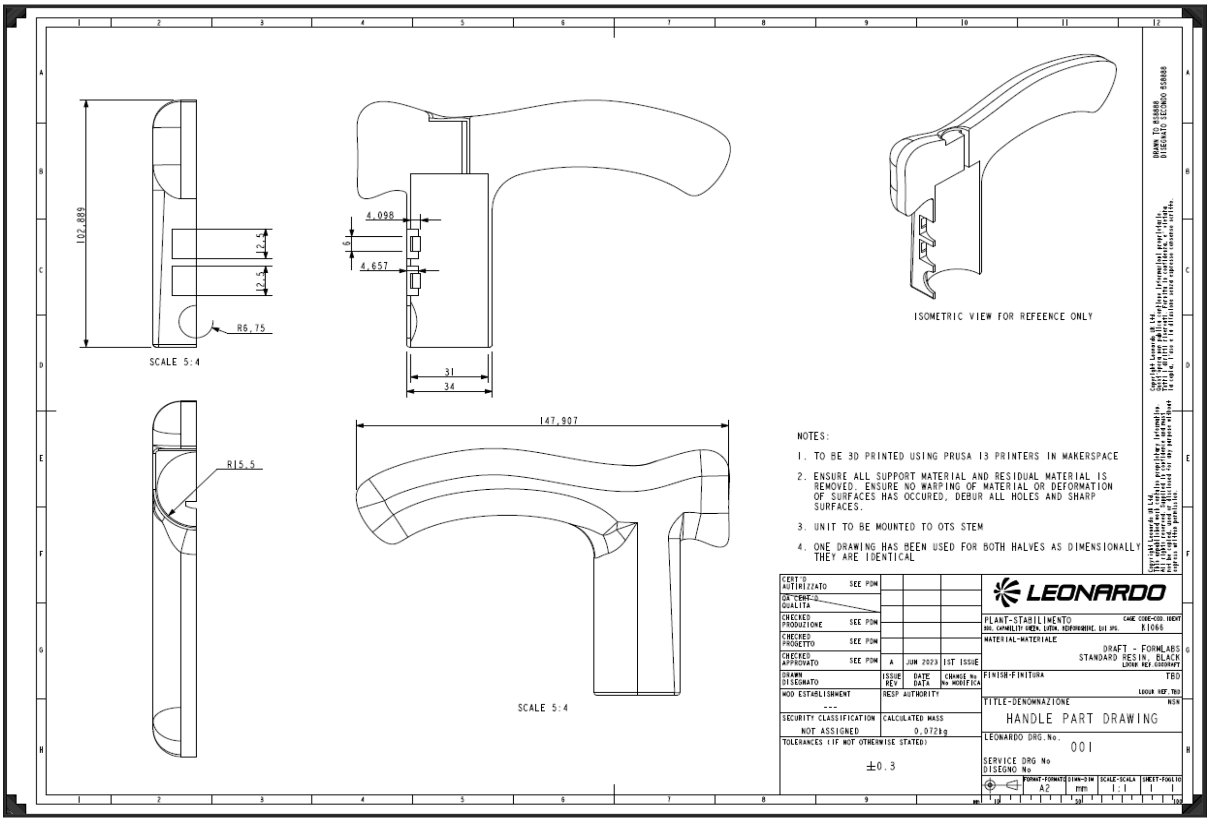


Figure 25: Walking Stick Handle Part Drawing

Part Renders

Generating renders of our parts is a great way to visulise them before fabrication. We are able to picture how they will look and assemble, allowing us to search for posssible errors before time and material is wasted.

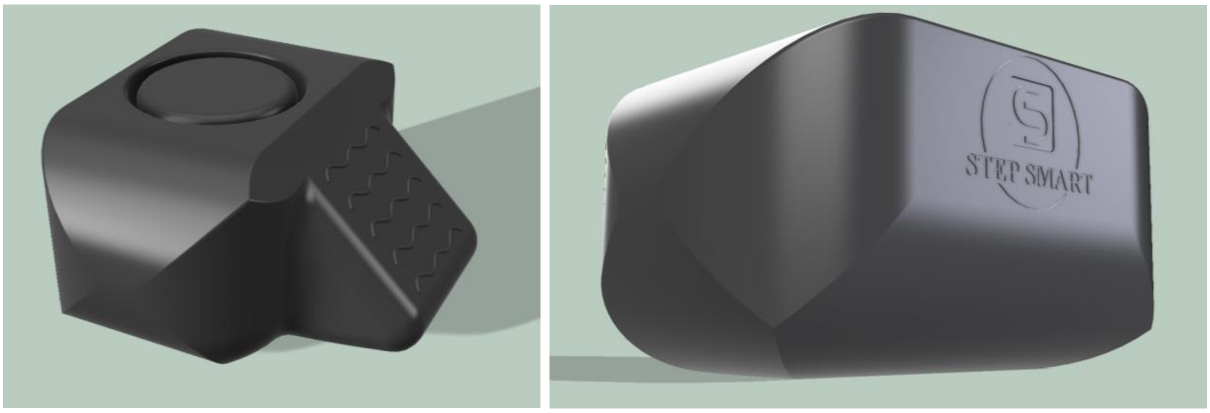


Figure 26: Walking Stick Foot Renders

Figure 27: Walking Stick Handle Render

Figure 28: Whole Assembly Render

Assembly Drawings

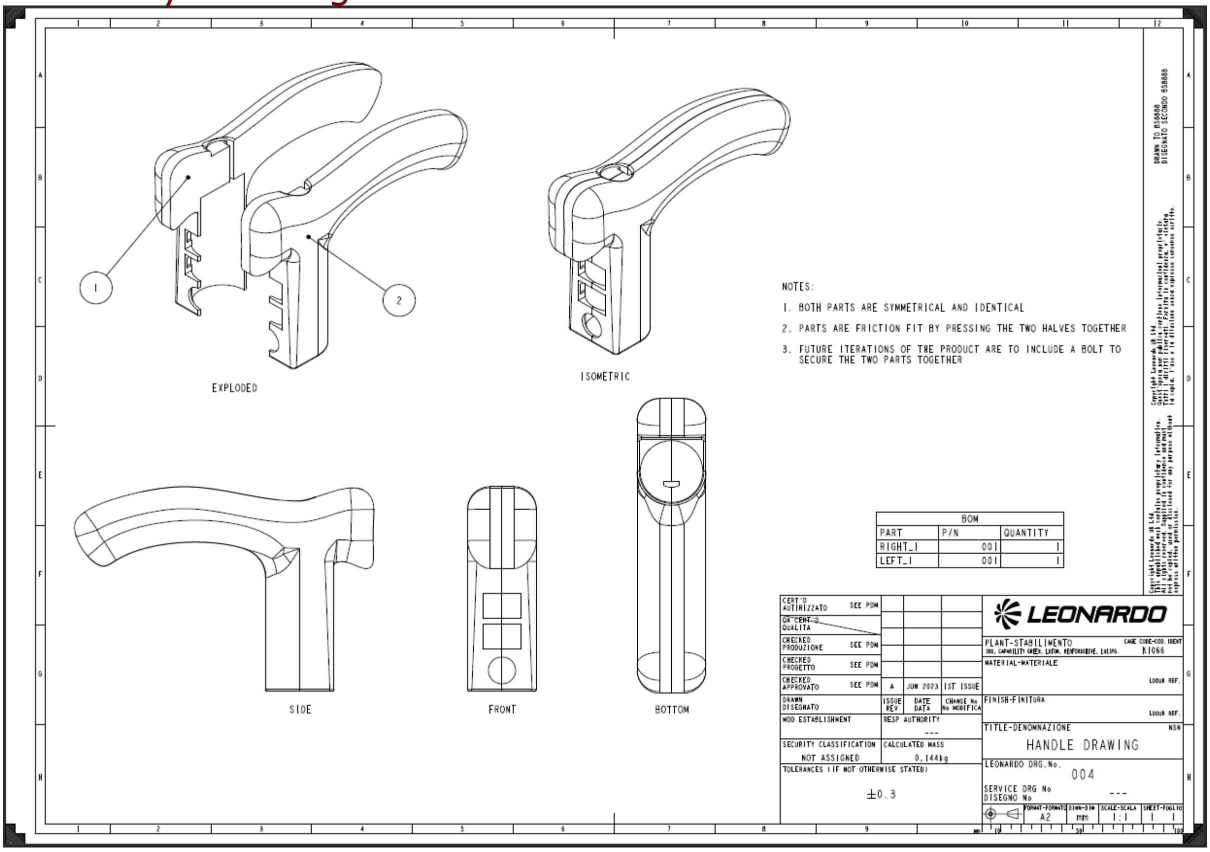


Figure 29: Handle Assembly Drawing

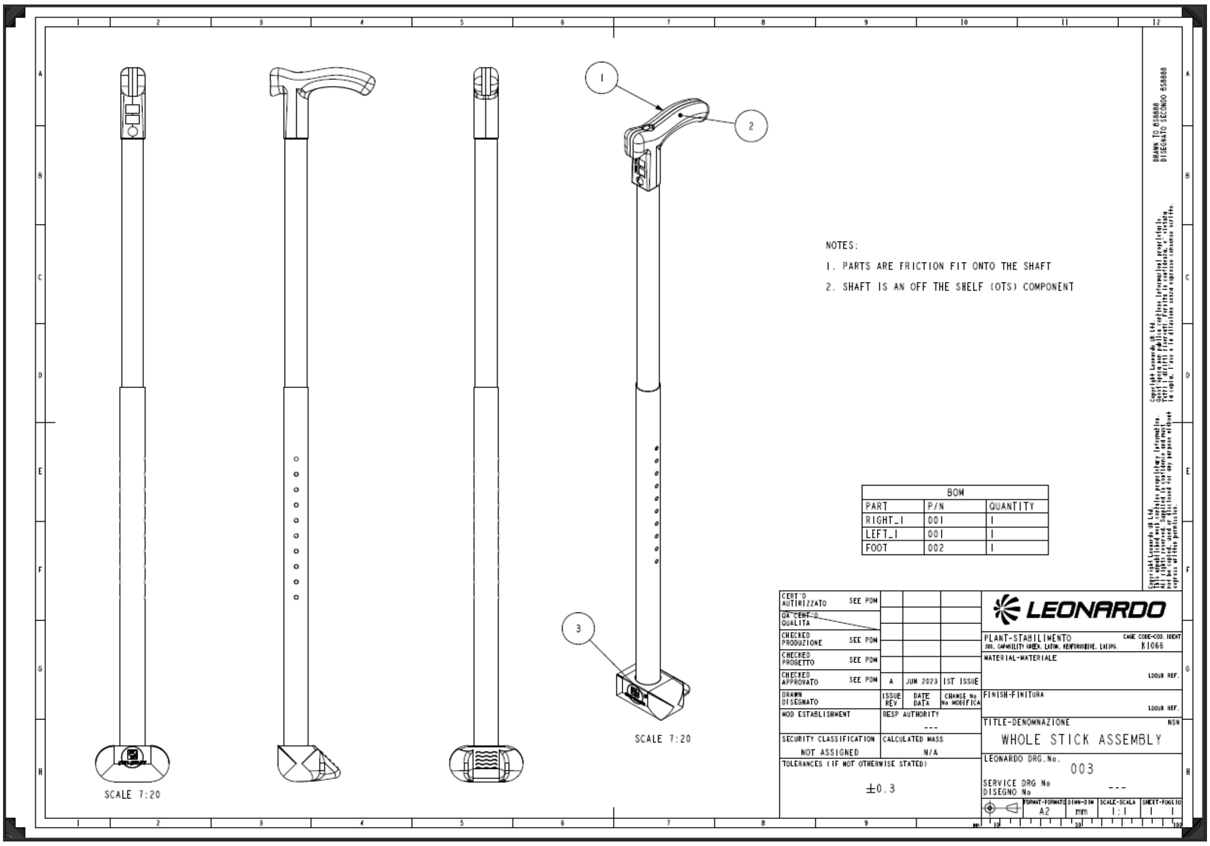


Figure 30: Whole Assembly Drawing

Simulations

To test for possible failure points, we simulated loads on our part models. Figure 31 shows our handle under 1000N of force (~100kg), which is over double our customer requirement.

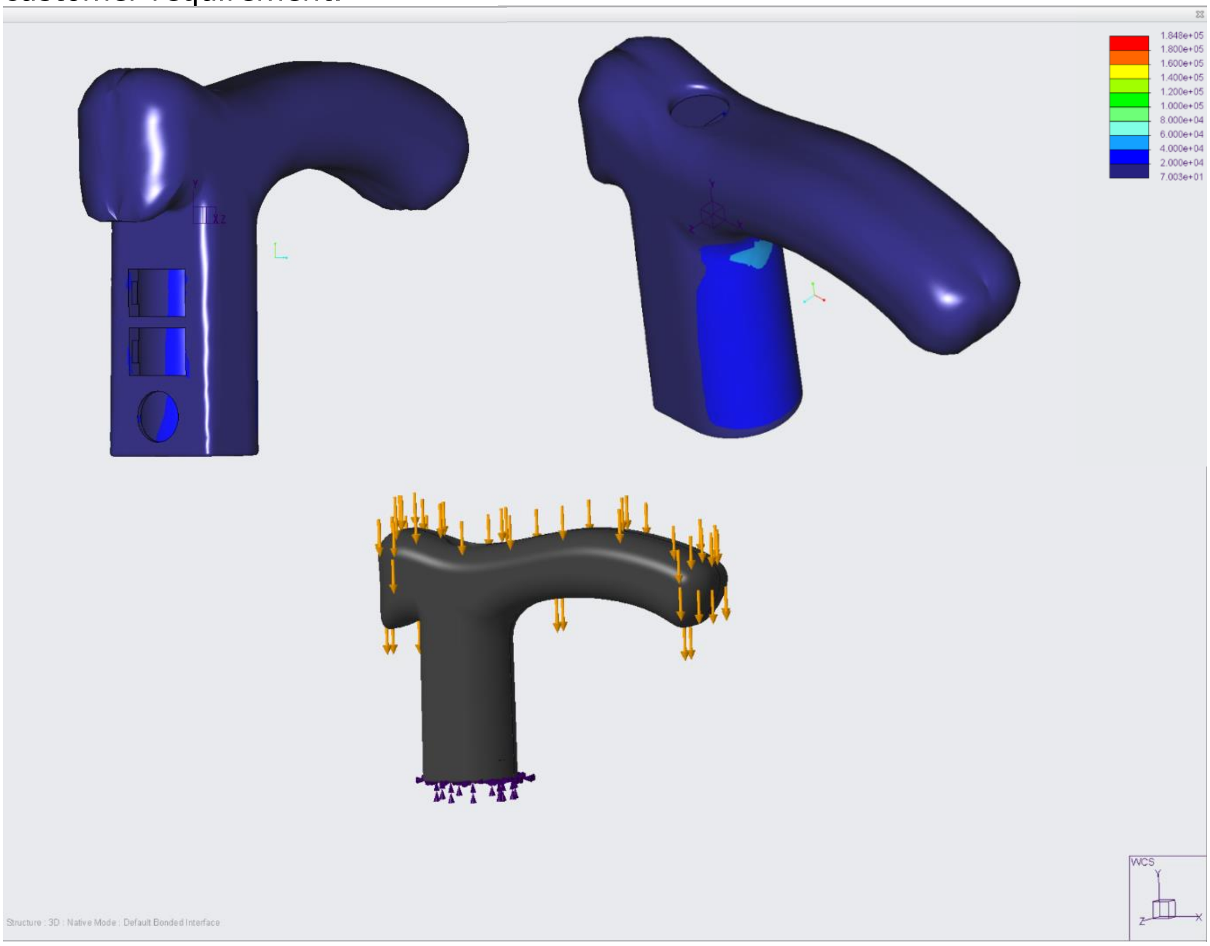


Figure 31: Handle Simulation

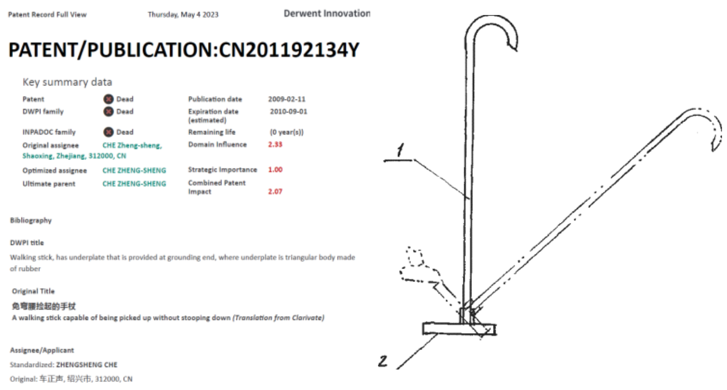
Thermal & Power Data

Part Name	Power	Temperature	Cooling
Arduino Nano 33IOT	5V - 18V Max: 21V Min: -0.3V	Thermal limits -40°C to 85°C.	NA
RGB LED's	5V 15 Watts Via 5V pin on Arduino	No Data	NA
Buzzer	3V -24V Max current: 10mA Via 3.3V GPIO pin on Arduino	No Data	NA
Pulse Sensor	3V - 5.5V < 4mA Via 5V pin on Arduino	No Data	NA

Table 8: Thermal and Power Data

Patents

During our development process, we not only examined competitors' patents but also explored filing our own patent for the unique design of our walking stick's foot. Protecting our design through a patent is crucial due to the risk of easy replication. We discovered existing patents for other ideas we had for the walking stick, which influenced the finalization of our design. Consultation with an Intellectual Property Specialist at Leonardo confirmed the need for a patent. Using the company's software, the specialist conducted a patent search, revealing a Chinese patent with a similar design. To proceed with patenting our design, we must establish clear distinctions that make it new and innovative.


