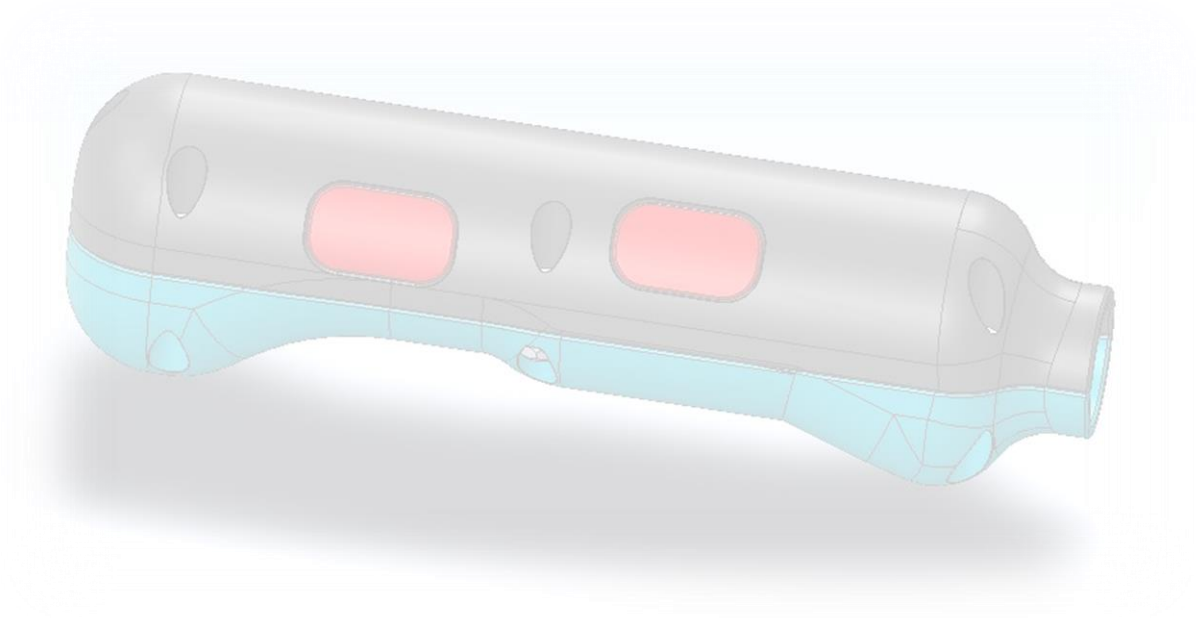
HECATE

HECATE: Helping and Carrying Amaurotic people To Explore



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Concordia University – Fall Semester 2017

AERO 444 – MECH 6941: Concurrent Engineering in Aerospace

Faculty of Engineering and Computer Science
Expectations of Originality

This form sets out the requirements for originality for work submitted by students in the Faculty of Engineering and Computer Science. Submissions such as assignments, lab reports, project reports, computer programs and take-home exams must conform to the requirements stated on this form and to the Academic Code of Conduct. The course outline may stipulate additional requirements for the course.

1. Your submissions must be your own original work. Group submissions must be the original work of the students in the group.
2. Direct quotations must not exceed 5% of the content of a report, must be enclosed in quotation marks, and must be attributed to the source by a numerical reference citation[1]. Note that engineering reports rarely contain direct quotations.
3. Material paraphrased or taken from a source must be attributed to the source by a numerical reference citation.
4. Text that is inserted from a web site must be enclosed in quotation marks and attributed to the web site by numerical reference citation.
5. Drawings, diagrams, photos, maps or other visual material taken from a source must be attributed to that source by a numerical reference citation.
6. No part of any assignment, lab report or project report submitted for this course can be submitted for any other course.
7. In preparing your submissions, the work of other past or present students cannot be consulted, used, copied, paraphrased or relied upon in any manner whatsoever.
8. Your submissions must consist entirely of your own or your group's ideas, observations, calculations, information and conclusions, except for statements attributed to sources by numerical citation.
9. Your submissions cannot be edited or revised by any other student.
10. For lab reports, the data must be obtained from your own or your lab group's experimental work.
11. For software, the code must be composed by you or by the group submitting the work, except for code that is attributed to its sources by numerical reference.

You must write one of the following statements on each piece of work that you submit:
For individual work: **"I certify that this submission is my original work and meets the Faculty's Expectations of Originality",** with your signature, I.D. #, and the date.
For group work: **"We certify that this submission is the original work of members of the group and meets the Faculty's Expectations of Originality",** with the signatures and I.D. #s of all the team members and the date.

A signed copy of this form must be submitted to the instructor at the beginning of the semester in each course.

I certify that I have read the requirements set out on this form, and that I am aware of these requirements. I certify that all the work I will submit for this course will comply with these requirements and with additional requirements stated in the course outline.

Course Number: _____ Instructor: _____
Name: _____ I.D. # _____
Signature: _____ Date: _____

[1] Rules for reference citation can be found in "Form and Style" by Patrich MacDonagh and Jack Bordan, fourth edition, May, 2000, available at http://www.encs.concordia.ca/scs/Forms/Form&Style.pdf.
Approved by the ENCS Faculty Council February 10, 2012

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Abstract

The number of visually impaired and blind people accounts for about 285 million according to the WHO statistics during the recent times. Out of these 39 million are blind. 63% of those with low vision and 82% of blind people are over 50 years of age. Of the 6 WHO world regions, North America has around 8 million people visually impaired and blind. Our project “HECATE-Guidance cane for visually impaired and blind people” aims to develop a product to help these people by guidance system.

Our innovative project aims at improving the way blind people can explore, cross the street or go to a place by creating a connected GPS stick that will guide them, thanks to impulsions, vibrations and proximity sensors. The top of the stick will look like a ball: through a direction impulsion, the owner will know in which direction he will have to go.

To program a path, the user will have to speak to an electronic Voiceover application on the stick that will connect to the internet, find the safest path and program the impulsions. There will be a speaker to assist the user understand the impulsions to follow.

Our first goal is to make this essential object affordable and non-intrusive for blind and visual impairment people. For achieving this, a through design of the product development process and market analysis by employing concurrent engineering method on this product and the report is done.

Keyword: HECATE, Guidance cane, sensors, Vibration, Voiceover application.

Introduction

A company that could design and develop a new product in the past had a guaranteed success that satisfied the needs at competitive prices. But this has changed over the past few decades. Time has also become a key factor in determining the product success. For a new product development organization or an existing organization time to market has become a driver for a business.

All these time centered approaches have one thing in common: they attempt to maximize the number of major design and development tasks that can be done concurrently, thus the concept of concurrent engineering. Concurrent engineering aims at achieving throughput time reductions by planning and executing design and development activities in parallel.

Our product “HECATE- Guidance cane for visually impaired and blind people” was also designed based on the concurrent engineering approach which emphasis on minimizing the total work load at the same time doing all the activities parallel to reduce the development time.

Based on Each person knowledge and experiences, we assigned different roles for everyone in the team after the second Gate (Analysis and General Environment). Each member of the group must do some research about all aspects on our subject to understand what each role implies. Our team is a cross functional team comprising of two mechanical engineers, one industrial engineer and one aerospace engineer.

We assigned the roles as following:

- Supply chain and Marketing: Antony
- Finance: Senthil Kumar
- Product Design and Quality assurance: Jagrat
- Manufacturing and Team leading: Zoé

We met weekly at the university library to take stock of our progression in work. At the end of each appointment, we created a report and assign tasks for the following week. We have an online shared folder (Dropbox) to keep the members updated on our work.

The major issues of our project will be to make the use able to navigate through traffic signals, to prevent from harming the owner’s hearing capacity and to communicate the itinerary to the user. We must mainly focus on the cost of HECATE and the interaction between the device and its user.

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Analysis and General Environment

Once we decided of an idea of a product to develop, we must study the market and its environment to understand the ins and outs of this sector in order to be competitive and efficient in our tasks.

Market Research

In the international Classification of Diseases, made by the World Health Organization, there are four levels regarding a loss or a lack of vision:

- Normal vision
- Moderate visual impairment
- Severe visual impairment
- Blindness

The last three terms are considered as **'low-vision'.**

A **blind** people cannot see at all. His visual acuity is worse than 20/400 and he has a visual field of 10 degrees or less.

Thus, a **deafblind** person has no capability of seeing nor hearing.

'**visually-impaired'** is the term that gather all the terms that are explained above. A person is considered as visually-impaired if he or she hasn't got a perfect or near perfect vision.

A low vision is the result of some diseases such as uncorrected refractive errors, cataract, glaucoma, age related macular degeneration, diabetic retinopathy, corneal clouding, childhood blindness or infections.

Uncorrected refractive errors are astigmatism, presbyopia, near sighted and far sighted.

The US National Federation of the Blind has inventoried in 2010 the estimated number of visually impaired people, divided in eight regions of the world. Regarding The north-American continent, there are around 7,975,100 visually impaired people. This means that around 3% of the population of this continent is considered as visually impaired.

Moreover, 65% of visually impaired and 80% of blind people are 50 years or older. This is explained by the fact that these diseases are mostly due to an old age (51% of the cases are due to the cataract).

Thus, our targeted community is not only blind people, but mainly all visually-impaired people in the North-America continent.

In the current market, there are different objects that help blind or visually impaired people to walk and to detect objects:

- Canes: walking canes, visually impaired canes, death blind canes and blind canes
- Mobility guides (this device is an integrated sensor that rings when un obstacle is near the user. It cannot replace any cane or guiding device)
- Compass
- Gps
- Guiding Dog
- Smartphones' application

The most common-used tools are canes and mobility guides.

A blind cane usually costs between 20 and 40 USD.

A mobility guide usually costs between 200 and 1550 USD.

Most of the mobility guides are a complement to cane and guiding dog. It only detects objects but cannot guide the person through a destination. The STEP-HER is an example of this.

Columbus Talking Compass (80 USD) is the only compass to give an itinerary but it does not prevent from obstacles and traffic jams.

SenseNav GPS (1550 USD) is the most expensive GPS for blind people because it gives information on the road about visits, routes, restaurants. An alternative for this system is the BrailleNote Gps (600 USD) by Humanware.

There are many guiding applications available on the Apple store and on the Google store. But only few of them are really conceived for visually impaired people. We can cite for instance RightHear (its cost is 200 USD – which is a lot for an application) or BlindSquare. Unfortunately, most of these applications aren't as efficient and safe as they're supposed to be.

After looking on forums, we found that most of visually-impaired people use the actual Google Maps application.

Except from a few advanced products, the main manufacturers for objects that blind and visually impaired people use are:

- Ambutech
- Drive
- Harvy
- IMerciv
- MaxiAids
- RezenTech / Reizen
- DO MORE
- HandiWorks
- HurryCane
- WCIB
- Independence Medical

	Guiding dog	Human Help	Cane	Application	GPS such as SenseNav	Mobility Guides
Cost	++++	++++	+	+ or +++	++++	+
Obstacle detection						
Itinerary-telling						
Need of charging						
Can be used independently						

This analysis has underlined the main characteristics to our project: HECATE must describe an itinerary at a low price and it must work independently. But as our project is new, we decided to launch a first product that will be using a free application such as Google Maps (or our own application) through a Bluetooth connection.

Analysis of Customer Needs

The blind and visually impaired community does not have the same primary needs as non-disabled people. The way they live, study, explore, walk, locate something is different from what we are currently used to.

To make our project efficient and interesting for the consumer, we have to understand their way of living to meet their needs.

We have done an online survey to find what customers are expecting from our product. We used the platform SurveyMonkey to offer an access in English and in French to our survey.

We posted our online survey on different Facebook groups and communities such as DV_CONSEIL or Visually Impaired Community.

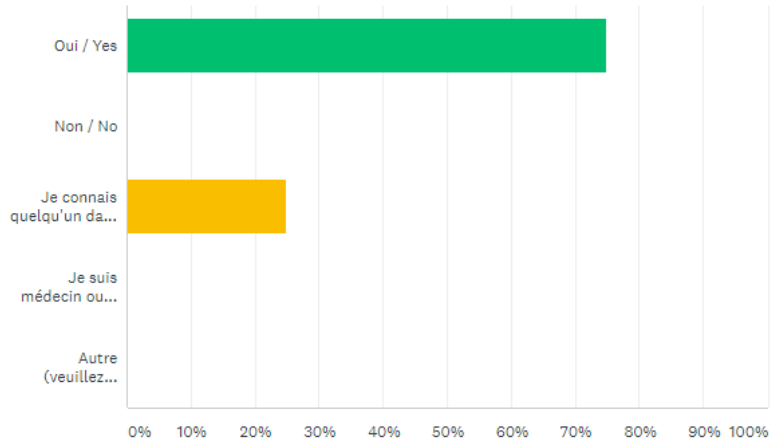
The following questions and answers are the results of our survey:

Q1

Customize Export

Etes-vous aveugle, déficient visuel ou connaissez-vous quelqu'un dans cette situation ? Are you blind, visually impaired or Do you know someone in this case ?

Answered: 24 Skipped: 0



ANSWER CHOICES		RESPONSES	
Oui / Yes		75.00%	18
Non / No		0.00%	0
Je connais quelqu'un dans cette situation / I know someone in this case		25.00%	6
Je suis médecin ou spécialiste dans ce domaine / I am a doctor or a specialist in this field		0.00%	0
Autre (veuillez préciser) / Other (please explain)	Responses	0.00%	0

RESPONSES (0) TEXT ANALYSIS MY CATEGORIES

Categorize as... Filter by Category Search responses

Showing 0 responses

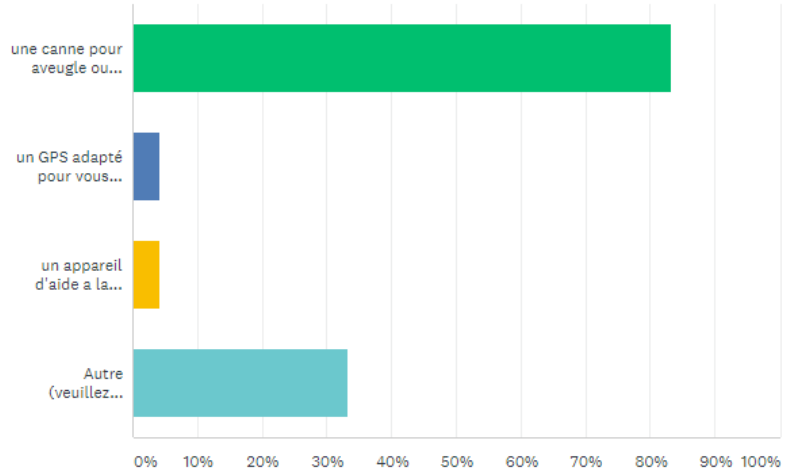
This first question proves that the people that have answered are directly concerned by our project. We obtained 24 answers to our survey. For a more accurate analysis, it should have been better to collect more feedbacks but as this community is difficult to reach (many associations refused to meet us or to answer our survey) and not omnipresent on social media, we evaluate that the number of 24 answers was sufficient. Moreover, this is a student project and not a product to be commercialized, so we can consider that 24 answers are sufficient to make an estimation of the market.

Q2

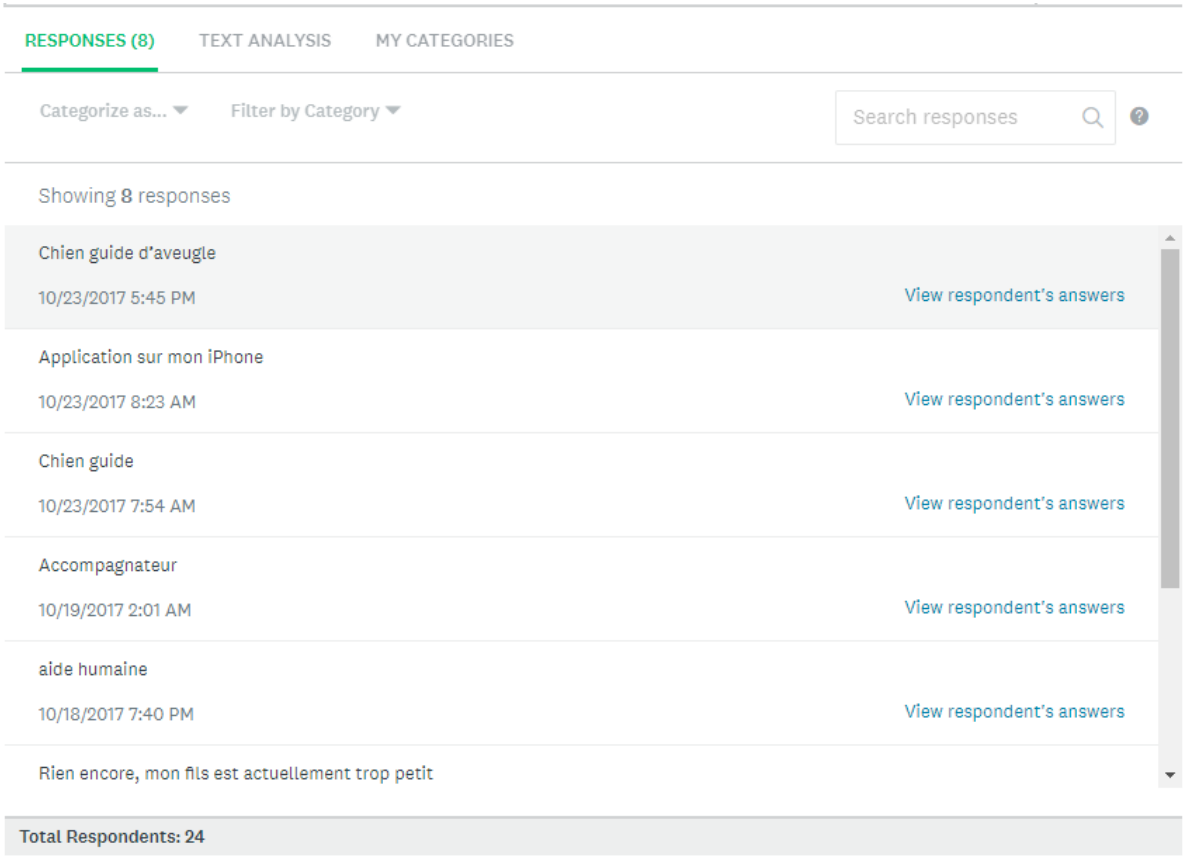
Customize Export

Possédez-vous les appareils suivants : Have you got the following devices :