Patent Record Full View   Thursday, May 4 2023   Derwent Innovation

PATENT/PUBLICATION:CN201192134Y

Key summary data

Patent	Dead	Publication date	2009-02-11
DWPI family	Dead	Expiration date (estimated)	2010-09-01
INPADOC family	Dead	Remaining life	(0 year(s))
Original assignee	CHE Zheng-sheng, Shaoxing, Zhejiang, 312000, CN	Domain Influence	2.33
Optimized assignee	CHE ZHENG-SHENG	Strategic Importance	1.00
Ultimate parent	CHE ZHENG-SHENG	Combined Patent Impact	2.07

Bibliography

DWPI title

Walking stick, has underplate that is provided at grounding end, where underplate is triangular body made of rubber

Original Title

免弯腰捡起的手杖

A walking stick capable of being picked up without stooping down *(Translation from Clarivate)*

Assignee/Applicant

Standardized: ZHENGSHENG CHE

Original: 车正声, 绍兴市, 312000, CN

Figure 32: Existing Patent

System Design

See figure 33 below for an overview of the system. Briefly, it covers all the connections between every component. This makes it easier to understand how everything will communicate without showing the technical detail.

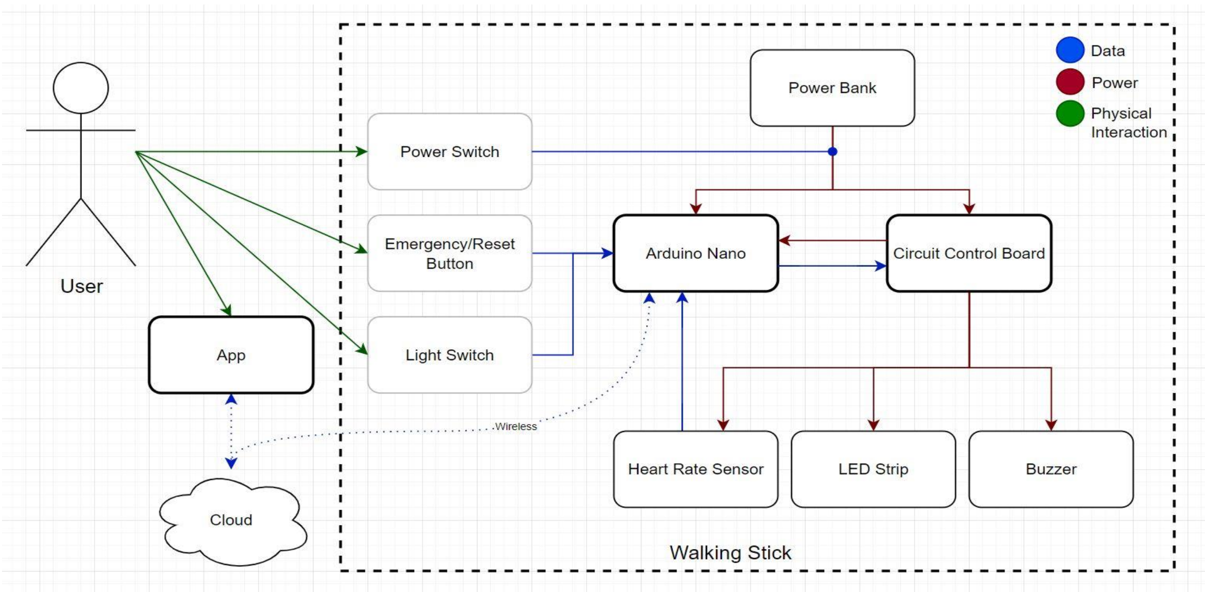


Figure 33: System Block Diagram

Electrical Design

Research was conducted to gain insights into which micro-controller or micro-processor would suit our project best. Table 9 shows the results and how we selected the Arduino Nano to move forward with.

Raspberry Pi Zero 2 W	Arduino Nano 33 IOT	ESP8266 Development Board
Python	C++	C/C++
Expensive £75	Affordable £20	Cheap £5
Micro**processor**	Micro**controller**	Micro**controller**
40 GPIO pins	14 GPIO + 8 analogue + 5 PWM + 13 LED pins	17 GPIO pins
3.3 output voltage	3.3 output voltage	3.3 output voltage
Has WIFI + Bluetooth	Has WIFI + Bluetooth	Has WIFI
No gyro	Has gyro	No gyro
Lots of documentation	Lots of documentation	Not so much documentation
Complicated	Simple (connectivity, use & setup)	Fairly simple
512MB RAM	1MB flash	1MB flash
11g	5g	10g
30 x 65	18 x 45	26 x 48
~600mW power consumption	~250mW power consumption	~350mW power consumption
	^^^^^^^^^^^^^^^^^^^^^^^^^^^	

Table 9: Controller Board Comparison

As the Arduino is popular for small projects, there are lots of projects we can draw inspiration from for parts of the circuit. The electrical design has multiple components to consider, see figure 34.

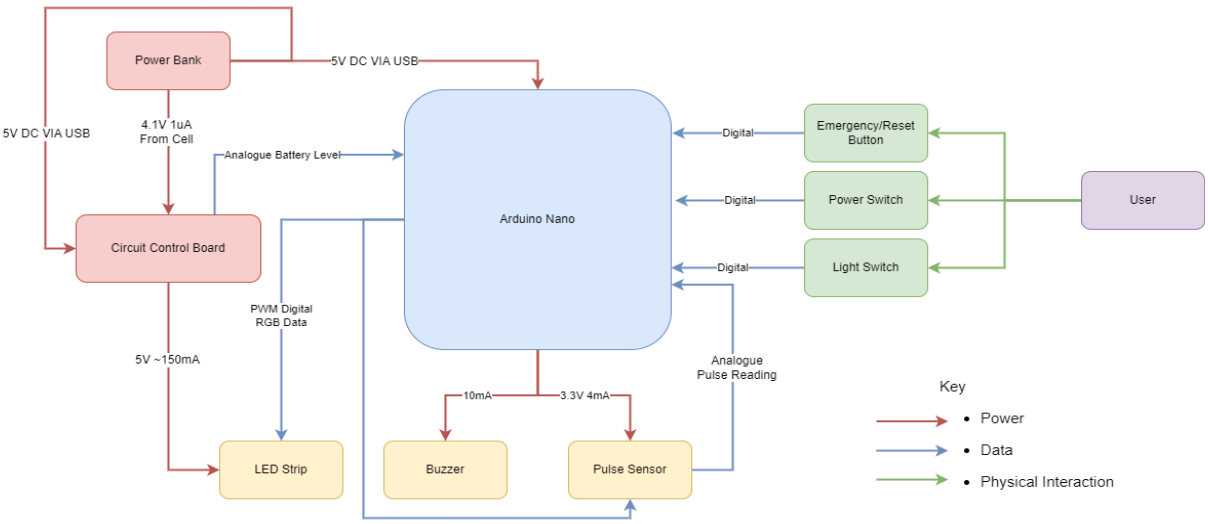


Figure 34: Electrical Hardware Design

Circuit Simulations

Due to the use of an Arduino Nano, which is an easy to use microcontroller, many of the connected components were plug-and-play and did not require simulations. However, the voltage switching logic circuit required simulating to confirm its compatibility, being the most complex part of our circuit. After running the LED strip with a fixed 5V supply in practice, we were able to determine the resistance to be 8Ω, so that we could model it within Falstad, an online circuit simulator. This enabled us to simulate both an NPN and P-MOSFET or dual NPN combinations. Both in circuit simulations and breadboard tests we found the P-MOSFET and NPN transistor combination to be superior, as it has virtually no leakage current. The simulation of this comparison is shown in figure 35.

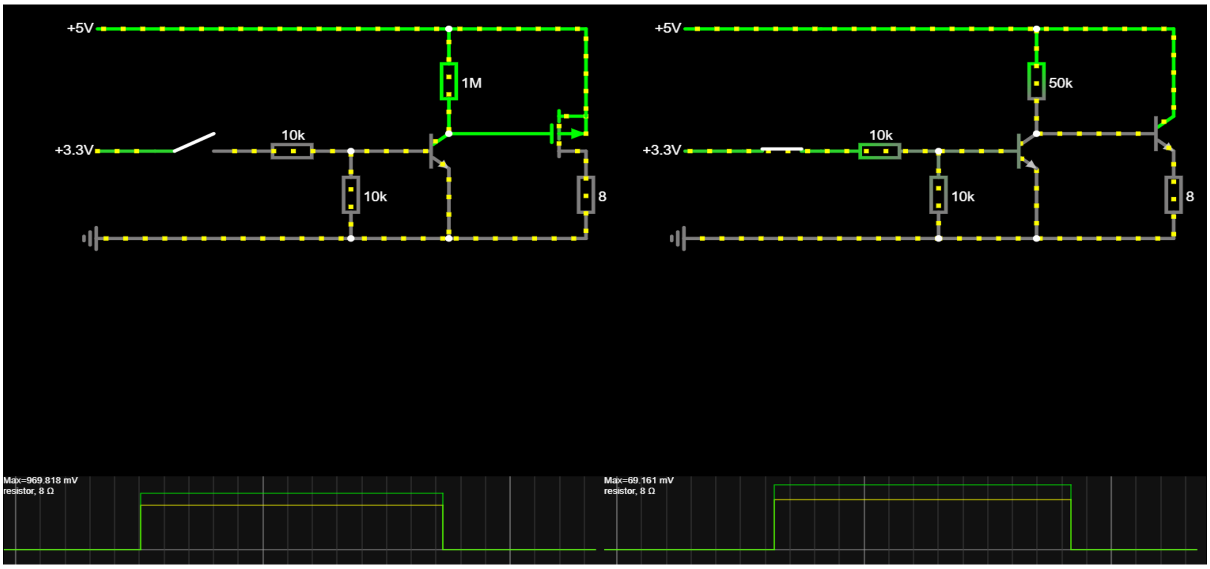


Figure 35: Circuit Simulation

Circuit Diagram

Our final circuit schematic can be found in figure 36. This was developed to control components such as the LED strip, heart rate sensor and buzzer. Another feature of the circuit is the ability to read the battery level via an analogue pin on the micro-controller.

We have made use of transistors to electronically switch these components on/off with software allowing for more functionality. The alternative was to connect these directly to the mechanical switches, but then the software would become more limited. This setup allows for features like displaying the battery level using the LED strip on start up.

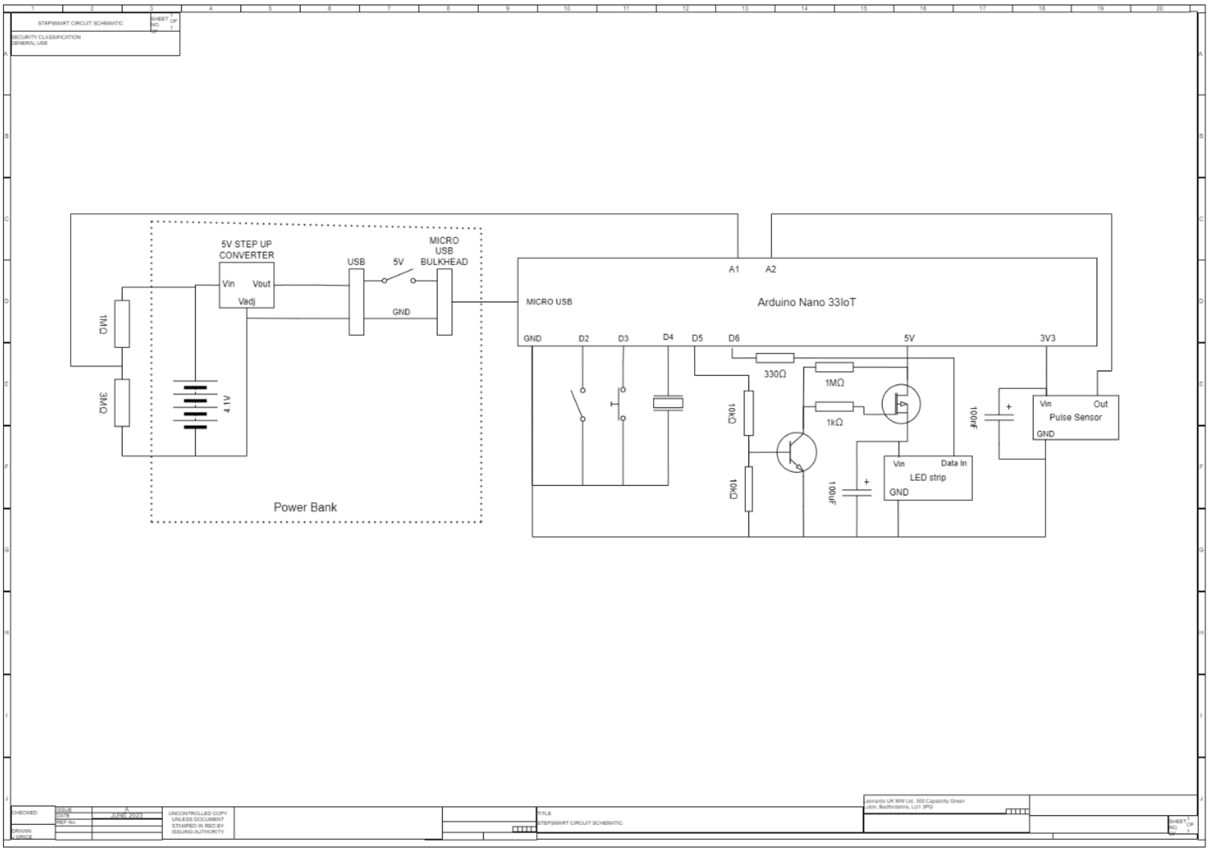


Figure 36: Circuit Diagram

Software Design

There are several elements of software to develop, seen in figure 37 below.

1. Arduino Code
There will be an Arduino built into the walking stick which will control all of its features, requiring software to operate.

2. The mobile app
Application to be downloaded and run on mobile devices to access information about a walking stick and control specific features.

3. Online API
Program to run on a server in the cloud and connect to an online database. This will take requests and provide information about the walking stick when either the app or the Arduino require information. Simply, it allows the app and walking stick to communicate.

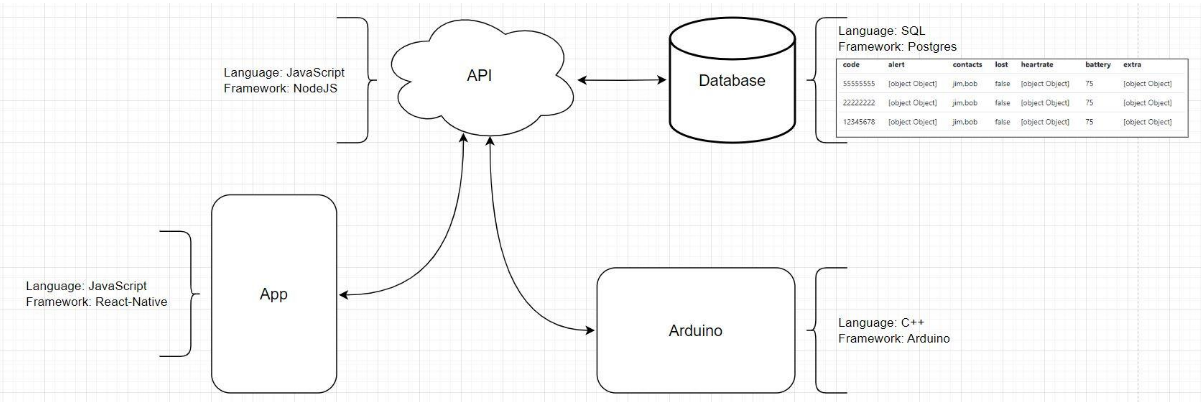


Figure 37: Software Overview

GitHub repositories will be used extensively throughout development (1 repo for each software element). This will allow better collaboration, reviews and security (GitHub.com/PeterM-13/SmartStepApp).

Software Architecture

For the app, figure 38 software architecture is proposed. Each page of the app will be a component, as well as other highly used elements such as buttons. This nicely aligns with the framework that will be used to develop the app, React-Native, which operates based on components. In figure 38, the directional arrows show inheritance. Only certain pages of the app require buttons, so by only instancing the button component in the required pages, we save memory and processing time.

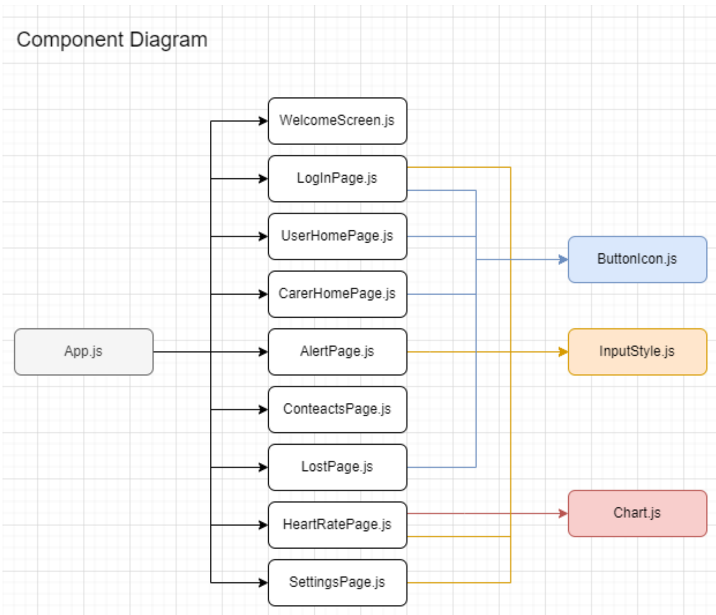


Figure 38: Software Component Diagram

A benefit of this component based architecture is that by using the same instance of, for example, the button component, any changes made to the button will update on all subsequent pages. This is efficient and very beneficial when developing an app.

Following on, we are proposing a different approach for the Arduino program, which is more event driven. Figure 39 presents an abstracted flow chart of the proposed algorithm, showing the basic functionality of the walking stick. As shown, there is a continuous loop waiting for an event to occur, where the code can then proceed to take action. As mentioned, this is an abstracted view as there are further details not included for simplicity, such as the steps to connect to the local network and sending an API request.