Answered: 24 Skipped: 0



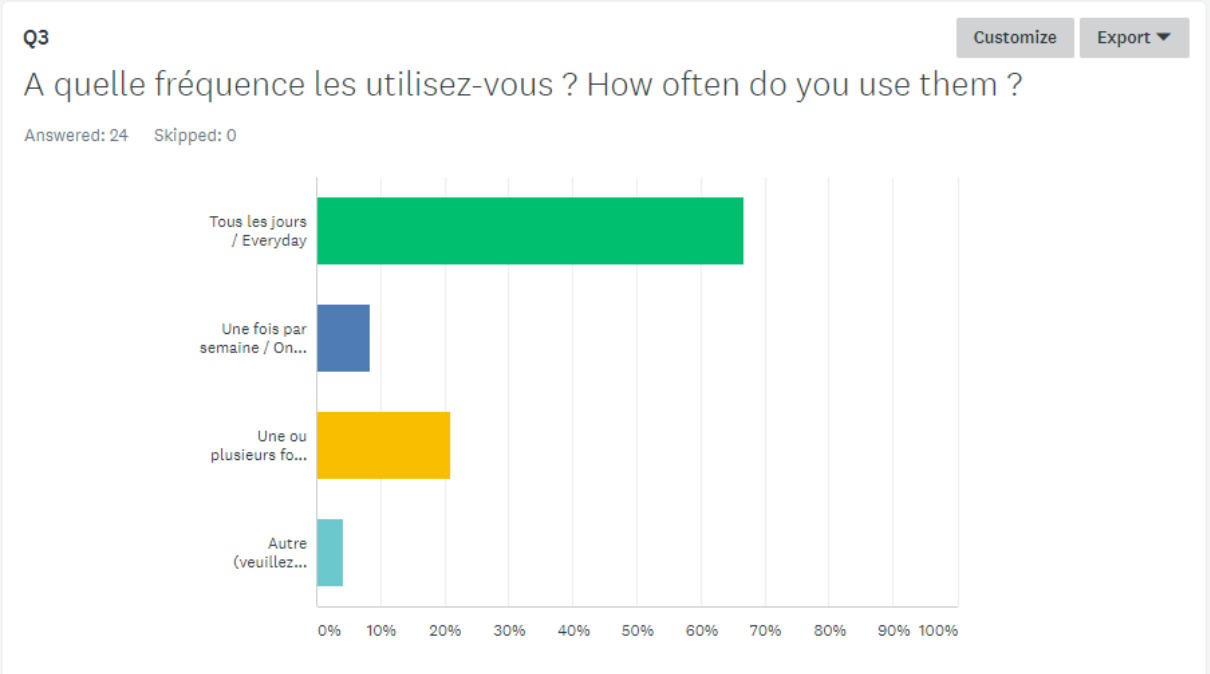
ANSWER CHOICES		RESPONSES	
une canne pour aveugle ou malvoyant / a blind cane or a visually impaired cane		83.33%	20
un GPS adapté pour vous déplacer / an adapted GPS to move about		4.17%	1
un appareil d'aide a la mobilité (éviter des obstacles, prévenir des chutes) / a Mobility-Aid device (to avoid obstacles, prevent from falling) ?		4.17%	1
Autre (veuillez préciser) / Other (please explain)	Responses	33.33%	8



This second question has allowed us to verify that our market researches were correct and that we covered most of the tools used by blind and visually impaired people.

English translation of the French responses:

- Guiding dog
- Blind cane / visually impaired cane / trekking poles
- Application on smartphones
- accompanist



ANSWER CHOICES		RESPONSES	
Tous les jours / Everyday		66.67%	16
Une fois par semaine / Once in a week		8.33%	2
Une ou plusieurs fois par mois / Once or more in a month		20.83%	5
Autre (veuillez préciser) / Other (please explain)	Responses	4.17%	1

RESPONSES (1) TEXT ANALYSIS MY CATEGORIES

Categorize as... Filter by Category Search responses

Showing **1** response

I use a white cane about 2 to 3 times a week and trekking poles daily.

10/16/2017 7:19 PM View respondent's answers

The third question is related to the frequency of use of all the products listed on the previous question. We can see that a majority of our audience uses their equipment daily.

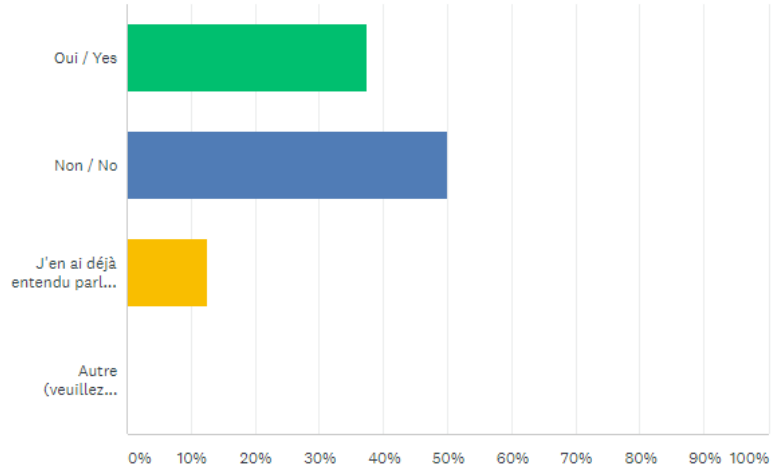
Thus, we can say that our product can be considered as important because our customers will use them every day. Therefore, we have to make sure that our product will be safe and secure, and as efficient as it can be.

Q4

Customize Export

Avez-vous déjà entendu parler d'un projet de canne connectée pour aveugle actuellement commercialisé ?Have you ever heard about a smart cane for blind people, that is actually on the market ?

Answered: 24 Skipped: 0



ANSWER CHOICES		RESPONSES	
Oui / Yes		37.50%	9
Non / No		50.00%	12
J'en ai déjà entendu parler mais le projet n'a pas été commercialisé.I have heard about it but it hasn't been commercialized yet.		12.50%	3
Autre (veuillez préciser) / Other (please explain)	Responses	0.00%	0
TOTAL			24

The fourth question has shown that most customers have already heard of a connected cane.

Q5

Customize Export

Il est temps de vous présenter notre projet : HECATEHECATE est une canne connectée : - Elle permet une programmation vocale du point ou vous souhaitez vous rendre- Elle vous guide jusqu'au point désiré à l'aide de commandes vocales, de vibrations au niveau du manche de la canne pour vous indiquer la direction à suivre- Elle vous prévient des dangers de la route en temps réel : travaux, feux de signalisation, imprévus, défauts de la chaussée.Etes-vous intéressés par cet objet ?----------

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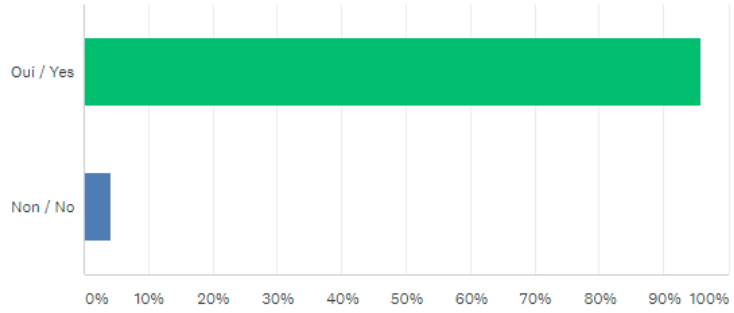
----------It is time to present you our project : HECATEHECATE is a connected cane :- It - It guides you through your destination thanks to vocal controls, vibrations on the handle of the cane to give you the direction to follow- It warns you in real time about dangers on your road : works, traffic signals, unforeseen events, defects on the pavement.Are you interested in this device ?

Answered: 24 Skipped: 0

Answered: 24 Skipped: 0



ANSWER CHOICES	RESPONSES	
Oui / Yes	95.83%	23
Non / No	4.17%	1
TOTAL		24

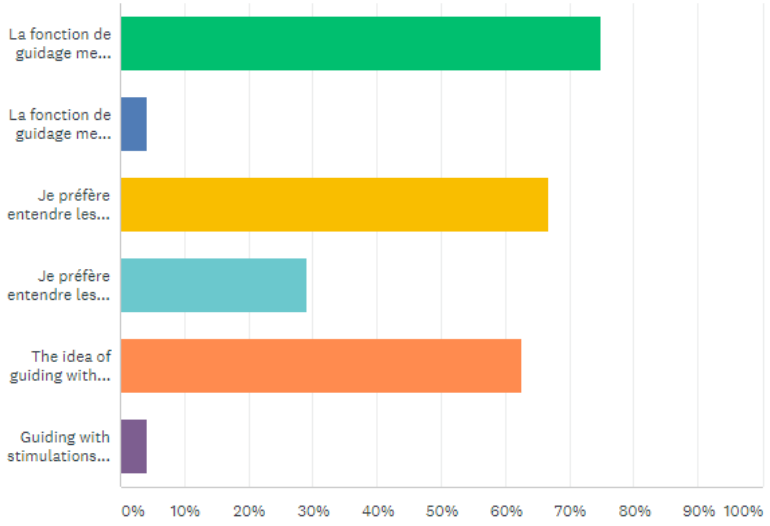
After introducing our product, all participants (except one) showed their interest in our project.

Q6

Customize Export

A propos de HECATE (veuillez choisir les affirmations qui vous correspondent) : About HECATE (please choose the sentences that correspond to you) :

Answered: 24 Skipped: 0



ANSWER CHOICES	RESPONSES	
La fonction de guidage me semble importante / The guiding function is important for me	75.00%	18
La fonction de guidage me semble inutile/ The guiding function is useless for me	4.17%	1
Je préfère entendre les instructions à travers un casque plutot qu'à travers un haut-parleur. I prefer to hear the instructions through a headset rather than throught loudspeakers.	66.67%	16
Je préfère entendre les instructions à travers un haut-parleur plutot qu'à travers un casque. I prefer to hear the instructions through loudspeakers rather than throught a headset.	29.17%	7
The idea of guiding with stimulations and impulsions is great	62.50%	15
Guiding with stimulations and impulsions is useless	4.17%	1
Total Respondents: 24		

To know what the most important features our product should have, we asked the customers to choose between six statements what they think is true for them.

After looking at their answers, we can say that:

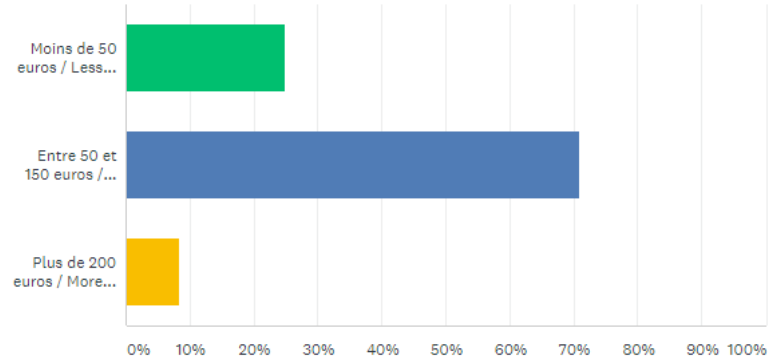
- the guiding function is prevalent
- the idea of guiding with impulsions holds the majority
- an important part of the audience prefers to hear the instructions through a speaker and not through a headset

Q7

Customize Export

A quel prix maximum êtes-vous prêt à payer pour obtenir ce produit ? At which maximum price you be ready to purchase it ?

Answered: 24 Skipped: 0



ANSWER CHOICES		RESPONSES	
Moins de 50 euros / Less than 50 euros	(50 euros = 60 USD = 45 GBP)	25.00%	6
Entre 50 et 150 euros / Between 50 and 150 euros	(150 euros = 180 USD = 133 GBP)	70.83%	17
Plus de 200 euros / More than 200 euros	(200 euros = 240 USD = 178 GBP)	8.33%	2
Total Respondents: 24			

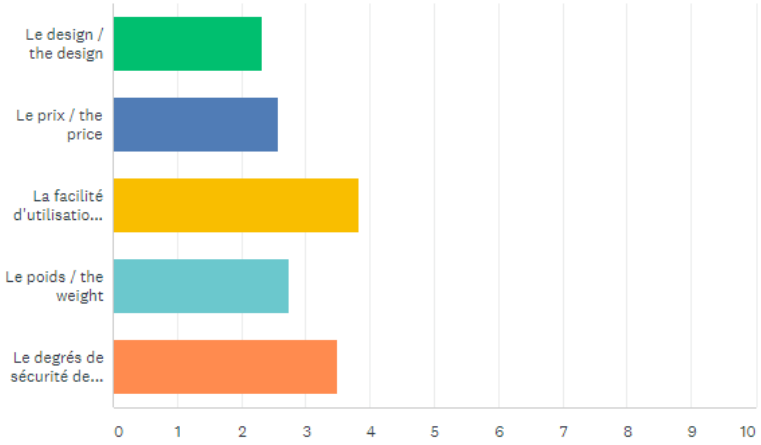
When asked about the correct price for such a product, most of the customers thinks that it should cost between 60 and 180 USD. We will use the data when discussing the cost of our product.

Q8

Customize Export

Quels sont vos critères de sélection (du plus important au moins important) ? What are your selection criterions (from the most to the less important one) ?

Answered: 24 Skipped: 0



	1	2	3	4	5	TOTAL	SCORE
Le design / the design	20.83% 5	4.17% 1	8.33% 2	20.83% 5	45.83% 11	24	2.33
Le prix / the price	8.33% 2	20.83% 5	25.00% 6	12.50% 3	33.33% 8	24	2.58
La facilité d'utilisation / the ease to use it	20.83% 5	54.17% 13	16.67% 4	4.17% 1	4.17% 1	24	3.83
Le poids / the weight	8.33% 2	12.50% 3	33.33% 8	37.50% 9	8.33% 2	24	2.75
Le degrés de sécurité de l'objet / how safe and secure it is	41.67% 10	8.33% 2	16.67% 4	25.00% 6	8.33% 2	24	3.50

Now that we know their estimated price of our product, we wanted to study their main criterions when purchasing this product. Their criterions in order (from the most important to the less important) are:

- Safety and Security of the product
- Ease to use it
- Weight
- Design
- Price

Consequently, we have to focus on safety and on the ease to use our product. The design will mainly depend on the ease of use. However, as the price is not the first criterion, we can allow it to be a little bit higher than they expected.

Q9

Export

Avez-vous des idées ou des commentaires pour améliorer notre produit ? Have you got any ideas to help us improve our product ?

Answered: 13 Skipped: 11

RESPONSES (13) TEXT ANALYSIS MY CATEGORIES

Categorize as... Filter by Category Search responses

Showing **13** responses

Information : Je suis malvoyante (LDMA) et non complêtement aveugle. La canne se devrait d'être pliable pour être rangée et transportée dans un sac. Réglable en hauteur. Si il y a une stimulation par vibrations, elles doivent s'accompagner d'instructions vocales simples et courtes. Le casque ne doit pas isoler l'utilisateurs des bruits et sons exterieurs. Grande autonomie pour les systèmes électroniques à l'intérieur : peu (et peu souvent) de manipulation pour recharger

10/29/2017 9:25 AM View respondent's answers

Possibilite de coupler la canne avec le smartphone

10/27/2017 4:50 PM View respondent's answers

La fonction de vibration pour indiquer les direction peut-être une bonne idée, mais elle me semble un peu trop complexe, car tout le monde ne tiens pas ça canne de la même façon, et devoir crisper sa main pour essayer de comprendre la direction... Peut-être juste faire un signale sonnor ou vibrand quand la canne pointe dans la direction correcte.

10/23/2017 3:09 PM View respondent's answers

Juste, Faites en sorte que la géolocalisation soit bien précise, à fin que nous puissions nous rendre dans l'endroit souhaité, avec succès. Ce n'est pas le cas de la plupart des GPS. Un grand merci pour ce beau projet. Informez-nous en des suites.

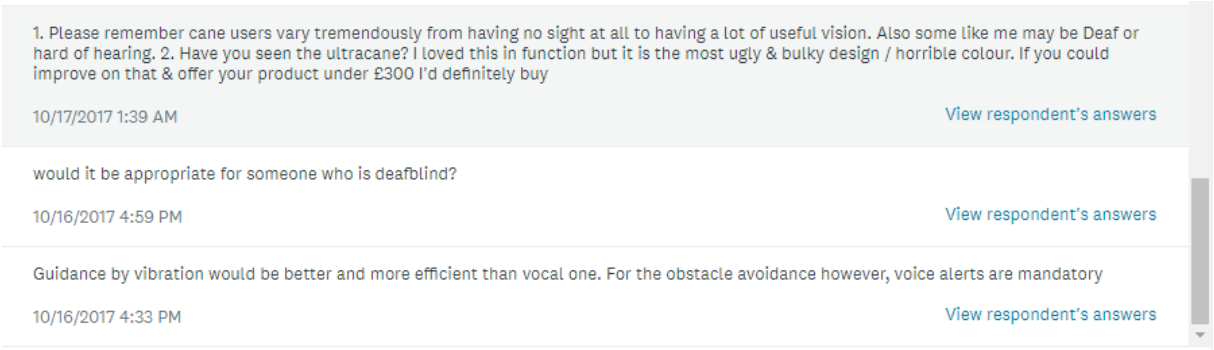
10/23/2017 9:32 AM View respondent's answers

Si le matériel est utilisé avec un casque, pour moi, la fonction Bluetooth et plus pratique que la fonction filaire

10/23/2017 7:54 AM View respondent's answers

Je suis assez frileuse avec les projets de canne connectée. Pour moi l'intérêt d'une canne est d'être au contact du sol et des obstacles. Toute information supplémentaire, vibration, impulsion, est une gêne et un parasite au guidage qui devient vite fatigant parce que détourne l'attention. Pour avoir testé plusieurs cannes connectées, la précision de la détection des obstacles est très faillible, beaucoup de choses, comme des personnes par exemple, sont détectées comme obstacles à tort et rajoutent autant de signaux inutiles et parasitant la concentration. Pour moi, le tout premier critère d'une canne blanche, c'est son poids. On la manie activement toute la journée et je n'ai eu de cesse d'aller à la recherche de la canne la plus légère et solide possible. Un dispositif connecté est forcément un poids, même minime, et un encombrement supplémentaire, que j.estime trop préjudiciable pour compenser les avantages. Quant à intégrer un GPS, nous possédons suffisamment d'outils performants sur les smartphones à l'heure actuelle. Intégrer un GPS à une canne n'est qu'un ajout de poids et d'encombrement dont je ne vois pas l'utilité quand mon GPS peut être bien au chaud dans ma poche. Pour finir, je n'aime pas du tout l'idée des commandes vocales. Je déteste me faire remarquer dans la rue, le fait d'avoir une canne le fait bien assez pour moi, aussi j'aime taper mes infos sur mon GPS en tactile et je n'apprécie pas du tout d'utiliser les commandes vocales quelles qu'elles soient. Sans parler des difficultés que ça peut poser en milieu bruyant. J'ai conscience que ce commentaire n'a rien d'encourageant. N'oubliez pas que je ne suis qu'une utilisatrice non-voyante avec des habitudes bien précises, que la canne connectée ou même simplement électronique ne me convient absolument pas mais ce n'est pas le cas de tout le monde. Je serai toutefois curieuse de connaître l'abouqissement de votre travail et je tirerai mon chapeau à celui qui me présentera un objet qui me fera changer d'avis. Je dirais qu'à mon sens, le plus important c'est de se concentrer sur un objet .peu encombrant et peu lourd. Il faudrait que l'on n'ait pratiquement aucune différence avec une canne ordinaire, quitte à ce que le dispositif se trouve dans un boîtier sans fil que l'on garde dans la poche plutôt que sur la canne elle-même, qui doit rester super maniable.