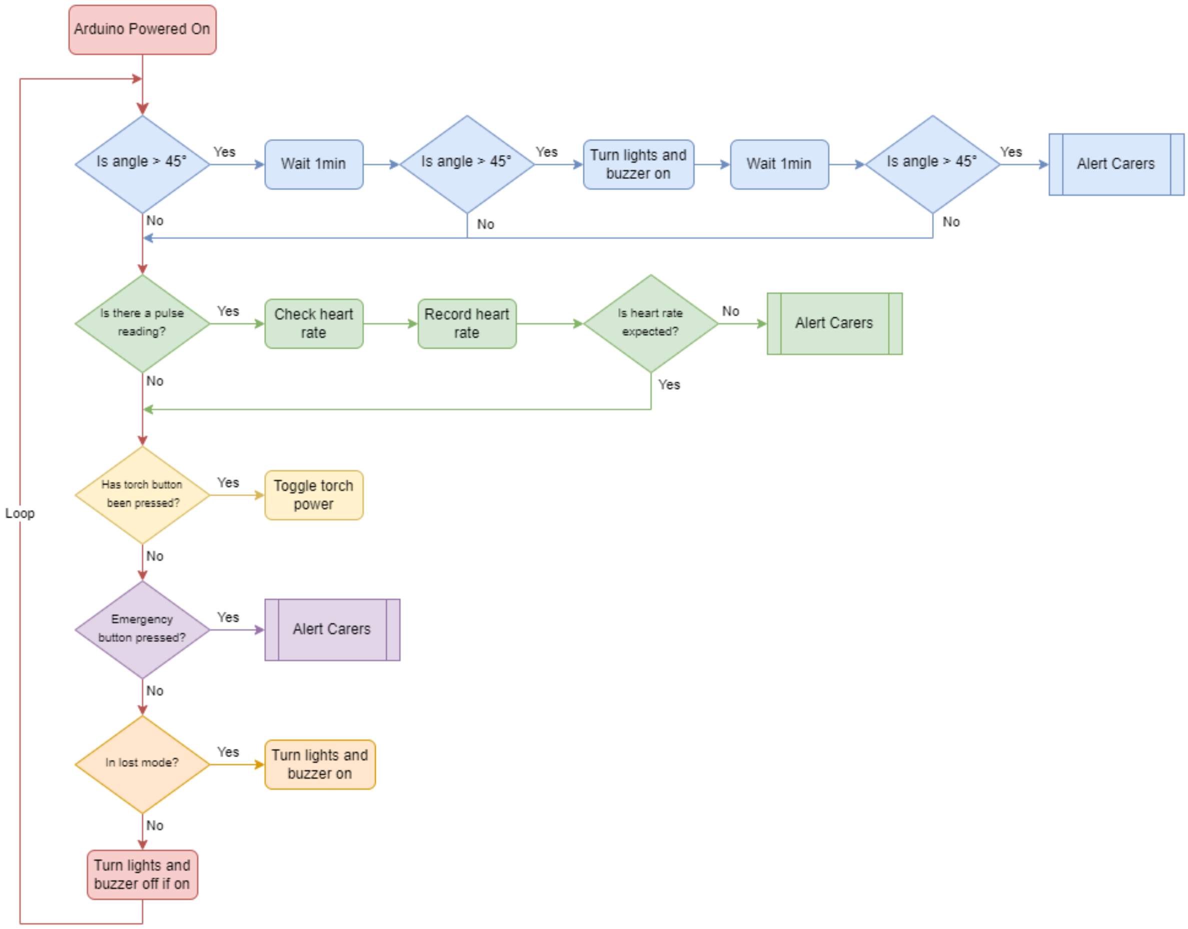


Figure 39: Arduino Algorithm

User Interface and User Experience

How users interact with our app has a significant effect on their experience using our product. Therefore, a lot of consideration has gone into how the app should look and feel. Knowing our target audience is essential for this. We know potential users include people of age so we ensured the app was easy to navigate with large, clear icons and text, to account for worse vision and a weaker understanding of the technology.

Using a design software called Figma, we designed the entire app before writing any code (figure 40). Using Figma we were able to lay out every page and visualise what the app could look like. This allowed us to get others to review our design and suggest improvements. As a result, we condensed our initial 3 setup pages into just one simpler page, making the process easier for first-time users. Doing all this before writing code boosts development, as we didn't waste time writing code before finding these improvements.

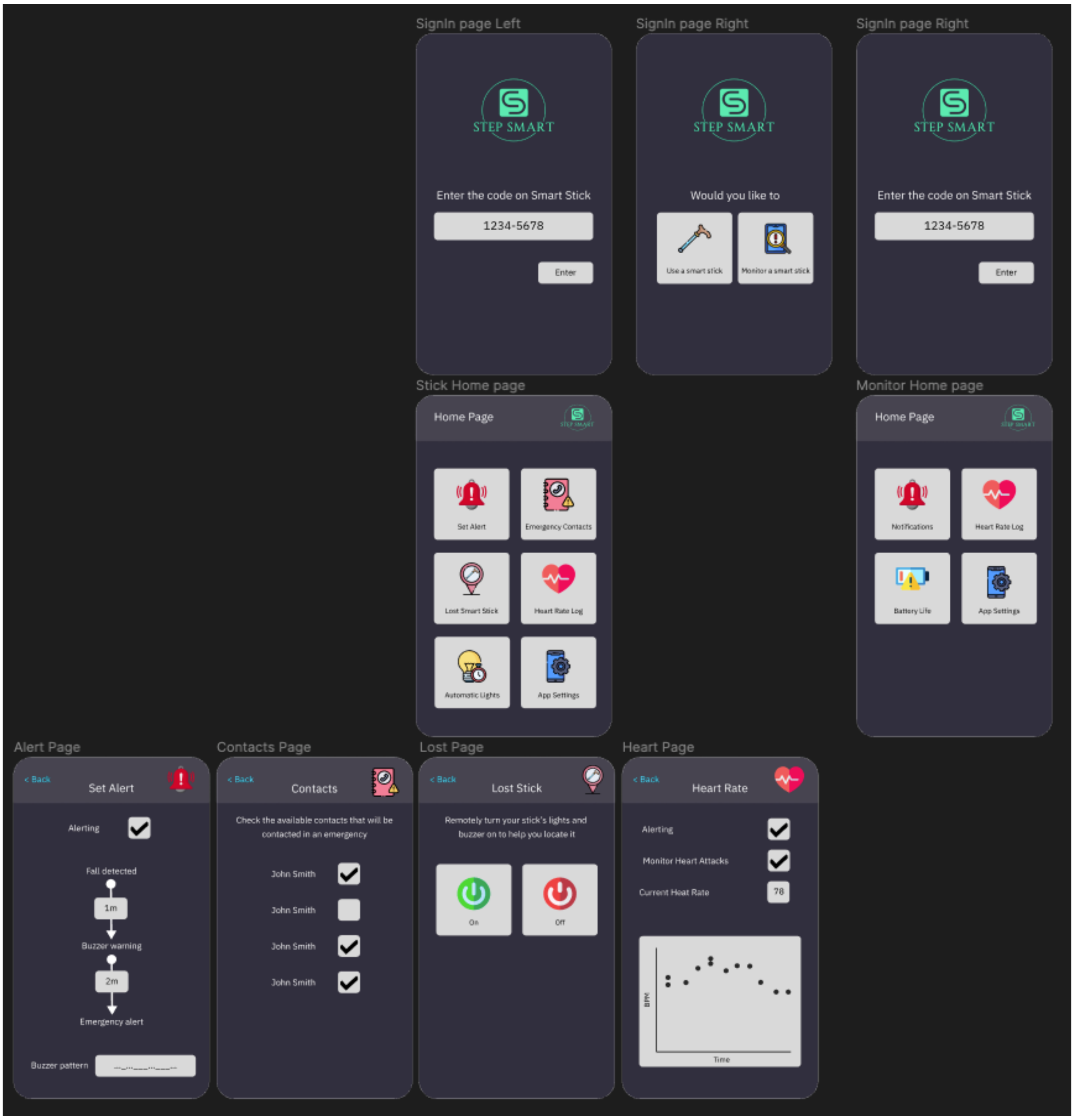


Figure 40: App User Interface

Software Test Plan

Testing is an important part of development and is essential to ensure high quality results. Therefore, we created a detailed test plan, table 10, which aligns with our software requirements. Refer to the software requirements, tables 6 & 7, using the reference number.

Ref. No.	Test	Pass Requirement	Equipment
1a	Drop stick 100 times	Software detects >=99 falls	N/A
2a	Use stick sensor and compare to smart watch	Softwrae measures heart rate within 5pbm	Smart watch or medical heart rate sensor
3a	Send notification to device on different network	Device receives notifcation	Smart phone
4a	Press button and Arduino LED reacts	LED toggles with button press	Arduino, buttons/switches
5a	Download software successfully to Arduino	Builds successfully	Arduino, Laptop, USB-B cable
6a	Test 3a & 1a together	When fall, devices gets notified	See above
7a	Download code, power off, then power on. Software should run	Software runs successfully	Ardiuno
8a	Software updates cloud based database via wifi	Database updates	Arduino, network router
1b	App can be used and interacted with on an iPhone	App gets certified	iPhone
2b	App updates by connecting to database	App displays updates information	iPhone, laptop
3b	Sign in to app with unique code	App recognises code and allows access	iPhone
4b	App shows battery life	App shows accurate batter life	iPhone, stick, multimeter
5b	App shows live data from stick	Measure heart rate on stick, see on app	iPhone, stick
6b	Drop stick and wait for notifiaction on app	App generates notifications	iPhone, stick
7b	Survey, get older peoples opinion on text size, colours, etc	Positive feedback	iPhone
8b	Setup 2 Arduinos with stick code and check app	App monitors just 1	iPhone, 2 Arduinos
9b	Press 'lost' button on app	Stick buzzes and flashes	iPhone, stick

Table 10: Software Test Plan

Furthermore, we intend to make use of unit tests which should be implemented during the development phase. After a change in the code, these unit tests will be run to ensure the developed features still function. This should catch errors as early as possible and help ensure the codes integrity.

With the use of a program called Cypress, we plan to run automatic tests for the UI too, that will literally click buttons and type into text fields to check their functionality. This will pick up on buttons not working as expected and missing input validation.

Manufacturing Process

Manufacturability Analysis

Design Element	For Prototype	For Mass Production
Foot	We initially started with some rough sketches in a design meeting then we have made multiple 3D printed feet to prototype and will continue to develop them further.	The foot will be 3D printed or we could consider other manufacturing alternatives such as injection moulding.
Handle	We initially started with some rough sketches in a design meeting then we have made multiple 3D printed handles to prototype and will continue to develop them further.	We want our final handle to be plastic so would consider injection moulding this part too, to keep production costs low and production rate high.
Stem	We chose to use PVC pipe during the prototype however for the real thing we will use a stem we purchase so that it already has the height adjustability.	We would produce our own height adjustable stems using a telescopic method to keep production cost down.
Arduino	We chose an Arduino due to the properties previously discussed in our SDR. We will have to write code for this to be functional for our needs.	For production we would have the code ready to load onto each board so that we can speed up production after development.

Table 11: Manufacturability Analysis

Manufacturing Flow

Figure 41: Manufacturing Flow

Maintainability Analysis

Please refer to the business case; Maintainability Analysis.

Producibility Plan

To ensure a smooth manufacturing process for our product, we have developed a comprehensive Producibility Plan (Hobbs, Producibiltiy Plan, 2023). This plan encompasses various aspects, including the Failure Modes and Effects Analysis (FMEA), which helps identify and mitigate potential failures during production. Furthermore, we have incorporated Design for Excellence (DfX) Principles, specifically focusing on three key areas:

- Design for Manufacturing (DfM)
- Design for Assembly (DfA)
- Design for Testing (DfT)

This has been captured in following diagram:

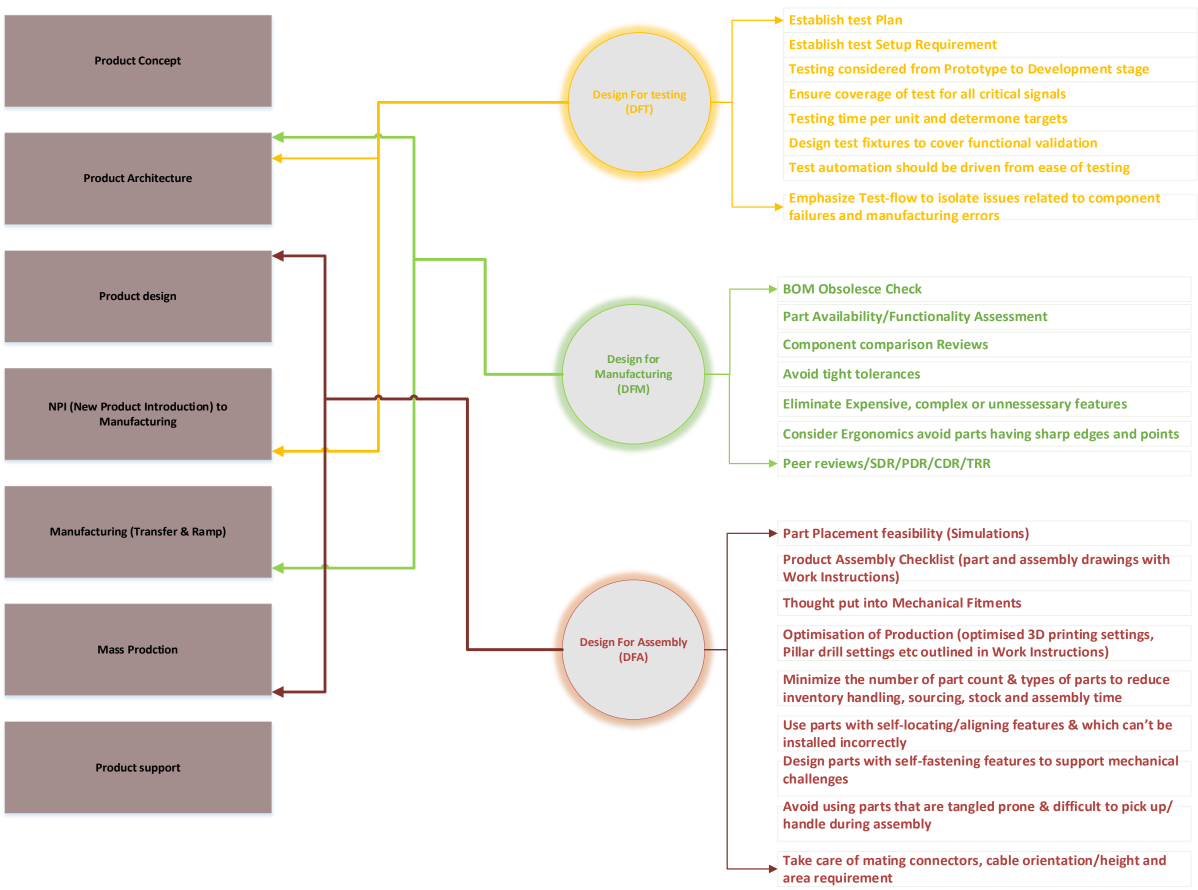


Figure 42: Design for Excellence (DfX) Diagram

Drawings List

Please see Producibility Plan, for the full list of drawings with descriptions and associated sub-assemblies (Hobbs, Producibiltiy Plan, 2023).

Special Facilities

For our prototype, we were able to make use of a designated work space within our company. When considering how to manufacture our product, significant thought went into what facilities would be required. The team researched the purchase of an industrial space to better understand the size and costs involved, please see the Producibility Plan (Hobbs, Producibiltiy Plan, 2023).

Manufacturing Floor Plan

One of the considerations with this space, if we were to acquire it, was how would we make use of the space to be able to maximise our production? We therefore created a factory layout to show exactly how our products will progress through manufacturing process. We have tried to create a flow in a clockwise loop fashion starting at goods in, to the manufacture, to test, to quality assurance and finally to goods out. Please refer to Producability Plan for a detailed breakdown on each section and more (Hobbs, Producibiltiy Plan, 2023).

The space also provides for a commercial area in the form of offices. This is of a high importance as these will be used for the following; marketing, sales, research, customer support, supplier and sponsor relationships and more. Other rooms included which are not related to the manufacturing process are the staffroom and toilet facilities.

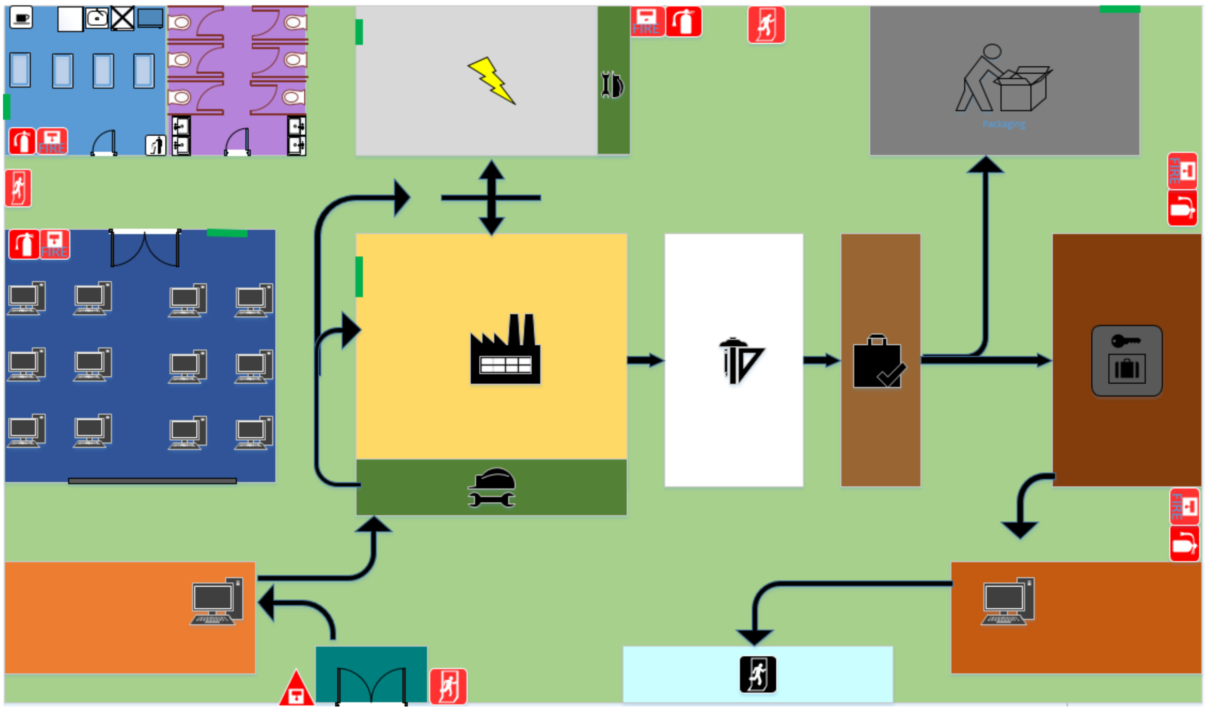
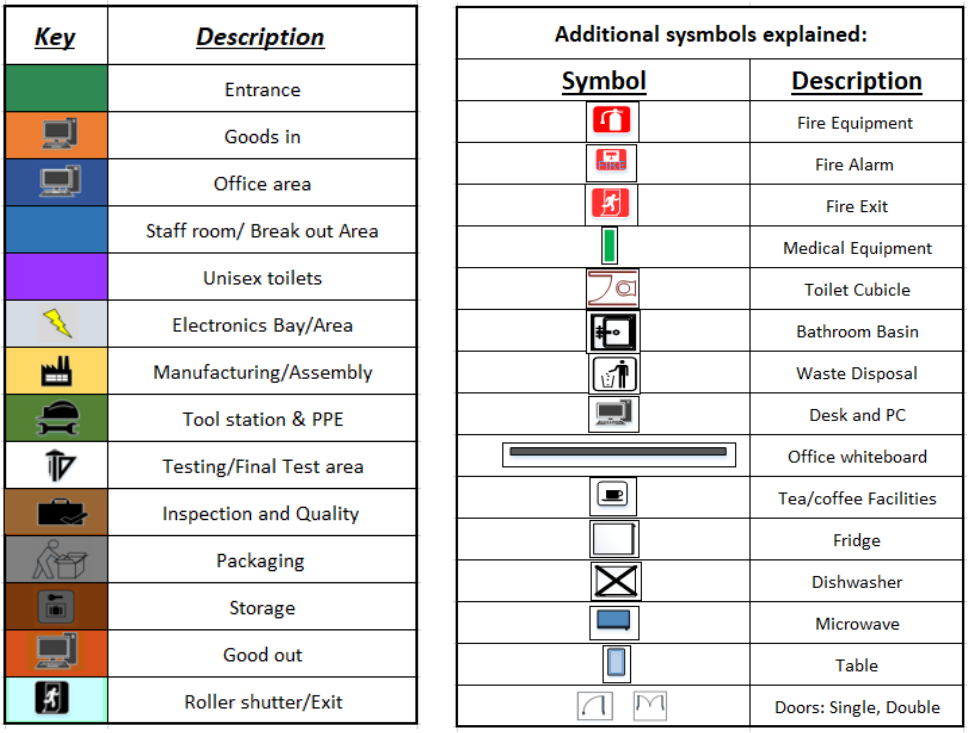


Figure 43: Manufacturing Floor Plan



Key	Description
	Entrance
	Goods in
	Office area
	Staff room/ Break out Area
	Unisex toilets
	Electronics Bay/Area
	Manufacturing/Assembly
	Tool station & PPE
	Testing/Final Test area
	Inspection and Quality
	Packaging
	Storage
	Good out
	Roller shutter/Exit

Additional sysmbols explained:	
Symbol	Description
	Fire Equipment
	Fire Alarm
	Fire Exit
	Medical Equipment
	Toilet Cubicle
	Bathroom Basin
	Waste Disposal
	Desk and PC
	Office whiteboard
	Tea/coffee Facilities
	Fridge
	Dishwasher
	Microwave
	Table
	Doors: Single, Double

Figure 44: Floor Plan Key

Special Type Test Equipment

Special Type Test Equipment (S.T.T.E.) is test equipment designed or purchased specifically for the product. For the prototype, the team will want to use this opportunity to get the physical product in good shape and complying with any regulation and legislation in relation to our product. The intention is to use standardised methods at this stage and get to know the scope of equipment needed. This should help us when it comes to mass production with equipment verification. Overall this strategy will give us greater clarity going forward and when considering specific factors such as the quantity needed for mass production and whether or not the testing equipment is to the standard we desire. The reason for a more standardised approach is because this would be more cost efficient and easier to implement into the production.

In terms of our actual product we have found one such item that is optional but may well be beneficial for the likes of testing. The smart walking stick by nature has to be able to bare weight of a human being, therefore durability and integrity of our product is paramount. We therefore believe we could benefit from the use of an ultra-sound/sonic tester. This could assist in the following ways:

- To help us determine internal damage/cracks in our prototype during testing.
- Helping us to expose/ exploit any areas of weakness and identify places where the durability may have a life.
- Especially useful for internal areas that may not be visible i.e. the internal structure of 3D printing
- Non-destructive and high accuracy

If we choose to implement this optional S.T.T.E, then further consideration would need to be taken on board such as ensuring the equipment itself to be as user friendly as possible. It also needs to be verified with the impact to the manufacturing flow, and weighted to see if it brings any additional benefit to the implied changes.

Figure 45: Example Ultrasonic Tester

New Processes

The team has not identified any new processes.

Tooling

With tooling it has been our mission not to change the scope too drastically between the prototype and main product. This is therefore reflected in the tools that have been identified for each stage – with most tools remaining the same. A notable difference is the switch from 3D printing to injection moulding, but this is more in line with mass production.

Tooling type Required	Prototype	Product	Requirement
Hammer	√	√	Hands and force, secure hold with vice
Vice	√	√	Strong reliable surface for attachment point
Saw	√	√	Protective Gloves and Vice/clamp stand
File(s)	√	√	Hands and a range of sizes/types to get a good finish
Hand Drill	√	√	Will require eye protection and a range of drill bits
Set of Screwdrivers	√	√	Hands. A range of sizes crosshead and flats
Centre Punch	√	√	Hands and Requires hammer

Soldering Iron	√	√	Requires electrical workbench setup: heatproof mat, vacuum tube, solder wheel
Helping Hands	√	√	Requires to be adjustable
Magnifying glass	√	√	Ideally as an additional feature to helping hands, so hands free
Wire cutters	√	√	Correct storage facility (tool box), inspection before and after use
Wire Strippers	√	√	Correct storage facility (tool box), inspection before and after use
Glue gun	√	×	Correct storage facility (tool box), inspection before and after use
3D printer	√	×	Full setup, Only trained personnel
Injection moulding	×	√	Full setup, Only trained personnel
PPE			
Gloves (optional)	√	√	Cut resistant
Googles	√	√	Compliant to BS EN 166
Air extractor	√	√	Must be in working order and on when soldering
Boots	×	√	Steel toe caps or equivalent when in the workshop/warehouse environment
Overalls/Lab coat	×	√	Must be of good fit, not damaged

Table 12: Tooling

Test Strategy

To maintain a high quality when manufacturing our product, we have designed a test strategy for production testing. This includes taking a random sample of walking sticks off the manufacturing line and checking quality assurance (with visual and load tests), system tests (using test functions in the software and electronics) and normal distribution hypothesis testing. See figure 46 below for a visual representation and example of the statistical hypothesis testing.

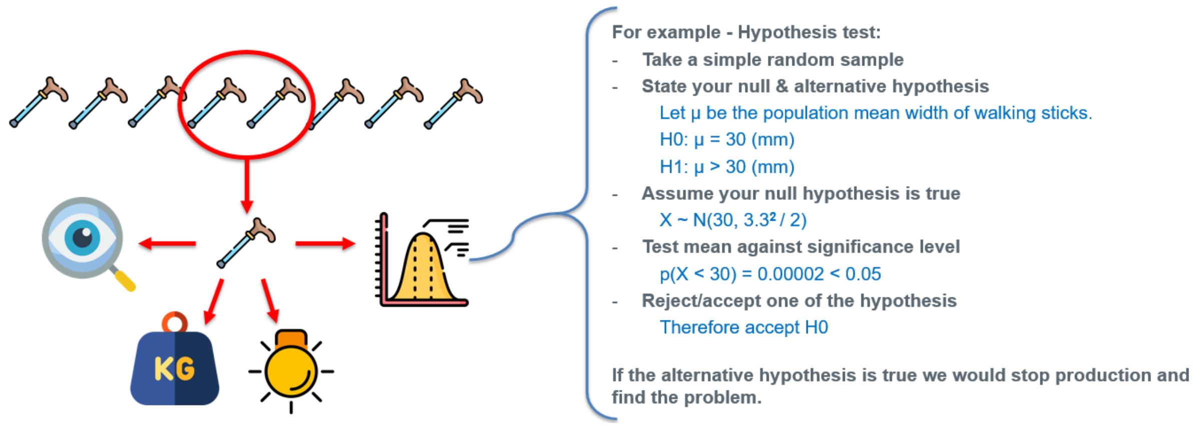


Figure 46: Test Strategy for Production Testing

Test Plan

Below is a table of tests to be utilised during the visual and system tests of the production test strategy. Also reference the Producability Plan for more detail on the test plan (Hobbs, Producibiltiy Plan, 2023).

Importance	Ref. No	Test
High	1	We would have to initially test all products to work out if we were getting any defects with the original manufacturing techniques/ components.
	2	We would have to ensure all test technicians have the required training and equipment to carry out their jobs effectively and safely.
	3	Make sure to report any near misses or health and safety risks.
	4	Develop manufacturing to make the product better if any failures occur.
	5	Visual inspection of the product (check for good quality solder joints and all tracks on the boards being intact to make sure it will not cause any electrical issues such as short circuiting, etc)
	6	All electrical checks, continuity checks, bonding checks and PAT testing where applicable.
	7	Check functionality of the Arduino board.
	8	Functional testing, check all capabilities are working correctly, fall detection etc.
	9	Drop testing to make sure the product is durable. And continues working afterwards.
	10	Fatigue testing of the stick over a period of time, test that the material does not weaken and become dangerous for the user.
Low	11	Then move to batch testing if the failure rate was low.

Table 13: Test Plan

Test Schedule

Hardware	15th	10th	20th	30th	1st	15th	30th
Produce CAD & 3D print parts							
Finalise electronics design							
Begin electronics systems test							
Assembling parts together							
Perform system tests							
Perform changes based on test results							
Any aspirational features							
Software							
Install Arduino libraries							
Setup API and database							
Develop Arduino algorithm							
Develop app GUI							
Perform software tests on components and system							
Verify and release app							
Add additional features							

Figure 47: Test Schedule

Test Matrix

Stage	Item	Plan	1/06/23	12/06/23	30/06/23	12/07/23	30/07/23	Ref. No
Individual	Heart rate monitor	Plug heart rate monitor into the Arduino to test it for functionality, compare to a physical reading of the person testing pulse to check for accuracy or a medical scanner we could use from occupational health.		CDR				2
	Switches	Test the switches on a multimeter before install, then when in the product test functionality,		CDR				10
	Height adjustability	Test the height adjustability on the stem is suitable for all customers.		CDR				3
	Fall detection	Drop test the stick and check that it is notifying/ alarming the fall.		CDR				1
Multi-Component Test	Full system	Check for all functionality on the stick, make sure all switches and all electronics are working flawlessly at all levels of adjustability, make sure the self-writing feature is easy to do with the additional weight inside the product		CDR				1
	Charging	Test the charger speed and function by seeing how long to a full charge and check that the charging station works correctly every time. This would have to be PAT tested.		CDR				6
	Application	This would require having a target market to evaluate the application for the product. See that the application is fit for purpose and functional.		CDR				5
Software	Initial software	Check for all functionality on the stick, make sure all switches and all electronics are working flawlessly at all levels of adjustability, make sure the self-writing feature is easy to do with the additional weight inside the product		CDR				
	Final software	The software would be tested using the product and making sure all of the functions work correctly.		CDR				

Figure 48: Test Matrix

Quality Plan

Please refer to the business plan where the quality plan is discussed within purchasing contracts.

Critical Processes

- CAD – must ensure engineering drawings are correct dimensions and suitable for 3D printing.
- Pillar Drill – Holes for the stem must align correctly.
- 3D/injection moulded processes (3D printing – Must bear in mind potential lead times if 3D printer is in use).
- Soldering of electronic components:
  Note: Soldering – likely to solder electronic components should be compliant to IPC standards. (Minimum class 1 for prototype), joints to be inspected by on-site personnel with IPC-610 qualification – to ensure quality. For the actual product, as a medical device, IPC may need to be higher.
- Assembly and installation (of mechanical and electronic parts).

Manufacturing Risk Assessment

Please see reference (Rickards, 2023) for a better look at our risk assessment. This covers all the hazards we identified with manufacturing a product as well as their severity. Our team appreciate the importance of health and safety, especially within working environments like the manufacturing process we have suggested. Therefore, it is necessary to recognise the risks associated and analyse potential dangers, in order to lower the probability injury.

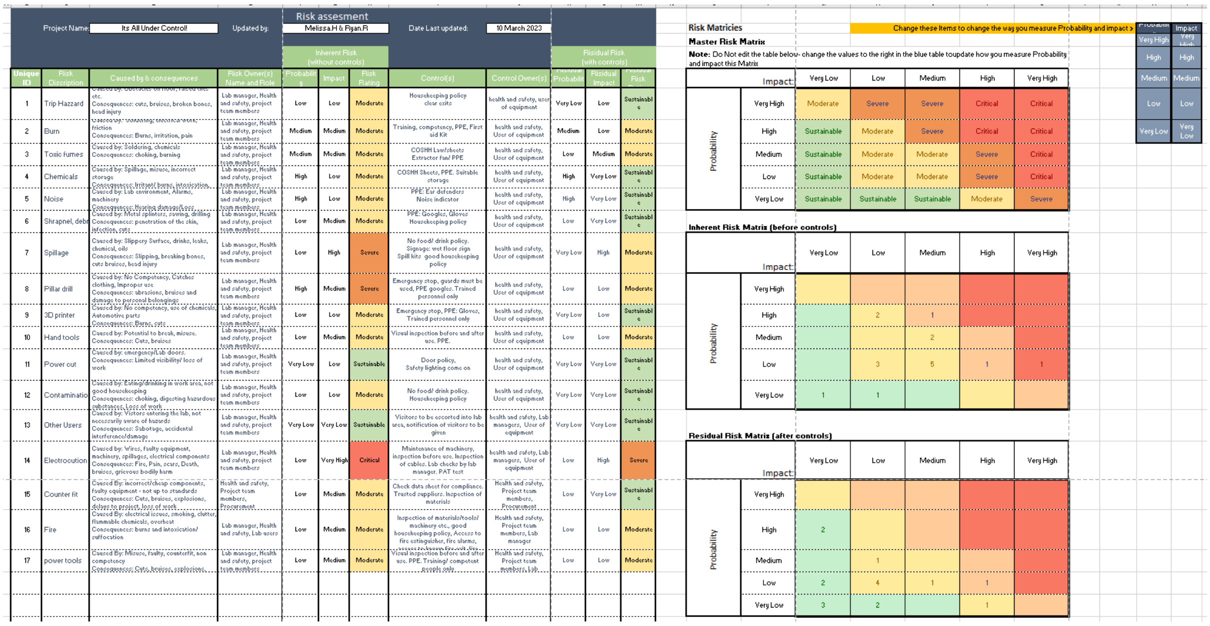


Figure 49: Manufacturing Risk Assessment (Rickards, 2023)

Distribution

Packaging

Sustainability and packaging go hand in hand. Careful consideration has been put into our packaging. Below, figure 50, outlines the features of our packaging, including the contents, logos, branding, reading materials and important health and safety information.

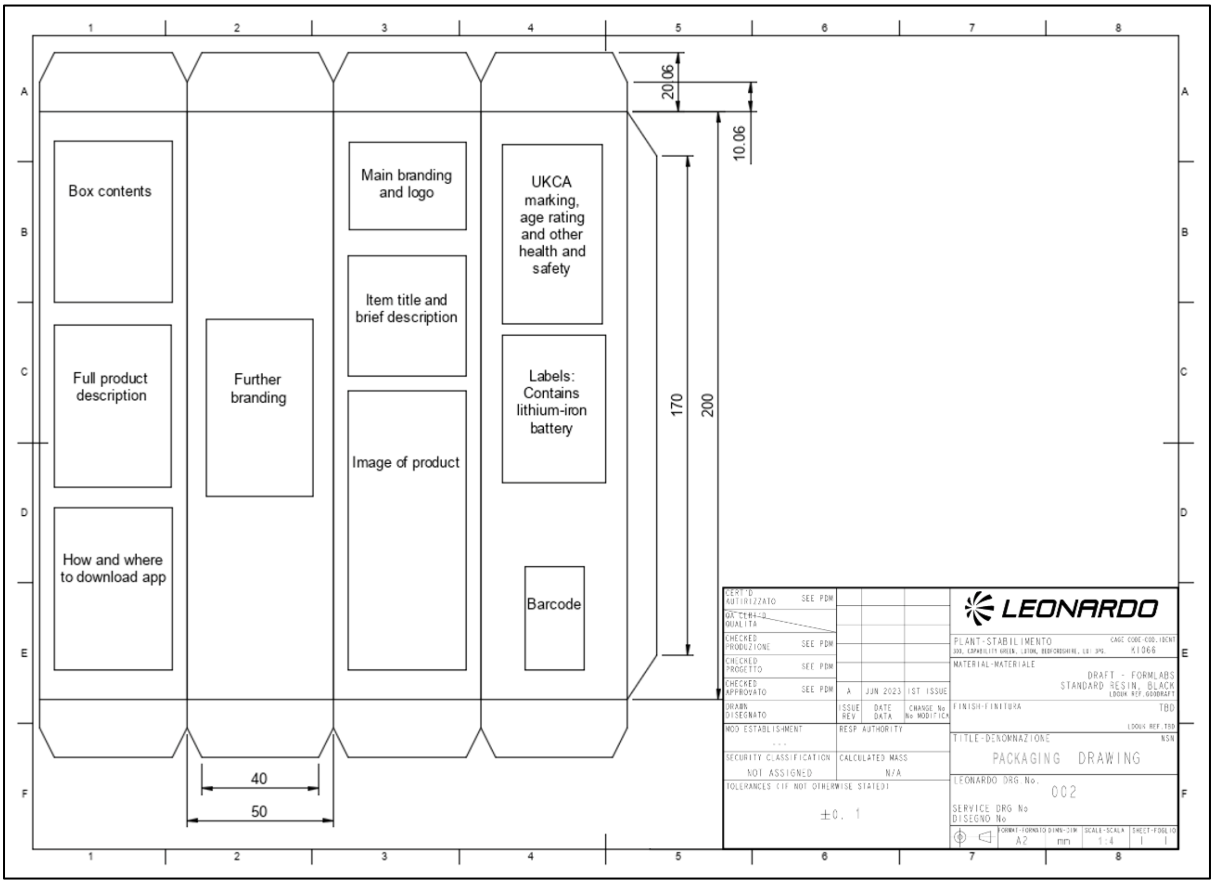


Figure 50: Packaging Design

The next consideration for the team is the materials used for packing. In terms of our packaging design we kept the five R's (Reduce, Reuse, Repair, Rot, and Recycle) in mind.