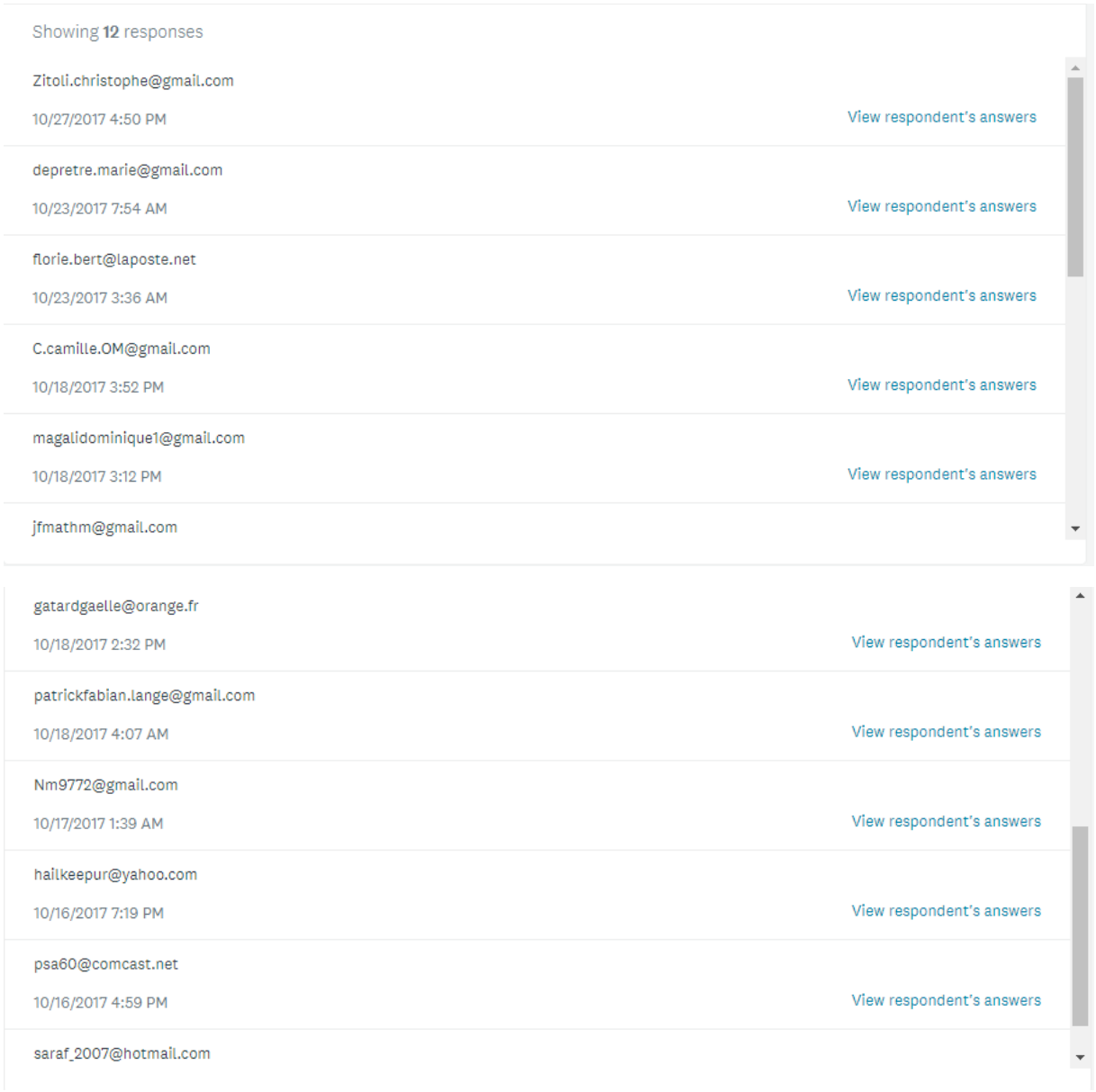
10/23/2017 3:36 AM View respondent's answers



As a last question, we ask them their opinion and the suggestions on our product. They are listed above.

The main ideas in the French comments are:

- dog poop detection (most common fear of blind children)
- Bluetooth connection for vocal instruction on headset or smartphone
- Foldable cane
- Precise localization
- An attention to the cane's weight must be provided
- Give an attention to the way people will be holding the cane
- Making the cane vibrate only when it is on the direction the user must go to
- The height of the cane must be adjustable



After seeing all these answers, we can say that the critical key success factors of HECATE are:

- Make an affordable product
- Have Strong communication with customers
- Put the technology at the service of the project
- Make safety a priority
- Proudly represent this project academically
- Use every method seen in class to improve our invention


Make safety a priority
Put a strong effort in the price management
Efficiently communicate with the customers and the blind and visually impaired community
Stay on the edge of the technology to serve the product
Make HECATE a pride in our curriculum
Apply the methods to improve the development

After looking on some previous researches on the subject and contacting some of the volunteers on our survey, we have found the main statements about the behavior when having a blind/visually impaired stick

- **The user doesn't like to have a vibration in the head**

When one of the five senses is diminished, the four others are overcoming the lack of information. Therefore, their hearing capacity is multiplied. This can cause headaches when walking on the streets next to a noisy crowd. A vibration in their head can alternate their orientation and senses.

- **The user prefers when only one hand is used**

Needing two hands to use a cane will prevent them from catching themselves up when falling or avoiding an obstacle.

- **They don't like auditory output because it prevents them from hearing the streets and thus decrease their safety**

Our idea of adding vibrations to it can be an asset of our project. But we must keep vocal instructions to make our product safe. Moreover, they will choose to have it through a headset or a speaker thanks to a Bluetooth connection.

- **They accord a great importance to the size and the weight of the helping object**

Our cane must be lightweight. After a team discussion, we first think of removing the obstacle detection to it (as it is heavy). Our cane will still be competitive because there are no other cane using vibration to guide its user. Another argument will be to increase the safety to it, compared to other product.

- **They don't want to 'scan' their environment when looking for obstacles**

That is the main drawback of mobility guides. The user has to scan its environment to make sure there is no obstacle in front of them. It is not efficient and time-consuming.

Competitor Analysis

The competitor analysis is very essential for a new product to ensure a commercial success. It is an essential part of a company marketing plan. This analysis is also crucial for meeting the target specifications. If the customer is to buy our product, it is necessary to know why the customer would prefer our product over all the other products. What benefits does our product have? Moreover, the major consideration people make while buying a product is 'is it affordable?' These questions can be answered using the competitor analysis.

The major issue of a design office to develop a smart cane is to provide safety, independent mobility for a visually impaired person and allow them to live like a normal person. Independently, the need for assistive devices for navigation and orientation has increased. So far, products available in market only use voice and vibration technologies, but they are only used to help them avoid obstacles. There is no product available in market that can be directly compared to HECATE.

Some products have been developed until the deployment stage, but they never hit the market in the northern-American continent. They are also considered for estimating the target specification. From the survey, people want something which is simple. They can get by any obstacle with a simple white cane. But it is very difficult for them to navigate around places. In addition, the ones which help them navigate are not affordable. The following are some canes which were developed to help the blind and visual impaired,

An Indian company named Assitech has developed a cane capable of detecting and avoiding obstacles at a cost of 50$USD. However, this doesn't have the capability to help people navigate. It employs the vibration technology to help avoid obstacles [3].

The Smart Cane was presented originally by Central Michigan University's students. It is a portable device that is equipped with a sensor system. The system consists of ultrasonic sensors, microcontroller, vibrator, buzzer, and water detector to guide visually-impaired people. It works with servo motors, ultrasonic sensors, and fuzzy controller to detect the obstacles in front of the user. The Smart Cane has achieved its goals in detecting the objects and obstacles, producing the needed feedback but this did not have the capability to guide the user [2].

Bharambe et al. developed an embedded device to act as an eye substitution for the vision impaired people that helps in directions and navigation. The authors implemented the proposed algorithms using an Android application. The role of this application is to use GPS, improved GSM, and GPRS to get the location of the person and generate better directions. The embedded device consists of two HC-SR04 ultrasonic sensors (Yuyao Zhaohua Electric Appliance Factory, Yuyao, China), and three vibrator motors. But the device came with the wood foundation which is not detachable. They also employ costly systems. This product was not manufactured by any company [2].

From the competitor analysis some initial target values were specified for most important factors according to the product as well as customer point. Data extracted from the survey and the following table were used for further development of the product and the best possible technology which could be employed to increase market value and make it affordable.

There are also other products which were proposed by researchers, but they never hit the market. They are listed below on the table [1]:

PRODUCT	DESCRIPTION	COST	LIMITATION	USED TECH.
Smart cane	A portable device to be used for obstacle detection	high	Cannot guide people	Ultrasonic technology
Eye substitution	Navigates and gives direction	High (1790)	Not detachable	GPS, GSM and GPRS, ultrasonic technology
Fusion of Artificial Vision and GPS	wearable device that mounted on the user's head and guide them using GPS.	low	Not preferred by user. Uncomfortable Not tested for navigation purpose and was used only object avoidance.	GPS, GIS, Vision based positioning system SpikeNet algorithm
RFIWS	Uses radio frequency identification tag to navigate	N/A	Limited to particular area. RFID were difficult to detect when wrapped.	Ultra-high frequency
A Low Cost Outdoor Assistive Navigation System (LowCost Nav)	A navigator with 3D sound system was developed to help blind people in navigating.	low	Sound inaudible in noisy area.	GPS technology Geo-Coder-US Module MoNav Module Bluetooth
Ultracane	Uses ultrasonic sensor to detect objects	N/A	Dynamic objects couldn't be detected. Smaller range	Ultrasonic sensor, (trans-receiver) Arduino UNO microcontroller, wireless X-bee S1 trans receiver module.

There are two patents recorded in the Northern American continent:

- US 8,812,231 B1
- US 5,097,856

The first patent (US 8,812,231 B1) deals with a GPS guided walking cane and has been patented by Rebecca Brickous in 2014. It is composed of a cane and an electronic device (a smartphone) with Braille keyboard and displays to communicate with the blind user.

The second patent (US 5,097,856) concerns an electronic talking stick for the blind and has been patented by Chi-Sheng in 1992. This can be considered as an old patent and is no longer competitive because the technology used is outdated and the weight of this device is heavy compared to what we want to design.

The use of vibrations to guide a visually-impaired user isn't mentioned in any patent.