The exterior is likely to be a corrugated cardboard and this will be the main feature of the packing. This has the advantage that it is both durable, offers good support and is easily stackable when in storage. Overall, cardboard boxes are easy to recycle, lowering the impact to the planet.

In order to support the product and hold it securely whilst in transit, our team would invest in Mushroom packaging. Mushroom packaging is fantastic as it acts as a mould around the product for a snug fit, allowing for the product to be adequately protected. Mushroom packaging is biodegradable and therefore better for the planet.

Figure 51: Mushroom Packaging

Shredded paper packaging may also be used to fill gaps in the packaging and act as a shock absorber. Like Cardboard mesh, shredded paper is widely recyclable.

Although we feel that the above should suffice, if there is a need for plastic material in future packaging, we will ensure that the plastic we use is sustainably sourced both being biodegradable or recyclable and only being used where plastic cannot be feasibly replaced.

After considerable research, we also recognise that there are new developments in the world of eco-friendly packaging. Other notable options would be using corn-starch – although this was ruled out because of the ethnical factor of food waste to produce it. One up and coming new product on the market was seaweed packing, this is an area of consideration. The team may consider this in the future as a viable option depending on how this packaging type matures.

Labelling

As shown in the packaging drawing above (figure 50) labelling is a key consideration. Certain labels will be shown on the packaging for health and safety, indicating how to correctly handle and store the product as well how to correctly dispose of it. The table below shows some of the identified labels used in the packaging, although this table is not all inclusive. A labelling table will also be within the user manual for customers to refer to. See below:

Label Icon	**Label meaning/reasoning**
UN 3481 Flammable	It has been identified that our product will contain the use of Lithium Batteries. Lithium batteries are considered a Dangerous good under the DGR Regulations. This means when considering packaging we should comply with the law and feature warning labels.
	The packaging should be 100% recyclable, so this label should be on the product's packaging.
CE marking Conformity to the requirements of the applicable EC directives	Our product must comply with the CE marking / UK Equivalent (after Brexit), this is especially important for access to markets and because our product is classed as a medical device
Tidyman Dispose of this carefully and thoughtfully	Under the WEEE Directive, as the product is electrical goods there is a responsibility when it comes to end of life usage. We should ensure that products can come back to us for correct disposal or repair. The Tidyman icon is to indicate some thought I required for this product.
0-3 Not suitable for children under 3 years	Due to the potential of small parts coming lose there is an age restriction on the product as defined by the following labels.

Table 14: Labelling

Branding

STEP SMART

Figure 52: Step Smart Logo

Branding holds significant importance for our team's potential manufacturing of the walking stick. Our vision encompasses developing different iterations and versions of the product, making it necessary to establish a recognisable brand that symbolises quality. Our goal is to become the customer's first choice, establishing our brand as intellectual property alongside copyrights and trademarks.

To embody our brand, we have designed the "Step Smart" logo (figure 52), which represents our products and reflects our vision for quality. The logo's simplicity and effective use of alliteration make it memorable and easily pronounceable. It strikes a balance between a technically advanced product ("Smart") and a modern, uncomplicated design. The logo caters to our split target audience and aims to position us as the preferred provider of superior walking sticks.

With our logo and brand, we aspire for customers to choose our products with confidence and pride. The "Step Smart" logo will prominently be displayed on company documentation, events, marketing material and our products, ensuring consistent brand recognition throughout our operations.

Transportation

As our product develops over time, it is essential that our company considers our environmental impact towards the planet. Not only is this a prominent consideration for our team, but research shows that environmental impact is an increasing concern for customers. For this reason, significant consideration went into the transportation of our product.

Certain types of transportation could be ruled out immediately such as air travel, as we were not currently planning to enter the US market. Generally, our vision would be to get a strong footing in the UK market, and optionally EU markets in the future. In the product's infancy we would aim for a more local market and then expand to cover the whole of the UK. Whilst we are local we would make use of eco-friendly electric vans. National transportation, would be in the form of biodiesel/renewable diesel lorries. If we did want to venture into the EU market, the company would look to rail networks to get the product across Europe. Trains are better for the environment providing 80% less carbon emissions compared to trucks and ships. Considering our secondary user might prefer online buying, we would strive to strike a collaboration; to sell our product through the likes of Amazon/eBay that distribute using their own fleets.

Figure 53: Transportation Examples

Overall, the team understands the importance of being as environmentally friendly as possible, we would therefore implement additional procedures to further reduce our carbon footprint, such as:

- Creating Software for more efficient logistics, i.e. Better capacity, more efficient journey plans etc.
- We will look into Carbon offsetting initiatives after 5 years.
- Implement reviews bi-annually to identify more efficient processes.

Business Case

Market Research

Understanding the market and your target audience is vital to any business. Our target audience covers both the elderly aged 65+ and carers aged 25-65; our product is also available for people with mobility issues, disabilities and injuries. With our target audience and potential customers in mind, we have made our product as comfortable as possible for the physical users whilst also being technological enough to allow the carer to monitor the user.

When selling to a target audience you must first understand their viewpoint. We achieved this through asking family members/known contacts (that use walking aids) for their thoughts on our product, with plans to use them as a focus group again for our prototype. We also looked at reviews on websites to see the feedback on walking sticks, looking at 50 positive, 50 negative and middle ground reviews.

AB

★☆☆☆☆ **the attached photo is not instructions!**

Reviewed in the United States on 25 July 2022

Verified Purchase

How does it work and extend ? where are the instructions? Why is it so complicated?

No instructions ...a cane that fits in a purse and then extends for a 6'3" needs instructions . How about an unboxed video.

Mr. R.

★★★☆☆ **Only for petite hands! ...unless you want a T Grip handle (which it's not supposed to be!)**

Reviewed in the United Kingdom on 26 February 2023

Verified Purchase

Despite stating it has a long handle... it hasn't! The handle isn't long enough for my 'small' mans hands! As my palm doesn't fit, it can only be used as a T grip handle... which this stick isn't? This stick handle should be fine for a child or petite lady. Even my 10yr old preferred the grip on my other stick.

Victoria G

★★★★☆ **Graduable, but too high**

Reviewed in Spain on 15 December 2020

Verified Purchase

Easy to use, perfect quality and ergonomics, but maybe a little too high, which makes you have flexed your arm during use. It is sturdy and with a base that makes it easy to leave it where you want.
The flashlight is very useful and works perfectly with button batteries.
Regarding color, perhaps it would be more fun in others or include several prints that would make it more attractive to your purchase.
However, its value for money is extraordinary.

3 people found this helpful

Reviews were then documented and tallied in the two charts below. This gave us a clear view on the features customers liked and disliked, for example, the flashlight was highly welcomed but having a non-adjustable stick was not.

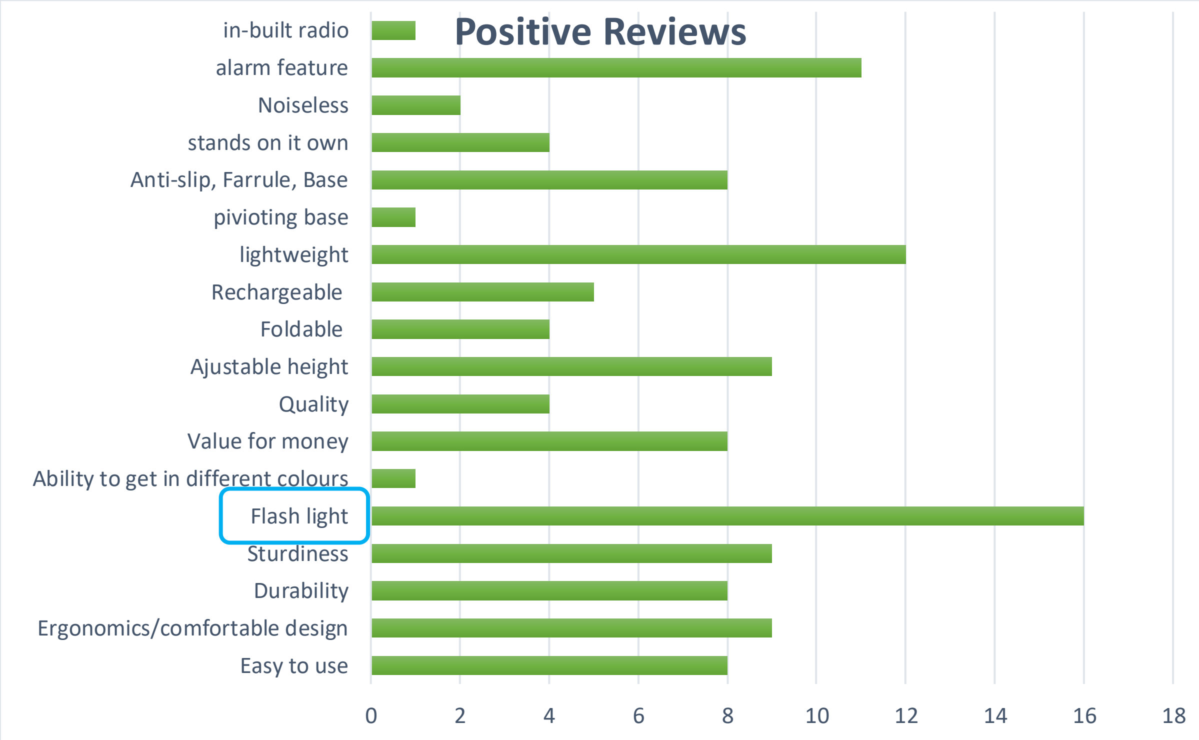


Figure 54: Positive Reviews Bar Chart

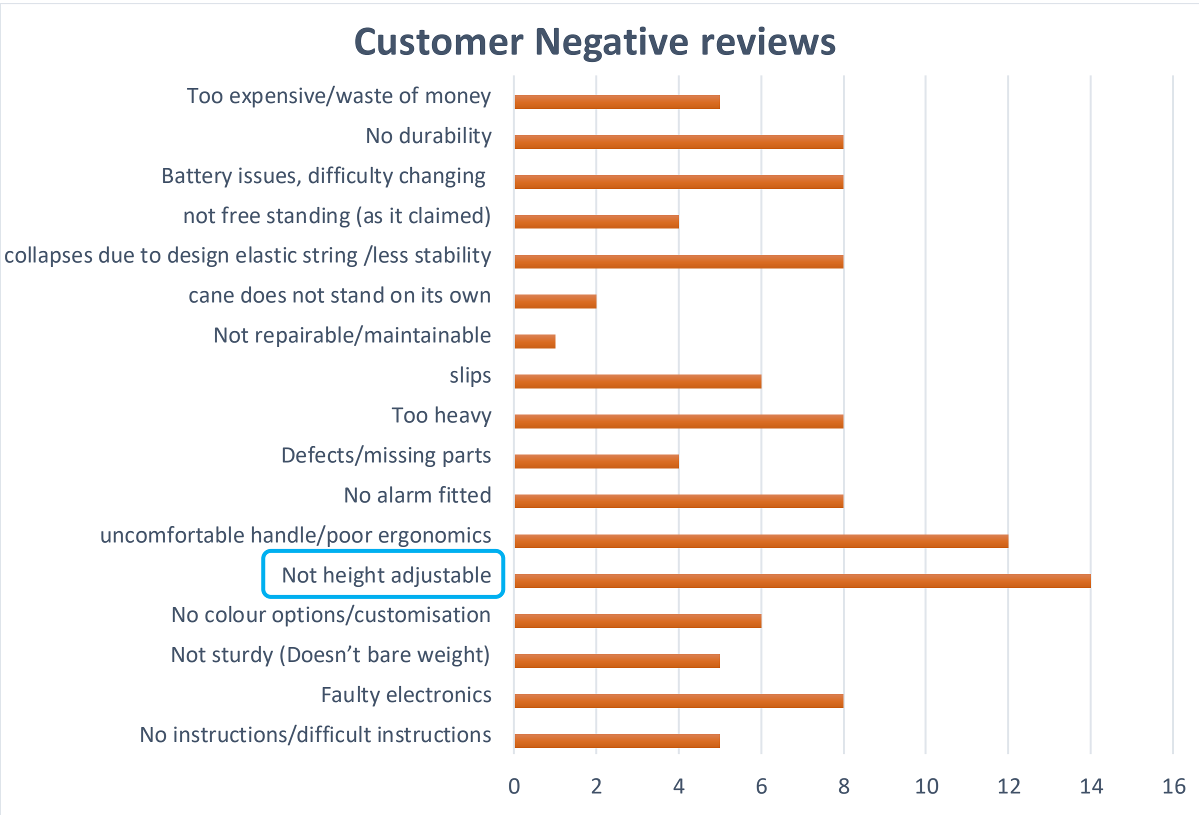


Figure 55: Negative Reviews Bar Chart

The second most negative review was the shape of the handle. From the reviews we've looked at we have concluded that this is down to personal preference. As mentioned briefly in the Walking Stick Handle section, we plan to use multiple handle designs when selling so that the customer may choose a handle that fits their needs and preference.

Existing Competitors

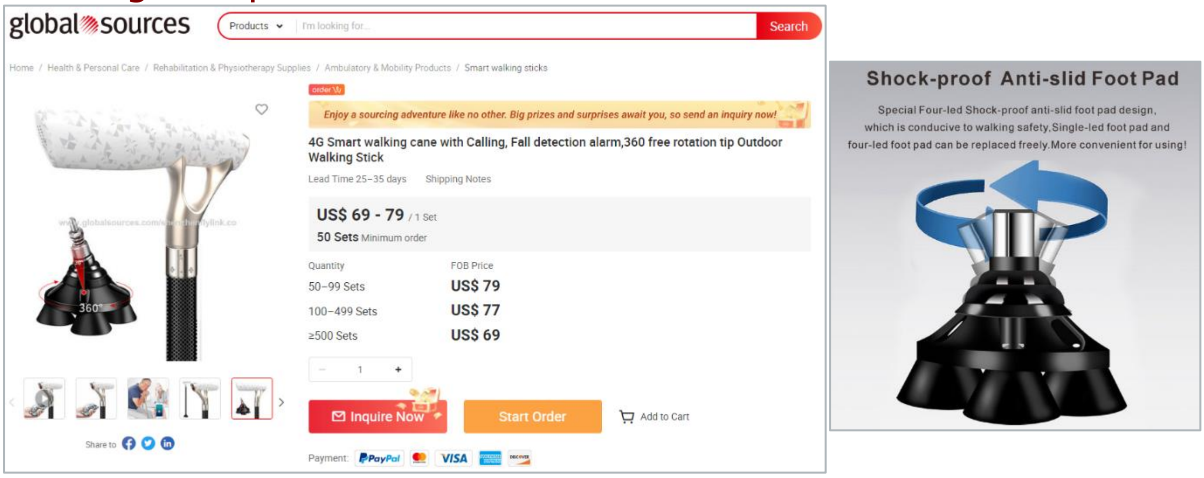


Figure 56: Existing Competitor 1

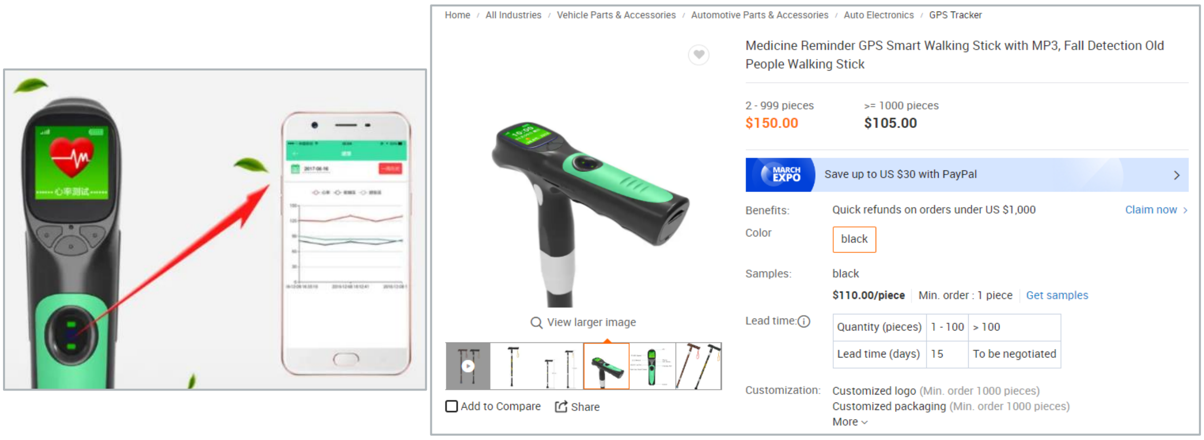


Figure 57: Existing Competitor 2

Our product has very few existing competitors, both of which are based in America; as a result, the UK market is solely ours. It is also important to note that although these two products are similar to ours; neither have our unique walking stick foot design.

The price of our competitors range from £75-£125, As a result we have matched the average competitor price and accounted for additional exportation costs allowing us to undersell our competitors. Coincidently, this closely matches our unit product cost, see in the Unit Production Cost section.

Costs

Engineering Costs

Our Engineering costs were recorded as £50 per hour for group meetings and £10 per hour for individual tasks.

To ensure a balanced workload we equally shared the hours spent on individual tasks, making sure to notify others if any support was necessary in our weekly meetings. As a result of the team's consistent hours and work we have reached 452 total hours equalling £6,600 total engineering cost.

engineering costs			
1 year forecast	1 year = 1000Units		
Task	Assigned	Time (hours)	Cost (£50/hour)
Group Team meetings = £50 per hour			
meetings	everyone	52	£ 2,600.00
individual tasks = £10 per hour			
General - System			
Customer Requirements	Melissa	20	£ 200.00
System level Requirements	Peter	20	£ 200.00
Management Plan	Joe	20	£ 200.00
Engineering Plan	Tom	20	£ 200.00
Gantt Chart	Melissa/Peter	20	£ 200.00
Preliminary Hazard Assessment	Joe	20	£ 200.00
Compliance to requirements	Melissa	20	£ 200.00
Engineering Cost	Ryan	20	£ 200.00
Work Breakdown Structure	Peter/Joe	20	£ 200.00
Unit Production Costs	Ryan	20	£ 200.00
Logistics			
Maintainability analysis (updated as re	Ryan	20	£ 200.00
Production			
PRR -Risk Assessment	Ryan/Melissa	20	£ 200.00
PRR - S.T.T.E.	Melissa	20	£ 200.00
PRR -New Processes	Melissa	20	£ 200.00
PRR -Make/Buy Plan	Ryan	20	£ 200.00
PRR -Manufacturing Flow	Tom	20	£ 200.00
PRR -Test Plan	Tom	20	£ 200.00
PRR -Procurement Plan	Ryan	20	£ 200.00
additional hours			
additional hours	ALL	40	£ 400.00
Totals			£ 6,600.00

Table 15: Engineering costs

Material Costs

The table 16 details the materials we are using to build our prototype as well as the amount per material and overall costs in comparison to our budget.

Prototype/unit					
item	Description	Vendor	Qty	Unit Cost	Total
1	Handle (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	RS UK	1	£ 6.70	£ 6.70
2	Foot (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	Sinclair & Rush	1	£ 6.70	£ 6.70
3	TOPAI WS2812B RGB LED Pixel Strip 1M 144LEDs, SMD 5050 IC 5V Individually Addressable White PCB IP20 NO-Waterproof Cuttable Smart Flexible LED Lighting	Amazon	1	£ 16.99	£ 16.99
4	sourcing map 2Pcs,12mm Red Momentary Push Button Switch Round Flat Button SPST NO	Amazon	1	£ 6.98	£ 6.98
5	EnergyQC Mini Portable Charger 5000mAh for Mobile Phone Small Power Bank Ultra-Compact External Battery Pack with 2.4A Output Compatible with Xiaomi Huawei Samsung and More	Amazon	1	£ 20.87	£ 20.87
6	StarTech.com 6in Micro USB Cable - A to Micro B - USB to Micro B - USB 2.0 A Male to USB 2.0 Micro-B Male - 6-inches - Black (UUSBHAUB6IN)	Amazon	1	£ 3.92	£ 3.92
7	Pulsesensor pulse heart rate sensor for Arduino open source hardware development pulse sensor	Amazon	1	£ 8.12	£ 8.12
8	Arduino Nano 33 IoT (with headers)	ThePiHut	1	£ 26.20	£ 26.20
9	4X Mixed Illuminated Lighted LED On/Off Rectangle Rocker Switch Car Dash 12V	Amazon	1	£ 3.45	£ 3.45
10	Intercom Buzzer, Akozon 3-24V Piezo Electronic Tone Buzzer Alarm Continuous Sound Cable Dash Warning Buzzer Length 100mm	Amazon	1	£ 3.99	£ 3.99
11	Aluminium Round Tube Pipe Metric 300mm to 1000mm Length 6mm to 31mm Diameter	Ebay	1	£ 10.99	£ 10.99
12	Aluminium Round Tube Pipe Many sizes lengths Aluminum Alloy Bar Rod Strip 1	Ebay	1	£ 13.57	£ 13.57
13	Bipolar (BJT) Single Transistor, NPN, 100 V, 6 A, 65 W, TO-220, Through Hole (1+off)	Leonardo	2	£ -	£ -
14	Through Hole Resistor, 3 Mohm, 1 W, ± 2%, Axial Leaded, 500 V (5+ off)	Leonardo	1	£ -	£ -
15	MF25 1M Through Hole Resistor, 1 Mohm, MF25, 250 mW, ± 1%, Axial Leaded, 250 V (10+ off)	Leonardo	1	£ -	£ -
16	MCRE000049 Through Hole Resistor, 10 kohm, MCRE, 125 mW, ± 5%, Axial Leaded, 200 V (5+ off)	Leonardo	2	£ -	£ -
17	MRS25000C3300FCT00 Through Hole Resistor, 330 ohm, MRS25, 600 mW, ± 1%, Axial Leaded, 350 V (10+off)	Leonardo	1	£ -	£ -
18	YR1B200RCC Through Hole Resistor, 200 ohm, R, 250 mW, ± 0.1%, Axial Leaded, 500 V (1+off)	Leonardo	1	£ -	£ -
19	ECA1VAM101X Electrolytic Capacitor, 100 µF, 35 V, ± 20%, Radial Leaded, 2000 hours @ 85°C, Polar (1+ off)	Leonardo	1	£ -	£ -
20	MCRH100V104M5X11 Electrolytic Capacitor, 0.1 µF, 100 V, ± 20%, Radial Leaded, 2000 hours @ 105°C, Polar (1+off)	Leonardo	1	£ -	£ -
21	ZXMP10A13FTA Power MOSFET, P Channel, 100 V, 700 mA, 1 ohm, SOT-23, Surface Mount	Leonardo	1	£ -	£ -
22	CFR50J1K0 Through Hole Resistor, 1 kohm, CFR, 500 mW, ± 5%, Axial Leaded, 350 V	Leonardo	1	£ -	£ -
		Total budget =	£	250.00	
		Budget used =	£	128.48	
		Budget left =	£	121.52	

Table 16: Prototype Material Costs

Just under half of our materials come from within Leonardo, this is to save money and allow for faster testing of our prototype. This will not be the case in our mass production plan for materials.

From this, we can easily identify that of the £250 we have to spend, our prototype uses £128.48, allowing for nearly half of the budget left over to go towards any additional components we may need or towards any potential solutions to any issues that arise.

mass production = 1000/1year					
item	Description	Vendor	Qty	Unit Cost	Total
1	Handle (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	RS UK	1000	£ 6.70	£ 6,700.00
2	Foot (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	Sinclair & Rush	1000	£ 6.70	£ 6,700.00
3	TOPAI WS2812B RGB LED Pixel Strip 1M 144LEDs, SMD 5050 IC 5V Individually Addressable White PCB IP20 NO-Waterproof Cuttable Smart Flexible LED Lighting	Amazon	1000	£ 16.99	£ 16,990.00
4	sourcing map 2Pcs,12mm Red Momentary Push Button Switch Round Flat Button SPST NO	Amazon	1000	£ 6.98	£ 6,980.00
5	EnergyQC Mini Portable Charger 5000mAh for Mobile Phone Small Power Bank Ultra-Compact External Battery Pack with 2.4A Output Compatible with Xiaomi Huawei Samsung and More	Amazon	1000	£ 20.87	£ 20,870.00
6	StarTech.com 6in Micro USB Cable - A to Micro B - USB to Micro B - USB 2.0 A Male to USB 2.0 Micro-B Male - 6-inches - Black (UUSBHAUB6IN)	Amazon	1000	£ 3.92	£ 3,920.00
7	Pulsesensor pulse heart rate sensor for Arduino open source hardware development pulse sensor	Amazon	1000	£ 8.12	£ 8,120.00
8	Arduino Nano 33 IoT (with headers)	ThePiHut	1000	£ 26.20	£ 26,200.00
9	4X Mixed Illuminated Lighted LED On/Off Rectangle Rocker Switch Car Dash 12V	Amazon	1000	£ 3.45	£ 3,450.00
10	Intercom Buzzer, Akozon 3-24V Piezo Electronic Tone Buzzer Alarm Continuous Sound Cable Dash Warning Buzzer Length 100mm	Amazon	1000	£ 3.99	£ 3,990.00
11	Aluminium Round Tube Pipe Metric 300mm to 1000mm Length 6mm to 31mm Diameter	Ebay	1000	£ 10.99	£ 10,990.00
12	Aluminium Round Tube Pipe Many sizes lengths Aluminum Alloy Bar Rod Strip 1	Ebay	1000	£ 13.57	£ 13,570.00
13	TIP41C Bipolar (BJT) Single Transistor, NPN, 100 V, 6 A, 65 W, TO-220, Through Hole (1+off)	Farnell	2000	£ 0.45	£ 890.00
14	MP006447 Through Hole Resistor, 3 Mohm, 1 W, ± 2%, Axial Leaded, 500 V (5+ off)	Farnell	1000	£ 0.07	£ 71.52
15	MF25 1M Through Hole Resistor, 1 Mohm, MF25, 250 mW, ± 1%, Axial Leaded, 250 V (10+ off)	Farnell	1000	£ 0.03	£ 31.74
16	MCRE000049 Through Hole Resistor, 10 kohm, MCRE, 125 mW, ± 5%, Axial Leaded, 200 V (5+ off)	Farnell	2000	£ 0.02	£ 34.50
17	MRS25000C3300FCT00 Through Hole Resistor, 330 ohm, MRS25, 600 mW, ± 1%, Axial Leaded, 350 V (10+off)	Farnell	1000	£ 0.05	£ 47.58
18	YR1B200RCC Through Hole Resistor, 200 ohm, R, 250 mW, ± 0.1%, Axial Leaded, 500 V (1+off)	Farnell	1000	£ 0.20	£ 202.80
19	ECA1VAM101X Electrolytic Capacitor, 100 µF, 35 V, ± 20%, Radial Leaded, 2000 hours @ 85°C, Polar (1+ off)	Farnell	1000	£ 0.09	£ 90.36
20	MCRH100V104M5X11 Electrolytic Capacitor, 0.1 µF, 100 V, ± 20%, Radial Leaded, 2000 hours @ 105°C, Polar (1+off)	Farnell	1000	£ 0.04	£ 37.14
21	ZXMP10A13FTA Power MOSFET, P Channel, 100 V, 700 mA, 1 ohm, SOT-23, Surface Mount	Farnell	1000	£ 0.24	£ 235.20
22	CFR50J1K0 Through Hole Resistor, 1 kohm, CFR, 500 mW, ± 5%, Axial Leaded, 350 V	Farnell	1000	£ 0.03	£ 32.82
	Total budget =	£ 250,000.00			
	Budget used =	£ 130,153.66			
	Budget left =	£ 119,846.34			

Table 17: Mass Production Material costs

The table 17 details the material cost for our mass production plan in the first year.

Changes between the prototype plan and mass production plan include the switch from Leonardo as a supplier over to Farnell, allowing for easier purchase when buying in bulk. From the supplier switch, our overall spend has increased and the remaining budget has decreased.

As presented in the above table the total spend is £130,135.66 leaving us with the remaining budget of £119,816.34 for our first year, the remaining budget will be saved in case of issues and possible further research and development of our product to expand our walking stick range in the future.

Unit Production Cost

Unit production costs		
labour	£ 4.00	
engineering/fixed		£ 4.00
material cost	£ 129.69	
distribution	£ 5.00	
variable cost		£ 134.69
unit production cost		£ 138.69

Figure 58: Unit Production Costs

Figure 58 details the unit production cost of each product, which will be used for when we estimate our mass production sales.

The labour cost was calculated using the total individual task costings detailed in table 15 and divide by 1000 to get the cost spent on a single product.

Material cost was calculated through the unit price of each material it takes to manufacture 1 product, refer to table 16.

Distribution was estimated at £5 per product.

All of this totalled £138.69

Selling Price

Using the unit production cost of the product we can easily identify a selling price.

For our first year, we will be using competitive and psychological pricing disguised as promotional pricing. Using this method, our selling price for the first year will be £139.99 per product.

After the first year we will remove our "first year promotion" and switch to our before discount price which has been identified with the use of cost-plus and psychological pricing. The percentage profit over cost chosen was 53% resulting in a cost-plus price of £212.20 that was then increased to £214.99 with the use of psychological pricing.

From this, we have decided to sell at:

1st year = £139.99

2nd year =£214.99

Financial Projections & 10 Year Plan

Sales estimates

year	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
Units	1000	2500	4000	5500	7000	8500	10000	11500	13000	14500
Unit production cost	£ 138,691.41	£ 346,728.53	£ 554,765.64	£ 762,802.76	£ 970,839.87	£ 1,178,876.99	£ 1,386,914.10	£ 1,594,951.22	£ 1,802,988.33	£ 2,011,025.45
Additional Costs										
patent attorney	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00	£ 72,000.00
machinery/equipment	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00	£ 50,000.00
warehouse	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00	£ 24,338.00
promotion	£ 15,000.00	£ 20,000.00	£ 20,000.00	£ 50,000.00	£ 100,000.00	£ 100,000.00	£ 100,000.00	£ 100,000.00	£ 100,000.00	£ 100,000.00
P/L rollover MAX	£ -	£ 160,039.41	£ 135,630.94	-£ 3,225.42	-£ 226,529.67	-£ 514,281.80	-£ 916,481.81	-£ 1,433,129.72	-£ 2,064,225.50	-£ 2,809,769.17
total costs (MAX)	£ 300,029.41	£ 673,105.94	£ 856,734.58	£ 955,915.33	£ 990,648.20	£ 910,933.19	£ 716,770.29	£ 408,159.50	-£ 14,899.17	-£ 552,405.72
Variance 5% (MIN)	£ 285,027.94	£ 639,450.64	£ 813,897.85	£ 908,119.56	£ 941,115.79	£ 865,386.53	£ 680,931.77	£ 387,751.53	-£ 14,154.21	-£ 524,785.44
sales	£ 139,990.00	£ 537,475.00	£ 859,960.00	£ 1,182,445.00	£ 1,504,930.00	£ 1,827,415.00	£ 2,149,900.00	£ 2,472,385.00	£ 2,794,870.00	£ 3,117,355.00
gross profit	-£ 160,039.41	-£ 135,630.94	£ 3,225.42	£ 226,529.67	£ 514,281.80	£ 916,481.81	£ 1,433,129.72	£ 2,064,225.50	£ 2,809,769.17	£ 3,669,760.73
gross profit	-£ 145,037.94	-£ 101,975.64	£ 46,062.15	£ 274,325.44	£ 563,814.21	£ 962,028.47	£ 1,468,968.23	£ 2,084,633.48	£ 2,809,024.21	£ 3,642,140.44

Figure 59: Sales estimates

The above table displays the sale estimates for our first 10 years of mass production. The table details the units sold, the UPC, additional fixed costs, profit and loss rollover. Costs are totalled and a variance of 5% is accounted for. The max cost is taken away from our sales to give us our max and minimum gross profit for the year.

As presented in the table we are in a loss for the first 2 years however, during the 3rd year we will break even and by the end of the year turn a positive gross profit for both max and minimum.

These sales estimates include a profit and loss rollover. This will be changed when we go into production and will help scale the business, contributing towards future expansion.

Breakeven

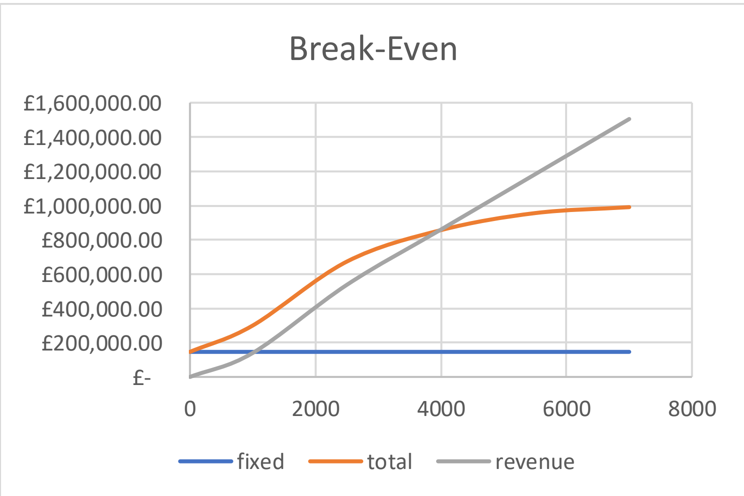


Figure 60: Breakeven Projection

Figure 60 demonstrates our sales in accordance to our fixed and variable costs.

From this graph we have identified that we break even on our 3945 product sold, making a profit on the 3946 product. This is further evidenced in the sales estimate.

Make and Buy Plan

When creating a product it is important to note the liability of the product and to assess whether we should buy or make our parts. Buying parts will reduce liability but increase costs, while making parts will reduce costs but increase liability. This led to the decision to split the product into buying and making parts, this will reduce the liability and the total costs.