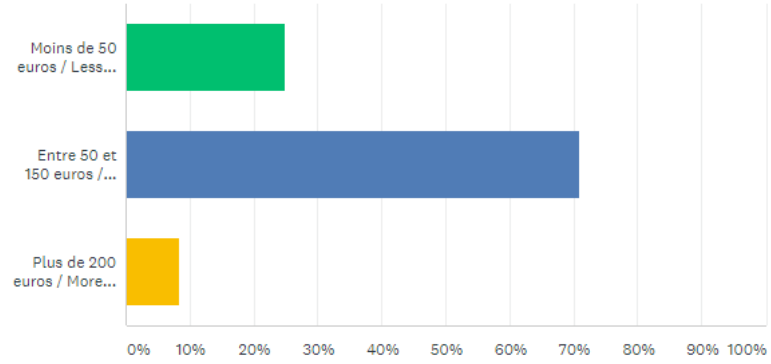
Price Analysis

Q7

Customize Export

A quel prix maximum êtes-vous prêt à payer pour obtenir ce produit ? At which maximum price you be ready to purchase it ?

Answered: 24 Skipped: 0



ANSWER CHOICES		RESPONSES	
Moins de 50 euros / Less than 50 euros	(50 euros = 60 USD = 45 GBP)	25.00%	6
Entre 50 et 150 euros / Between 50 and 150 euros	(150 euros = 180 USD = 133 GBP)	70.83%	17
Plus de 200 euros / More than 200 euros	(200 euros = 240 USD = 178 GBP)	8.33%	2
Total Respondents: 24			

To establish the first estimation of our product cost, we use the results of our survey to have a scale and an idea of our targeted price.

We can see on the diagram above that around 70 % of the audience will purchase the price if it is between 60 to 180 USD.

If we use this as a reference, the 9% of the people that have answered that they would buy it if it costs more than 240 USD.

Thus, we have around 80 per cent of our customers that will be satisfied with the price of an HECATE cane.

We assume that if our product price range is between 100 to 150 USD, a few people that have answered that they would buy for less than 60 USD will buy it.

Availability of Materials and Suppliers

Potential materials to consider

Broadly, we need to decide upon the category of the material that will best serve our purpose. The categories we considered are:

1. Light weight Metals (e.g Aluminium)
2. Plastics/Polymers
3. Composites
4. Wood

Out of these we eliminated the option of Wood because of strength limitations and evaluated the remaining options.

Availability & procurement aspects

For procurement, we decided to do it locally. Since we are in a development phase and with a budget constraint, we decided to procure ourselves the material locally, i.e. in and around Montreal. This will facilitate quick availability and will help us to evaluate a variety of options.

Category 1: Light weight Metals (e.g. Aluminum)

Aluminum is a low-density metal. It finds use in a huge variety of commercial applications. The Unalloyed type is ductile, exhibits moderate strength, and is very resistant to corrosion under most circumstances. Aluminum can be dramatically strengthened by the addition of appropriate alloying elements (Cu, Mg, Mn, Si, etc.).

Typical applications: The low density of this metal results in its extensive use in the aerospace industry, and in other transportation fields. Its resistance to corrosion leads to its use in food and chemical handling (cookware, pressure vessels, etc.) and to architectural uses.

Supply aspects & remarks: Aluminum can be purchased online and at any supplier location. It can be cut to our exact specifications.

Category 2: Plastics/Polymers

This material is continuously improving through innovation. Plastics are re-engineered to become lighter and more efficient all the time. There is a large variety of plastics available. Moreover, there is considerable flexibility in processing and fabricating plastic products. Plastic containers also can use about 38 percent less material than similarly sized steel cans.

Typical applications: From micro-sized components to complete consumer product devices plastic injection molding is used to manufacture a variety of consumer products for home, industry and electronics. In our case this can be our best option to go ahead with.

Supply aspects & remarks: Montreal has a strong base of companies that have excellent manufacturing capabilities with plastic materials.

Category 3: Composites

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.

The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

Typical applications: composite materials have gained popularity (despite their generally high cost) in high-performance products that need to be lightweight, yet strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers etc.). The new Boeing 787 structure including the wings and fuselage is composed largely of composites.

Supply aspects & remarks: Composites are highly engineered material and there is always high cost associated with them. Also, they have very specific fabrication method which require expertise. May not be a good choice for our case.

Definition of Specifications

After analyzing the customers' needs and their remarks, we can set the estimated final specifications of our product:

NO.	METRIC	UNIT	VALUE
1	Maximum safe volume of the speaker	dBA	<85
2	Total mass	Kg	<1.2
3	Object discretion	Subj.	Subj.
4	Handling size	cm	20-30
5	Charging Time of the Battery	hr	1 - 2
6	Minimum Bluetooth connection interval	s	0,02 - 30
7	Unit manufacturing cost	USD	60 - 70
8	Time to assemble to frame	min	4 - 5
9	Delivering Time	d	3 - 5
10	UV test duration to degrade rubber parts	hr	>400
11	Cycles to failure	Cycles	>500k
12	Bending strength	kN	>12

Now that we know more about our project, we are able to fil in the Specification form in the pages below:

PRODUCT SPECIFICATION SHEET

1

Table of Contents

1. DESCRIPTION OF PRODUCT

1.1 Brief Product Introduction:

A brief description of our product's purpose,

	Description
Product Name:	HECATE 1.0
Description of Product purpose and application	Enable blind people to go from one place to another with an itinerary. Make this invention affordable and non-intrusive.

1.2 Aesthetics:

The appearance of a product is one of the most important aspects in the customer buying process and can often make all the difference when compared with a similar product.

	Description
How does the product need to look? Feel?	The product is going to hand held and it needs to be comfortable to be handled by a human hand.
What is the color of your product?	 Proposed Pantone Color codes: For main housing: 19-4003 TPG Black Onyx For impulse buttons: 11-0110 TPG Buttercream
Does your product have a Finish	Proposed finish: For main housing: Low Gloss Plastic For impulse buttons: Matte wax finish
Does your product require a specific texture?	Impulse buttons need specific projections that helps to sense them with fingers.
Does your product require any other special features?	The product is subjected to small vibrations throughout its life cycle. This are of low frequency and the material must be able to sustain them.

1.3 Material:

	Description
Any special material to be used?	ABS, It is an acronym for Acrylonitrile Butadiene Styrene, a copolymer thermoplastic manufactured from the polymerization of Styrene and Acrylonitrile in the presence of Polybutadiene.
Any material restrictions to be avoided in the interest of safety?	Toxic, weak, light, heavy materials, etc.

2. MANUFACTURING PROCESS and QUANTITY

3

2.1 Quantity:

This will affect the production costs. (Can even mean alternative manufacturing processes need to be considered).

	Description
What is your Minimum Production Quantity?	Since we are the development stage we did some market research for potential buyers. Also some high initial tooling costs are involved. So, when we run full scale production the minimum production quantity we projected to be 80-100 per production shift.

2.2 Target Production Cost:

	Description
Target Costs	Examining the competing products that are currently on the market and our production costs we could offer the product between $130-$180.
Target Production Costs	The probabilistic cost of making our product will be around $80 - $85

3. PRODUCT DESIGN and PERFORMANCE

3.1 Design Time:

	Description
Expected design time	Prototype design time: 50 hours & Product refinement and final design: 60 hours

3.2 Expected product size and weight:

Provide your product's required size dimensions

	Description
Expected Product Size	7.5 inches X 2.5 inches X 2 inches
Expected Product Weight	Around 320 grams. (This is calculated using Solidworks® 2016 and does not include the weight of metal cane that is attached to the device)
Expected Product Diameter	Elliptical product (Maxima = 2.5 inches, Minima = 2 inches)
Expected Product Thickness	0.13 inches / 3.3 millimeters

3.3 Performance Requirements:

4

Expected product performance requirements.

	Description
How Often	The product can be operated 8 hours in a continuous run.
Power Requirements.	The product will be operated on a battery similar to a cell phone battery with a voltage rating between 3.7V - 4.2V
Shelf Life	Length of time product may be stored without becoming unfit for use, consumption, or sale: If stored more than years the product become unfit for use since the least warranty on electronic components is of vibration motors which is 3 years.
Service Life	Expected lifetime, or the acceptable period of use in service: 10 years for electronics and the plastic casing if not abused by user can lasts for lifetime.

3.4 Service Environment:

Describe the environment in which the product will operate. What type of environment/conditions will your product be subjected to?

	Description
Operating temperature range for this product?	-20º C to 50º C
Will product be exposed to dirt or other contaminants (corrosive fluids, fire, water, etc.)?	No. The recommended operating conditions should avoid harsh environment.
What wear and tear will product experience, if any?	Can experience impact load if dropped from hand or mishandled.

4. ERGONOMICS

4.1 Ergonomic Requirement

HECATE's primary function is to help Amaurotic people to navigate and explore. Since it's operated by visually impaired persons we made some specific considerations such as,

	Description
Which user/operator features are desirable in this product?	Visually impaired individuals
Are there problem areas for users/operators? Can we design around them?	Yes, we have avoided having sharp corners on the product. We did this considering the fact that the individual will pick up or grab the device from any area because of impaired vision.
Height, strength, are amongst the variables of the target user that must be considered	Product must be able to function properly for what kind of audience? A product that requires assembly cannot be too complicated to set up. Product may need to include instructions. Ex: Shoe rack rods and connectors need to connect easily. Product cannot require too much strength to set up.

4.2 Expected Product Maintenance:

	Description
Can the product be maintenance-free?	No.
Is there any maintenance required?	Since it has moving parts and subjected to vibrations it must be serviced once in six months of operation.
Parts that need maintenance will need to be easily accessible for cleaning.	The electronics and impulse carrying buttons are made easily detachable and accessible to replace and service
If routine maintenance is required, can it be done by the owner/operator?	No.
Will professional maintenance be required?	Yes.

4.3 Off-the-shelf component parts:

	Description
Which parts of this product must be purchased or sourced elsewhere, if any?	Vibration motors, Battery pack & Foldable cane.
Is the quality and reliability of purchases parts adequate for this design?	Not adequate at this movement further development efforts are required.