MAKE/BUY = Prototype/unit				
item	Description	make/buy	Qty	Vendor
1	Handle (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	Make	1	RS UK
2	Foot (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	Make	1	Sinclair & Rush
3	TOPAI WS2812B RGB LED Pixel Strip 1M 144LEDs, SMD 5050 IC 5V Individually Addressable White PCB IP20 NO-Waterproof Cuttable Smart Flexible LED Lighting	BUY	1	Amazon
4	sourcing map 2Pcs,12mm Red Momentary Push Button Switch Round Flat Button SPST NO	BUY	1	Amazon
5	EnergyQC Mini Portable Charger 5000mAh for Mobile Phone Small Power Bank Ultra-Compact External Battery Pack with 2.4A Output Compatible with Xiaomi Huawei Samsung and More	BUY	1	Amazon
6	StarTech.com 6in Micro USB Cable - A to Micro B - USB to Micro B - USB 2.0 A Male to USB 2.0 Micro-B Male - 6-inches - Black (UUSBHAUB6IN)	BUY	1	Amazon
7	Pulsesensor pulse heart rate sensor for Arduino open source hardware development pulse sensor	BUY	1	Amazon
8	Arduino Nano 33 IoT (with headers)	BUY	1	ThePiHut
9	4X Mixed Illuminated Lighted LED On/Off Rectangle Rocker Switch Car Dash 12V	BUY	1	Amazon
10	Intercom Buzzer, Akozon 3-24V Piezo Electronic Tone Buzzer Alarm Continuous Sound Cable Dash Warning Buzzer Length 100mm	BUY	1	Amazon
11	Aluminium Round Tube Pipe Metric 300mm to 1000mm Length 6mm to 31mm Diameter	BUY	1	Ebay
12	Aluminium Round Tube Pipe Many sizes lengths Aluminum Alloy Bar Rod Strip 1	BUY	1	Ebay
13	Bipolar (BJT) Single Transistor, NPN, 100 V, 6 A, 65 W, TO-220, Through Hole (1+off)	BUY	2	Farnell
14	Through Hole Resistor, 3 Mohm, 1 W, ± 2%, Axial Leaded, 500 V (5+ off)	BUY	1	Farnell
15	MF25 1M Through Hole Resistor, 1 Mohm, MF25, 250 mW, ± 1%, Axial Leaded, 250 V (10+ off)	BUY	1	Farnell
16	MCRE000049 Through Hole Resistor, 10 kohm, MCRE, 125 mW, ± 5%, Axial Leaded, 200 V (5+ off)	BUY	2	Farnell
17	MRS25000C3300FCT00 Through Hole Resistor, 330 ohm, MRS25, 600 mW, ± 1%, Axial Leaded, 350 V (10+off)	BUY	1	Farnell
18	YR1B200RCC Through Hole Resistor, 200 ohm, R, 250 mW, ± 0.1%, Axial Leaded, 500 V (1+off)	BUY	1	Farnell
19	ECA1VAM101X Electrolytic Capacitor, 100 µF, 35 V, ± 20%, Radial Leaded, 2000 hours @ 85°C, Polar (1+ off)	BUY	1	Farnell
20	MCRH100V104M5X11 Electrolytic Capacitor, 0.1 µF, 100 V, ± 20%, Radial Leaded, 2000 hours @ 105°C, Polar (1+off)	BUY	1	Farnell
21	ZXMP10A13FTA Power MOSFET, P Channel, 100 V, 700 mA, 1 ohm, SOT-23, Surface Mount	BUY	1	Farnell
22	CFR50J1K0 Through Hole Resistor, 1 kohm, CFR, 500 mW, ± 5%, Axial Leaded, 350 V	BUY	1	Farnell

Figure 61: Make/Buy Plan

Key:

Green –we will make the part ourselves

Red – we will purchase the part

Amber – we will change our process between the prototype and mass production. For example, the parts we currently get from Leonardo will switch to Farnell for our mass production.

Resource Availability

item	Description	Vendor	Qty	Unit Cost	Total	BACK UP VENDORS 1	Qty	Unit Cost	Total	BACK UP VENDORS 2	Qty	Unit Cost	Total	BACK UP VENDORS 3	Qty	Unit Cost	Total
1	Handle (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	RS UK	1	£ 6.70	£ 6.70	Farnell	1	£ 6.46	£ 6.46	amazon	1	£ 14.99	£ 14.99	123-3D.co.uk	1	£ 3.74	£ 3.74
2	Foot (3D Printed – RS PRO 1.75mm random colour PLA 3D Printer Filament 250g 2017435	Sinclair & Rush	1	£ 6.70	£ 6.70	Farnell	1	£ 6.46	£ 6.46	amazon	1	£ 14.99	£ 14.99	123-3D.co.uk	1	£ 3.74	£ 3.74
3	TOPAI WS2812B RGB LED Pixel Strip 1M 144LEDs, SMD 5050 IC 5V Individually Addressable White PCB IP20 NO-Waterproof Cuttable Sm	Amazon	1	£ 16.99	£ 16.99	LEDspace	1	£ 22.50	£ 22.50	Pimoroni.com	1	£ 26.40	£ 26.40	fruugo.co.uk	1	£ 14.95	£ 14.95
4	sourcing map 2Pcs,12mm Red Momentary Push Button Switch Round Flat Button SPST NO	Amazon	1	£ 6.98	£ 6.98	switch electronics	1	£ 0.85	£ 0.85	Farnell	1	£ 1.08	£ 1.08	RS UK	1	£ 3.65	£ 3.65
5	EnergyQC Mini Portable Charger 5000mAh for Mobile Phone Small Power Bank Ultra-Compact External Battery Pack with 2.4A Output C	Amazon	1	£ 20.87	£ 20.87	UK Banggood	1	£ 10.55	£ 10.55	Argos	1	£ 15.99	£ 15.99	Living social	1	£ 6.99	£ 6.99
6	StarTech.com 6in Micro USB Cable - A to Micro B - USB to Micro B - USB 2.0 A Male to USB 2.0 Micro-B Male - 6-inches - Black (UUSBHAU	Amazon	1	£ 3.92	£ 3.92	parkem.co.uk	1	£ 4.99	£ 4.99	CPC	1	£ 4.14	£ 4.14	Zoro tools	1	£ 1.19	£ 1.19
7	Pulsesensor pulse heart rate sensor for Arduino open source hardware development pulse sensor	Amazon	1	£ 8.12	£ 8.12	Mediapress	1	£ 9.59	£ 9.59	Robotshop.com	1	£ 9.72	£ 9.72	Pimoroni	1	£ 21.00	£ 21.00
8	Arduino Nano 33 IoT (with headers)	ThePiHut	1	£ 26.20	£ 26.20	farnell	1	£ 21.42	£ 21.42	Amazon	1	£ 29.99	£ 29.99	RS UK	1	£ 23.62	£ 23.62
9	4X Mixed Illuminated Lighted LED On/Off Rectangle Rocker Switch Car Dash 12V	Amazon	1	£ 3.45	£ 3.45	switch electronics	4	£ 1.00	£ 4.00	CPC	4	£ 2.52	£ 10.08	RS UK	4	£ 3.71	£ 14.84
10	Intercom Buzzer, Akozon 3-24V Piezo Electronic Tone Buzzer Alarm Continuous Sound Cable Dash Warning Buzzer Length 100mm	Amazon	1	£ 3.99	£ 3.99	Farnell	1	£ 0.43	£ 0.43	CPC	1	£ 2.80	£ 2.80	RS UK	1	£ 4.70	£ 4.70
11	Aluminium Round Tube Pipe Metric 300mm to 1000mm Length 6mm to 31mm Diameter	Ebay	1	£ 10.99	£ 10.99	metals4u.co.uk	1	35.62	£ 35.62	pipe dream fittings	1	4.79	£ 4.79	RS UK	1	49.19	£ 49.19
12	Aluminium Round Tube Pipe Many sizes lengths Aluminum Alloy Bar Rod Strip 1	Ebay	1	£ 13.57	£ 13.57	tube clamps direct	1	£ 9.42	£ 9.42	1st choice metals	1	£ 3.07	£ 3.07	the metal store	1	£ 3.07	£ 3.07
13	Bipolar (BJT) Single Transistor, NPN, 100 V, 6 A, 65 W, TO-220, Through Hole	Farnell	2	£ 0.45	£ 0.9	Digi-Key UK	2	£ 1.24	£ 2.48	CPC	2	£ 0.77	£ 1.54	RS UK	2	£ 0.06	£ 0.12
14	Through Hole Resistor, 3 Mohm, 1 W, ± 2%, Axial Leaded, 500 V	Farnell	1	£ 0.07	£ 0.07	Digi-Key UK	1	£ 2.22	£ 2.22	CPC	1	£ 0.14	£ 0.14	RS UK	1	£ 0.02	£ 0.02
15	MF25 1M Through Hole Resistor, 1 Mohm, MF25, 250 mW, ± 1%, Axial Leaded, 250 V	Farnell	2	£ 0.03	£ 0.06	Digi-Key UK	1	£ 0.11	£ 0.11	CPC	1	£ 1.25	£ 1.25	RS UK	1	£ 3.48	£ 3.48
16	MCRE000049 Through Hole Resistor, 10 kohm, MCRE, 125 mW, ± 5%, Axial Leaded, 200 V	Farnell	2	£ 0.02	£ 0.03	Digi-Key UK	2	£ 0.78	£ 1.56	CPC	2	£ 1.02	£ 2.04	RS UK	2	£ 0.06	£ 0.12
17	MRS25000C3300FCT00 Through Hole Resistor, 330 ohm, MRS25, 600 mW, ± 1%, Axial Leaded, 350 V	Farnell	1	£ 0.05	£ 0.05	Digi-Key UK	1	£ 18.26	£ 18.26	CPC	1	£ 1.93	£ 1.93	RS UK	1	£ 0.08	£ 0.08
18	YR1B200RCC Through Hole Resistor, 200 ohm, R, 250 mW, ± 0.1%, Axial Leaded, 500 V	Farnell	1	£ 0.20	£ 0.20	Digi-Key UK	1	£ 1.61	£ 1.61	CPC	1	£ 1.01	£ 1.01	RS UK	1	£ 0.05	£ 0.05
19	ECA1VAM101X Electrolytic Capacitor, 100 µF, 35 V, ± 20%, Radial Leaded, 2000 hours @ 85°C, Polar	Farnell	1	£ 0.09	£ 0.09	Digi-Key UK	1	£ 0.10	£ 0.10	CPC	1	£ 0.62	£ 0.62	switch electronics	1	£ 0.29	£ 0.29
20	MCRH100V104M5X11 Electrolytic Capacitor, 0.1 µF, 100 V, ± 20%, Radial Leaded, 2000 hours @ 105°C, Polar	Farnell	1	£ 0.04	£ 0.04	Digi-Key UK	1	£ 0.64	£ 0.64	CPC	1	£ 0.06	£ 0.06	switch electronics	1	£ 0.40	£ 0.40
21	ZXMP10A13FTA Power MOSFET, P Channel, 100 V, 700 mA, 1 ohm, SOT-23, Surface Mount	Farnell	1	£ 0.58	£ 0.58	switch electronics	1	£ 0.41	£ 0.41	mouser UK	1	£ 0.38	£ 0.38	RS UK	1	£ 2.29	£ 2.29
22	CFR50J1K0 Through Hole Resistor, 1 kohm, CFR, 500 mW, ± 5%, Axial Leaded, 350 V	Farnell	1	£ 0.15	£ 0.15	Digi-Key UK	1	£ 0.67	£ 0.67	Cricklewoodeletronics	1	£ 0.60	£ 0.60	RS UK	1	£ 1.62	£ 1.62
	Total budget =	£ 250.00				£ 250.00				£ 250.00				£ 250.00			
	Budget used =	£ 130.64				£ 160.35				£ 147.61				£ 159.15			
	Budget left =	£ 119.36				£ 89.65				£ 102.39				£ 90.85			

Table 18: Backup Suppliers

As presented in the table above it is clear to see that there is a high amount of resource availability with multiple choices of back up suppliers.

However, as shown in table 18, our current suppliers offer the most quality and cost effective materials.

Critical Suppliers and Materials

Our critical suppliers are Amazon and Farnell for when we enter mass production. Our team chose these two suppliers based on their price, risk and history, looking at what they can provide and how much at one time, whilst also accounting for the risk of the supplier going bust/obsolete. Other back-up suppliers covered in table 18 will have to go through a capability assessment (refer to Purchasing Contracts & Quality Plan) before being considered a critical supplier.

All materials presented in table 16 are critical materials required to produce a single walking stick, the way we plan to ensure material quality and avoid counterfeit material is through a purchasing contract (refer to Purchasing Contracts & Quality Plan).

Maintainability Analysis

Red

- Stick snapping after long-term use – depending on where the stick breaks it may be fixable or a new one may need purchasing, in both cases we will have to fix it for the customer.

Yellow

- LED light strip stops working – this can be for a number of reasons however the reason should be obvious for the user e.g. power = recharge / broken LED = replacement (the LED breaking is unlikely as there will be protection to avoid it smashing.
- In the case the buzzer no longer works, customers may need to send the stick back to us so that we may fit a new one in.
- Inaccurate heart rate sensor results – this may occur after long-term use and the sensor has worn down. A replacement may be needed.

Green

- Due to foot and handle being 3D printed, may lead to short lifespan if walking stick is continually dropped – this would require a replacement part being made and sent to the customer or alternatively spares are sent when purchased
- App connectivity could lose connection – this could be due to a number of reason the majority lies in the users' personal router for an easy fix.
- Colour of plastic could fade overtime – this can be fixed by recolouring, this can be done by the user or by us.
- Loss of power – due to a use of a power bank this is an easy fix with the user just needing to charge the walking stick.
- Adjustability setting stuck – easy to fix/unjam.

In conclusion, it is clear the smart walking stick is a fairly easy to maintain. The current life expectancy of Smart Step stick is three to seven years, depending on the amount of times it is dropped within that time. As a result, this means none of the above maintainability risks will arise, until after that time period, and thus does not reduce the value of the overall product.

Purchasing Contracts & Quality Plan

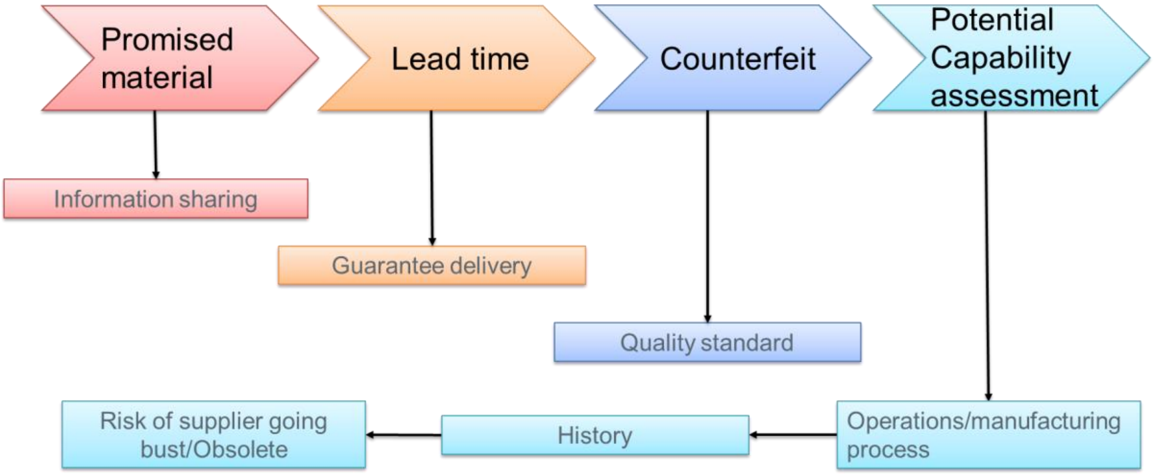


Figure 62: Purchasing Contract

When contacting a supplier for the first time we will send them a purchasing contract, which details the promised material, lead-time, counterfeit and a potential capability assessment.

- Promised material: allows for clear communication between us and the supplier, by having the material known early, talks between us and the supplier can happen faster and there will be no confusion over what we want from them.
- Lead-time: allows for a guaranteed delivery, within reason, by putting a condition on the lead-time the supplier is encouraged to keep to the promised timelines. There are exceptions for when the supplier does not meet the delivery date if an acceptable reason is given. The lead-time will be discussed and agreed on by both the parties.
- Counterfeit: By having a counterfeit clause we can ensure that parts being sold are of an acceptable quality, having been tested and accepted before being sent.
- Potential capability assessment: the capability assessment will cover the operations/manufacturing process, history of the supplier and risk of the supplier going bust/obsolete. Once the capability assessment has been completed, we will have a better understanding of our supplier and a better idea if they are a risk or opportunity. By gaining more knowledge on our supplier, we can also build trust and benefits in the longer term.

Having a purchasing contract in place allows for an effective quality plan, this is due to the contract ensuring that the supplier is up to our standard, their parts sold are of an acceptable quality. This ensures that the product we manufacture is of a high quality with a longer life expectancy.

Marketing

The ways we will promote our product are through partnerships with various charities and organisations. For example:

- Age UK
- Carers UK
- The Partially Sighted Society
- Guide Dogs
- Alzheimer's Society
- Scope
- NHS
- Team Trees
- Which?

The two partnerships we will focus on are the NHS and Team Trees. The reason for this is to allow for more efficient carbon offsetting. As well as having a partnership with one of the biggest providers of walking sticks. Our company wishes to reach a point with the NHS where they recommend our walking stick the same way dentists recommend Oral-B. Other forms of promotion we will cover are: newspapers, leaflets, word of mouth and advertisements.

Sustainability

We have looked at sustainable/environmentally friendly 3D printing materials. After further research we have decided to implement this material further down the line of our operations. However, we will have to perform repeat testing before we make the switch.

We also plan to implement carbon offsetting in our product where for every product we manufacturer, we will work with Team Trees to plant a tree, by doing this we can counter the carbon we create when manufacturing our product. If our 1st year forecast goes as planned (refer to Sales estimates) we would have planted 1000 trees in our 1st year of operations.

Final Summary

Final Proposal

The final concept of our smart walking stick (Figure 28: Whole Assembly Render) embodies our vision to provide a comprehensive and user-centric solution for individuals in need of walking assistance. With the walking stick's extensive range of features, it aims to improve safety, enhance mobility, and empower users to confidently navigate their daily lives. By addressing the specific needs and preferences of our target market, we believe that our final concept has the potential to revolutionise the walking stick industry and make a positive impact on the lives of those who rely on walking aids for support and independence.

Unique Characteristics

The Step Smart walking stick boasts a wide range of features, many of which are unique. Table 19 summarises the final feature list.

Feature	Unique	Justification
Fall detection	×	Based on research this technology has been developed before.
Heart rate monitoring	×	Based on research this technology has been developed before.
Height adjustability	×	This is almost expected from a walking stick.
Light / torch	-	Although other walking sticks have included lights, we feel we have taken this further by using a more modern LED strip, which displays colour and has more functionality that *just* a torch.
Alarm / buzzer	-	Some existing smart sticks have alarms, but we hope to develop this further and allow extra customisation for the user, allowing them to set their own tones and volume.
App compatibility	-	Once again, other sticks are being sold with app compatibility, however we feel we are taking this further, with more customisation and integration.
"Lost Mode"	√	This is a feature we will develop from scratch, and feel will be a valuable feature for our users.
Self-righting foot design	√	This distinctive feature sets it apart from traditional designs, enhancing usability and providing unmatched convenience for users.

Table 19: Feature List

Conclusion

Throughout our journey in developing this smart walking stick, our team has embarked on a remarkable exploration of innovation and collaboration. Guided by our passion for enhancing the lives of individuals in need, we have meticulously crafted a business case that showcases the immense potential of our product. This summary encapsulates the valuable lessons we have learned, the joys we have experienced, the challenges we have overcome, and the insights we have gained for future endeavours.

One of our key strengths was our exceptional organisation and efficient workflow management. By utilising tools such as Confluence and OneNote, we established a centralised platform for accessing shared files and fostering effective communication. Adopting agile methodology enabled us to adapt swiftly to changing requirements and prioritise tasks effectively. Regular team retrospectives allowed us to reflect on our progress, identifying areas for improvement, and implementing necessary adjustments. As a result, we maintained a structured and streamlined development process.

In our pursuit of excellence, we consistently went above and beyond. Conducting extensive market research, we delved into Amazon comments and engaged with potential users to gain valuable insights and refine our product offering. Recognising the importance of adhering to safety standards, we proactively reached out to organisations such as BSI to ensure our walking stick complies with industry regulations. Embracing innovation, we leveraged 3D printing technology to finalise our unique walking stick foot design, which has the potential to revolutionise the user experience and holds promise for future patent opportunities.

Our meticulous reviews and rigorous testing processes yielded outstanding results. The team passed all our internal assessments, receiving excellent feedback across the board. This validation not only affirms the quality of our product, but also instils confidence in our ability to deliver an exceptional user experience.

While our journey was filled with accomplishments, we encountered challenges along the way. Initially lacking expertise in manufacturing proved to be a hurdle, but it presented a valuable opportunity for team members to expand their knowledge and skills in previously unfamiliar areas. Embracing the learning mind-set, we actively sought resources, engaged in self-directed learning, and collaborated with external experts to overcome obstacles. This expertise not only strengthened our capabilities but also showcased our resilience and adaptability as a team.

As we conclude this report, we are excited about the next stage of our journey: generating a fully functional prototype of the Step Smart walking stick. Our comprehensive business case, coupled with the valuable lessons and solid foundation we have established, positions us for success in bringing this innovative product to market. With an unwavering commitment to excellence and a passion for enhancing the lives of our users, we are confident that the Step Smart walking stick will make significant impact in the realm of home automation and user safety.

References

The team has put an incredible amount of effort into these supporting documents, so we strongly advise you to read them too.

COUNCIL OF THE EUROPEAN COMMUNITIES. (1993, June 19). *Council Directive 93/42/EEC of 14 June 1993 concerning medical devices*. Retrieved from Legislation.gov.uk: https://www.legislation.gov.uk/eudr/1993/42/introduction

EUROPEAN UNION. (2020, December 8). *The Medical Devices (Amendment etc.) (EU Exit) Regulations 2020*. Retrieved from Legislation.gov.uk: https://www.legislation.gov.uk/uksi/2020/1478/introduction/made

Hobbs, M. (2023). *Customer Requirements.*

Hobbs, M. (2023). *Ergonomics Research.*

Hobbs, M. (2023). *Ergonomics Research.*

Hobbs, M. (2023). *Producibiltiy Plan.*

Hobbs, M. (2023). *Product Qualification and Acceptance Plans.*

Metcalfe, P. (2023). *PUCH Matrix Diagram.*

Metcalfe, P. (2023). *System Requirements.*

Rickards, R. (2023). *Manuafcturing Risk Assesment.*

Team:It'sAllUnderControl. (2023). *CDR Presentation.*

Team:It'sAllUnderControl. (2023). *Gantt Chart.*

Team:It'sAllUnderControl. (2023). *PDR Presentation.*

Team:It'sAllUnderControl. (2023). *SDR Presentation.*

Warren Duce. (2017, December 6). *What is the Cause of Frequent Falls in the Elderly?* Retrieved from Hello Care: https://hellocare.com.au/cause-frequent-falls-elderly/

Appendix

Please see appendices listed below. These are additional figures referenced in the report, but located here for ease of reading (see following pages).

Figure 63: SDR Certificate

LEONARDO ELECTRONICS

Internal Use Only

DEV076-T-CO rev. 00.00
Template
November 2015

DESIGN REVIEW CERTIFICATE

Project Name: **IMechE Home Automation Challenge**		Line of Business: **Electronic Warfare**	
SAP Project ID: **n/a**	SAP Milestone ID: **n/a**	Review Date:	21/03/23
Design Review Identifier:	SDR Initial Review	Engineering Lifecycle Phase:	System Design
		TRL/SRL:	n/a
Design Authority:	n/a	Design Review Chair:	**Rob Armstrong**
Project Manager:	**Peter Metcalfe**	Phase/Gate Review Chair:	**n/a**

Main Issues assessed for this Review — Continue on new page if necessary

Product requirements and capture of compliance with requirements
Selection of solution
Initial market intelligence/business case
Resource plan/schedule
Costs; NRE, UPC
Make vs. buy; Procurement planning
Preliminary hazard assessment

Main Outstanding Actions (refer to Action Tracking Log for others) — Continue on new page if necessary

n/a

Overall Status of Product and Risks — Continue on new page if necessary

The team have made a very strong start to the Challenge.
Considered pros and cons of ideas; used an external reviewer & Pugh Matrix, selected Smart Walking stick. Have done some market research.
Amazon reviews of similar products used to generate customer requirements…good idea! Separate docuent produced.
System requirements derived from customer requirements.
The team are using the "Agile" approach, and are very well organised. They are making use of Confluence.
The Non-Recurring Engineering costs have been captured to-date, but need to be forecast for the full project.
Need to consider how you will test your product to ensure it meets the requirements (design proving) and has been manufactured correctly (production test)
Procurement plan needs to be produced for both protoype and production.

Review Results (Please strike out as appropriate)	Engineering Planning	Resources	Requirements	Solution Compliance	Test and Qualification
This review has PASSED	☐	☐	☐	☐	☐
If FAILED select one box for the most important reason for failure	Design for Manufacturing ☐	Supply Chain Capability ☐	Safety / Environmental ☐	Design for Supportability ☐	

Recommendations (If failed include date for follow on review) — Continue on new page if necessary

Calculate your Engineering costs for the full project
Make sure you consider the final product as well as the prototype
Create a more detailed Test Plan

Design Review Chair	**Rob Armstrong**		Date	**24/03/23**
Project Engineering Lead/Mgr	**Peter Metcalfe**		Date	
It is confirmed that all critical outstanding actions have been completed and a pass has been approved				
Design Review Chair			Date	

Template: DEV076-T-CO rev.00
Related Process DEV005-P-CO
(Proc. QUA005-P-CO)

Page 1 of 1

Figure 64: PDR Certificate

LEONARDO ELECTRONICS

Internal Use Only

DEV076-T-CO rev. 00.00
Template
November 2015

DESIGN REVIEW CERTIFICATE

Project Name: **IMechE Home Automation Challenge**		Line of Business: **Electronic Warfare**	
SAP Project ID: **n/a**	SAP Milestone ID: **n/a**	Review Date:	**10/05/2023**
Design Review Identifier:	PDR Initial Review	Engineering Lifecycle Phase:	Analyse Develop
		TRL/SRL:	n/a
Design Authority:	n/a	Design Review Chair:	**Rob Armstrong**
Project Manager:	**Peter Metcalfe**	Phase/Gate Review Chair:	**n/a**

Main Issues assessed for this Review — Continue on new page if necessary

Product requirements and capture of compliance with requirements
Risk & Opportunity understood
Market intelligence/business case
Resource plan/schedule
Costs; NRE, UPC
Electrical, Mechanical & Software design maturity
Test strategy
Manufacturing plan; labour costs, facilities, equipment, processes
Make vs. buy; Procurement planning
Hazard assessment

Main Outstanding Actions (refer to Action Tracking Log for others) — Continue on new page if necessary

Calculate your Engineering costs for the full project - Complete
Make sure you consider the final product as well as the prototype - Complete
Create a more detailed Test Plan - Complete

Overall Status of Product and Risks — Continue on new page if necessary

The team have continued to develop their smart walking stick concept, using the Agile methodology. They have already produced some prototypes in order to test the functionality of the product, and have some novel ideas regarding the self-righting mechanism to allow easy pick-up of a dropped stick.
The electrical design is already quite mature. Tests have been identified against product requirements. The team also need to consider production test, in order to ensure correct build of the product.
The Procurement Plan considers both the prototype and the final product.
Significant thought has been put into the size and layout of the production facility.

Review Results (Please strike out as appropriate)					
This review has PASSED	Engineering Planning ☐	Resources ☐	Requirements ☐	Solution Compliance ☐	Test and Qualification ☐
If FAILED select one box for the most important reason for failure	Design for Manufacturing ☐	Supply Chain Capability ☐	Safety / Environmental ☐	Design for Supportability ☐	

Recommendations (If failed include date for follow on review) — Continue on new page if necessary

Remove team meetings from Unit Production Cost calculations
Consider what tests should be performed for quality control of the product in manufacture

Design Review Chair	**Rob Armstrong**	[signature]	Date	**11/05/2022**
Project Engineering Lead/Mgr	**Peter Metcalfe**		Date	
Quality Assurance (Italy Only)	n/a		Date	
It is confirmed that all critical outstanding actions have been completed and a pass has been approved				
Design Review Chair			Date	

Some text has further information - Hover over to check — **Add pages as required**

Template: DEV076-T-CO rev.00
Related Process DEV005-P-CO
(Proc. QUA005-P-CO)

Page 1 of 1

Figure 65: CDR Certificate

Company Internal

LEONARDO ELECTRONICS

Internal Use Only

DEV076-T-CO rev. 00.00
Template
November 2015

DESIGN REVIEW CERTIFICATE

Project Name: **IMechE Home Automation Challenge**		Line of Business: **Electronic Warfare**	
SAP Project ID: **n/a**	SAP Milestone ID: **n/a**	Review Date:	12/06/23
Design Review Identifier:	CDR Initial Review	Engineering Lifecycle Phase:	Design Freeze
		TRL/SRL:	n/a
Design Authority:	**n/a**	Design Review Chair:	**Rob Armstrong**
Project Manager:	**Peter Metcalfe**	Phase/Gate Review Chair:	**n/a**

Main Issues assessed for this Review — Continue on new page if necessary

- Product requirements and capture of compliance with requirements
- Risk management plan
- Market intelligence/business case
- Resource plan/schedule
- Hazard assessment
- Costs; NRE, UPC
- Detailed Electrical/Mechanical/Software design
- Test strategy
- Maintainability analysis
- Make vs. buy; Procurement planning
- Manufacturing considerations; DFM, processes, facilities, logistics

Main Outstanding Actions (refer to Action Tracking Log for others) — Continue on new page if necessary

Remove team meetings from Unit Production Cost calculations - COMPLETE
Consider what tests should be performed for quality control of the product in manufacture - COMPLETE

Overall Status of Product and Risks — Continue on new page if necessary

The team have continued to make good progress on their product (Smart Walking Stick). They have successfully covered all aspects of the CDR review. They have produced detailed designs against their electrical, mechanical and software requirements. They have contacted BSI to understand applicable standards for their product. Parts have been ordered for their prototype, with most already received. They have considered commercial contracting arrangements with suppliers, as well as alternative vendors. They have built a strong business case for the product. They have considered environmental aspects, e.g. the sustainability of their packaging. They have thought through how to manufacture the product, including factory layout and design for manufacture.

Review Results (Please strike out as appropriate)

This review has PASSED
If FAILED select one box for the most important reason for failure

Engineering Planning	Resources	Requirements	Solution Compliance	Test and Qualification
☐	☐	☐	☐	☐
Design for Manufacturing	**Supply Chain Capability**	**Safety / Environmental**	**Design for Supportability**	
☐	☐	☐	☐	

Recommendations (If failed include date for follow on review) — Continue on new page if necessary

Carry out stress analysis for the stick
Focus on completion of the project report for submission
- Ensure the report is concise whilst showcasing the hard work you have put in
- Let Rob review it before you submit it

Prepare for TRR to review maturity of product validation against requirements

Design Review Chair	**Rob Armstrong**		Date	**13/06/2023**
Project Engineering Lead/Mgr	**Peter Metcalfe**		Date	
Quality Assurance (Italy Only)	**n/a**		Date	
It is confirmed that all critical outstanding actions have been completed and a pass has been approved				
Design Review Chair			Date	

Some text has further information - Hover over to check — **Add pages as required**

Template: DEV076-T-CO rev.00
Related Process DEV005-P-CO
(Proc. QUA005-P-CO)

Page 1 of 1

Company Internal

Table 20: Failure Models and Effects Analysis

Part/number	Potential failure mode	Potential failure effect	Sev (S) 01-Oct	Potential causes	Occ (O) 01-Oct	Controls	Det (D) 01-Oct	RPN	Actions (if any)
Toggle switches	Bent pins	Fails to switch power on/off	1	Poor soldering Poor Procurement	9	ATP-001 ATP-003-001/003	1	9	Inspection
	Jammed/stuck	Torch fails or cannot be turned off	8	Contamination	3		1	24	replace if necessary
	Contamination		4		3	Visual Inspections,	1	12	
	Poor connection /soldering		7		4		1	28	Storage correctly
Arduino	Burnt out IC's	Fails to power up	8	Voltage, Ampere, resistance miscalculation	2	ATP-001 & ATP 004	6	96	Correct storage, inspection and functionality test
	FOD	Shorts	2		2		6	12	
	ESD	cannot connect to other devices	2		2	Electrical tests, Lab policies, inspection	6	12	
	Bent pins		1		9		1	9	
	Damage connectors		6		4		1	24	
Push button	Bent pins	Fails to switch power on/off Walking stick cannot be reset/ buzzer cannot be silenced	1	Poor Procurement	9	ATP-001 – visual inspection & procurement capability analysis Correct Storage, Lab policies Correct Storage, Lab policies	1	9	Carry out inspection
	Jammed/stuck		8	Contamination	3		1	24	Inspect and clean
	Contamination		4	Contamination	3	Testing would be used to check reliability	1	24	Inspect and clean
	Poor connection /soldering		7	Poor soldering	4	(ATP-003-001/003)	1	28	Inspection, testing and validation. Clean and Re-solder
Power bank	Fails to hold charge	Fails to turn on	9	Poor procurement	3	(ATP-003-001/003)	1	27	Procurement review, inspection before use
	leakage	Loss of power	9		3	Inspection, functionality testing	3	81	
	Catching fire	smokes/ overheats	9		3		1	27	
	Faulty Connectors	Not able to operate/connect to devices	5		6		1	30	
USB cable	Faulty Connection	Not able to connector to charger/laptop	7	Materials selected not robust/ cheap procurement with low quality Mating parts incorrect	2	ATP-001 ATP 003 Testing – environmental testing	2	28	Material change inspection before use different procurement
	Bent/warped	Not able to operate	7	Materials selected not suitable	2	ATP-001 Determine material suitability	2	28	Material investigation/ change
LED strip (White)	No light	No power, Electrical/software fault blown from electrical surge	9	Procurement error, voltage rating not suitable. validate software	5	ATP-001 ATP 003 Resistor to protect from surges	1	18	Inspection and test, swap out for new one
	Too bright	Not enough resistance	4	Designed incorrectly	5	ATP-001 ATP 003 Simulation design	1	20	Create CP Change if values are found to be incorrect
	Too dim	Too much resistance	5	Designed incorrectly	5		1	25	Create CP Change if values are found to be incorrect

Heart rate sensor	No readings	No power	7	Ingredients used not suitable	5	ATP-001 ATP 003	2	70	investigation/ change
	Incorrect reading	Software/electrical fault	5	Ingredients used not suitable	5	Reliability Testing	2	50	investigation/ change
Buzzer	Distortion	Sounds but not correctly/clearly	7	Liquid Contamination	2	ATP-001 ATP 003 Design validation, Reliability Testing	2	28	Review design/ check tolerances
	To loud	Volume to loud	5	Defective, wrong procurement/software	2	ATP-001 ATP 003 Design validation, Reliability testing	2	20	Review design/ check tolerances
	To quiet	Volume to low	7	Defective, wrong procurement/software	2	ATP-001 ATP 003 Design validation, Reliability testing	2	28	Review design/ check tolerances
	No sound	No power	9	No power	3	ATP-001 ATP 003 Design validation, Reliability testing	1	27	Review design.
Aluminium Tube	Bent	Not mechanically sound	8	Danger to end user Durability questionable	4	ATP-001 ATP 002, ATP 005 ATP 006	1	32	Review design/ check tolerances
	Dented		8		4	Design validation,	1	32	
	Breaks under pressure		9		4	Reliability testing	1	36	
Handle	To large	Smaller hands will have difficulty gripping	7	Uncomfortable use	2	ATP-001 ATP 002, ATP 005 ATP 006 Validation needed at design stages, understanding of target audience	2	28	Re-design, implement tolerances
	To small	Won't be comfortable for larger hands to grip	7	Uncomfortable use	2	ATP-001 ATP 002, ATP 005 ATP 006 Validation needed at design stages, understanding of target audience	2	28	Re-design implement tolerances
	To bulky	Gains momentum when falling	7	Uncomfortable use	2	ATP-001 ATP 002, ATP 005 ATP 006 Validation needed at design stages, understanding of target audience	2	28	Re-design implement tolerances
Foot	To Large	Obstructs a user	7	Uncomfortable use	2	ATP-001 ATP 002, ATP 005 ATP 006 Validation needed at design stages, understanding of target audience	2	28	Re-design implement tolerances
	To Heavy	Cannot be lifted easily	7	Uncomfortable use	2	ATP-001 ATP 002, ATP 005 ATP 006 Validation needed at design stages, understanding of target audience	2	28	Re-design implement tolerances