5. SAFETY:

5.1 Expected product safety requirements

Product must be reasonably safe from design, manufacturing, and marketing defects.

	Description
Potential operator hazards	Products need to be made safe for consumers. The electronics should be efficiently shielded and should not come in contact with the user.
Potential for misuse/abuse.	The product to incorporate some shock absorbing material to minimize the effects of shocks that can result from dropping the product on ground.
Should product include safe operating instructions?	The operation instruction should be included with the product pack in the form of recorded voice instructions on a CD.

6 LOGO

	Description
Does your product include a Logo?	Yes. 

7. TESTING

7.1 Testing Requirements:

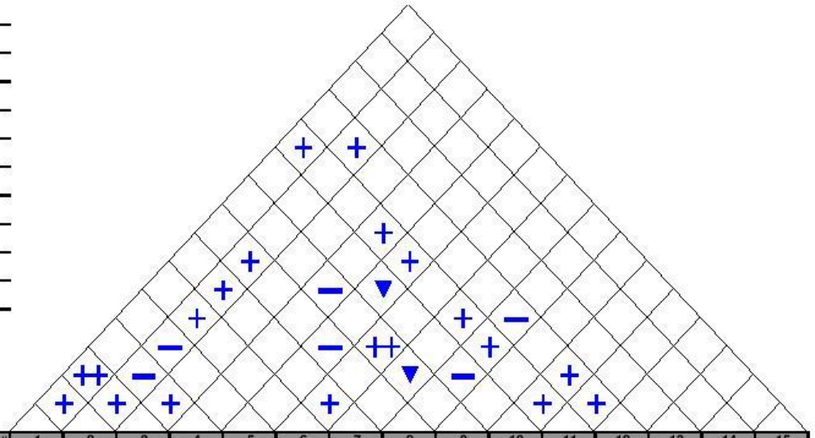
	Description
Do you know if your product has any testing requirements?	Ex: OPP Bag, Vacuum Sealed, Paper Boxing, Blister Pack, etc

8

Quality Function Deployment

Thanks to all these researches, we are now to draw the quality function deployment of our project :

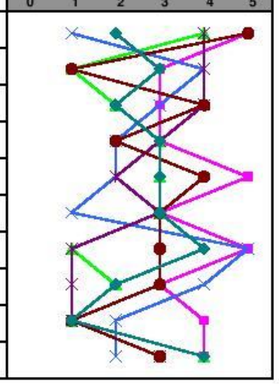
Title: House of Quality
Author: Zoe, Senthil, Jagrat, Antony
Date: 20/11/2017
Notes:



Legend		
⊙	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Ergonomic grip	selling price	aesthetic appeal	weight	energy consumption	compatability	folding cane	lifetime	Assembly time	Vibration	Conforms to international quality standards	Detection sensitivity	Our Company	smartcane	Fusion of artificial vision and GPS	eye substitution	RFIWS	lowcost Nav
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▼	▲	▼	▼	▲	x	▲	▼	x	x	▲							
				Target or Limit Value	N/A	$	%	kg	W-hr	N/A	N/A	years	seconds	Hz	%	V							
1	9	17,3	9,0	comfortable to use	⊙	⊙	O	⊙			O			O			5	4	1	4	5	2
2	9	1,9	1,0	More detection range		⊙			⊙			O				⊙	3	1	4	4	1	3
3	9	17,3	9,0	safety	▲	O								O	⊙	O	3	2	3	4	4	2
4	9	5,8	3,0	long battery back-up		O		O	⊙	O		⊙		⊙			3	3	2	3	2	3
5	9	17,3	9,0	Light weight		⊙		⊙			▲						5	3	2	2	4	3
6	9	5,8	3,0	Robust design	O	O	⊙	O			O	⊙			O		3	3	1	3	3	3
7	9	17,3	9,0	affordable		⊙	O	▲	▲			⊙					5	1	5	1	3	4
8	3	5,8	3,0	maintenance ability		O					O	O					3	2	4	1	3	2
9	9	5,8	3,0	Easy attachment / detachment from a white cane		⊙				O	O	▲	⊙				4	1	2	1	1	1
10	9	5,8	3,0	portability		O		⊙			⊙						4	4	2	3	3	4
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	2	1	3	3	6	5	1	6	3	6	0	5						
				Max Relationship Value in Column	9	9	9	9	9	3	9	9	9	9	9	9						
				Weight / Importance	190,4	657,7	155,8	415,4	86,5	34,6	173,1	288,5	51,9	155,8	173,1	69,2						
				Relative Weight	7,8	26,8	6,4	16,9	3,5	1,4	7,1	11,8	2,1	6,4	7,1	2,8						

Competitive Analysis (0=Worst, 5=Best)



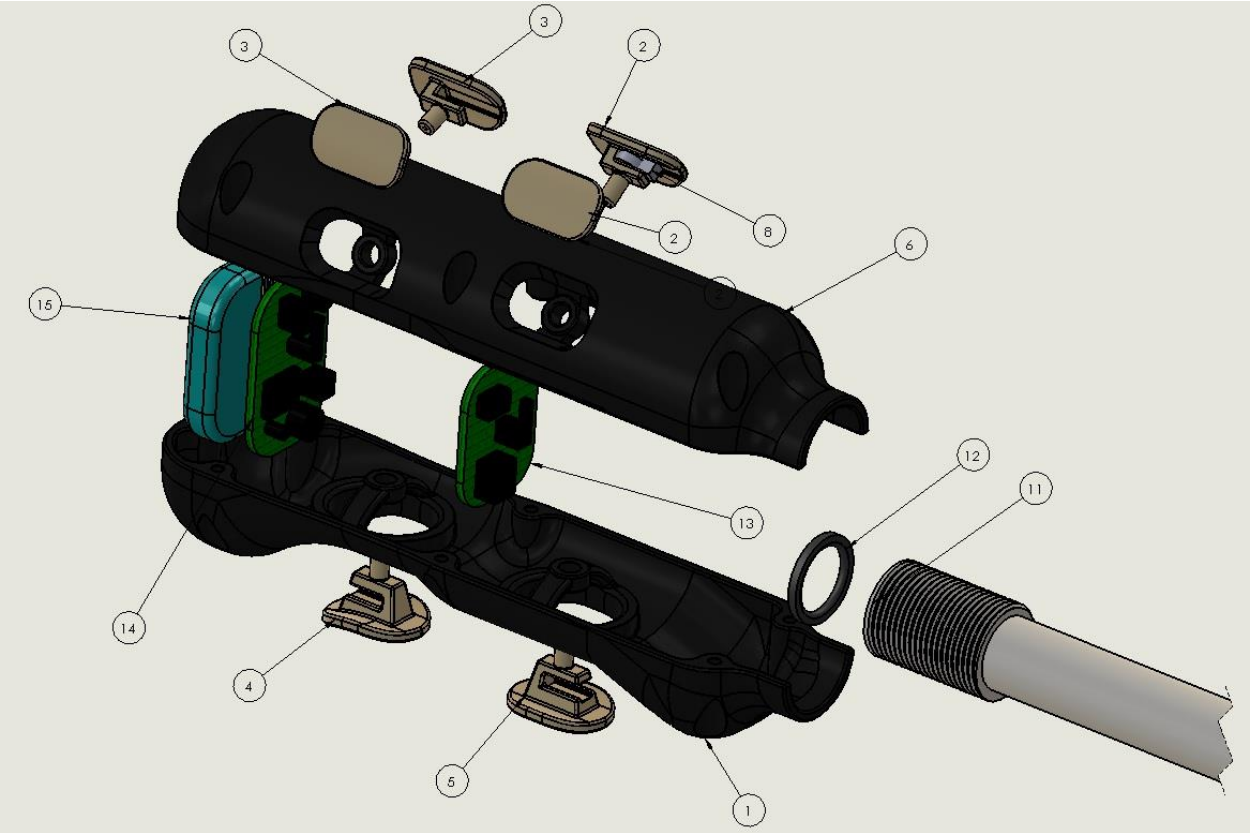
Powered by QFD Online (http://www.QFDOnline.com)

Preliminary Design

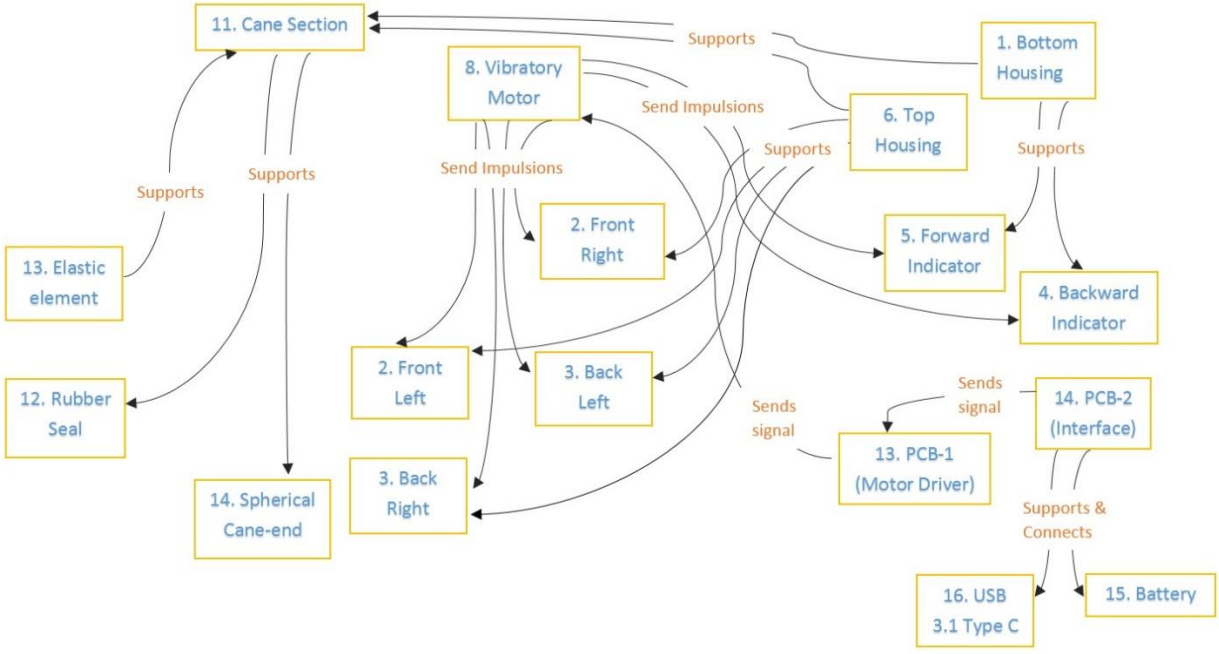
After targeting our project and all its ins and outs, we can draw the first design of HECATE.

Functional Analysis

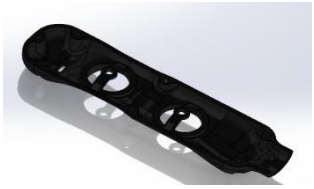
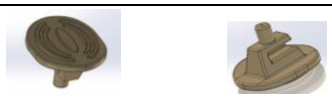
Exploded view of functional components:



Functional Analysis Diagram:



Product Structure of functional components:

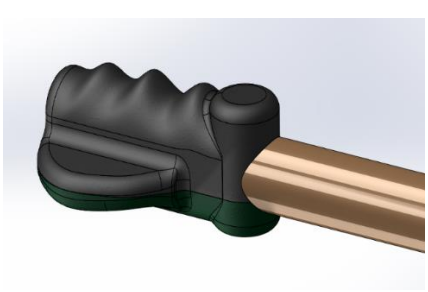
Part No.	Part Name	Drawing	Qty.	Overall Dimensions
1	Bottom Housing		1	8” x 1.5” x 1.23”
2	Front Left/Right Indicator		2	1.21” X 0.71” X 0.76”
3	Back Left/Right Indicator		2	1.21" X 0.71" X 0.61"
4	Backward Indicator		1	1.21" X 0.96" X 0.87"
5	Forward Indicator		1	1.21" X 0.96" X 0.86"
6	Top Housing		1	8" x 1.5" x 1.23"
8	Vibrator Motor		6	Type I = Dia. 0.31" & Type II = 0.33" X 0.18" X 0.16"
11	Cane Section		1	48" X Dia. 0.75"
12	Rubber Seal		1	TBD
13	PCB-1 (Motor Driver)		1	TBD
14	PCB-2 (Main PCB)		1	TBD
15	Battery		1	TBD

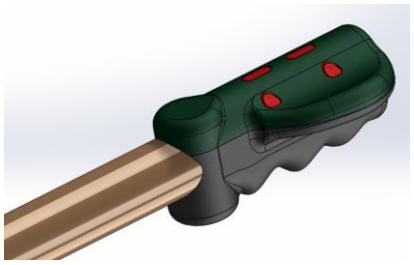
Concept Definition / Preliminary Sketches

In Concept definition we formulated the initial concepts with respect to the requirements of the product. Each concept is designed by keeping in mind the intended functions of the product and once it was done we proceeded to Concept Selection process.

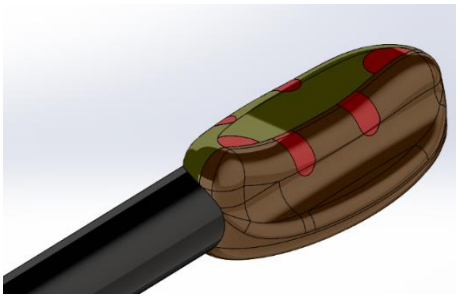
We evaluated three concepts and the preliminary designs are as shown in pictures below:

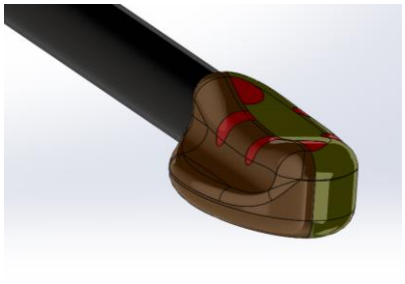
Concept A:



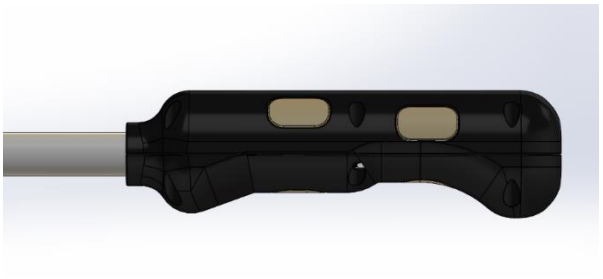


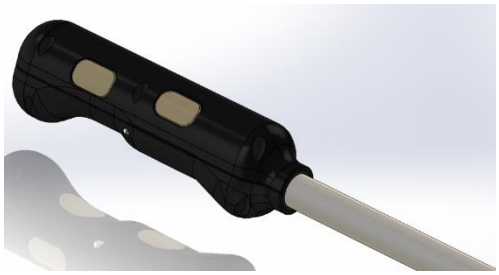
Concept B:





Concept C:





Further, In the Concept selection process we evaluated concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one of the concepts for further investigation, testing, & development.

With reference to Chapter 08 Concept Selection of *"Product Design and Development Book by Karl Ulrich and Steven D. Eppinger"*, we adopted a two-stage concept selection methodology.

1. The first stage is called concept screening
2. The second stage is called concept scoring.

Each is supported by a decision matrix which was used to rate, rank, and select the best concept. Both concept screening and scoring follow a 6 steps process which leads to the concept selection activity:

- Prepare selection matrix
- Rate the concepts
- Rank the concepts
- Combine and improve the concepts
- Select one or more concepts
- Reflect on the results and the process

The results from the above steps are tabulated in the Concept Screening matrix and Concept Scoring matrix as described in the following part.

Concept Screening Matrix

	Concepts		
Selection Criteria	A	B	C
Ease of handling	0	-	+
Ease of use	+	-	+
Readability of Settings	+	0	+
Position of Vibration sensors	-	-	+
Facilitate local vibrations and not to whole body	0	0	+
Accuracy	+	+	0
Durability	+	0	+
Ease of manufacture	-	-	-
Portability	-	-	+
Operation by both Right & Left-handed person	-	-	+
Sum of +'s	4	1	8
Sum of 0's	2	3	1
Sum of -'s	4	6	0
Net score	0	-5	8
Rank	2	3	1
Continue	No	No	Yes

Concept Scoring Matrix

For rating the concepts, a scale of 1 to 5 is used:

Relative performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Once the ratings are entered for each concept, weighted scores are calculated by multiplying the raw scores by the criteria weight. The total score is the sum of the weighted scores. Finally, each concept is given a rank corresponding to its total score.

		Concepts					
		A		B		C	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of handling	10	3	0.3	2	0.2	3	0.3
Ease of use	10	4	0.4	2	0.2	3	0.3
Readability of Settings	15	5	0.75	4	0.6	3	0.45
Position of Vibration sensors	10	5	0.5	4	0.4	4	0.4
Facilitate local vibrations and not to whole body	15	3	0.45	4	0.6	5	0.75
Accuracy	5	4	0.2	3	0.15	4	0.2
Durability	10	4	0.4	4	0.4	4	0.4
Ease of manufacture	5	1	0.05	1	0.05	3	0.15
Portability	10	1	0.1	1	0.1	5	0.5
Operation by both Right & Left-handed person	10	1	0.1	1	0.1	5	0.5
Total score		3.25		2.8		3.95	
Rank		2		3		1	
Continue		No		No		Yes	

Alternatives Selection

For every criterion of our product, we decided to choose between many options, regarding the survey, the behaviors of customers and the materials.

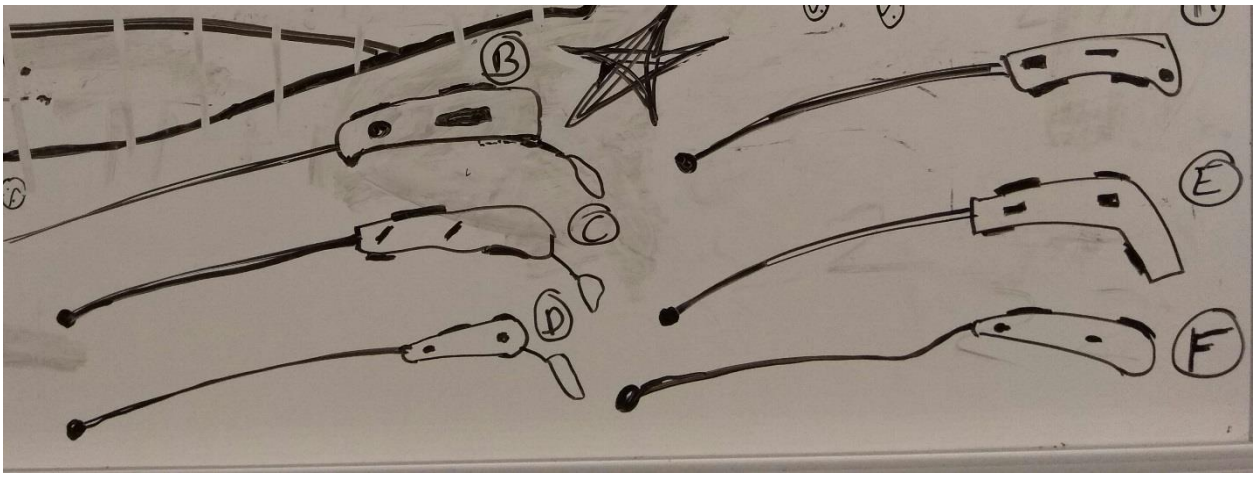
Each bold solution is our chosen one :

1. User interface for input
   A. **Via an application on computer/smartphones** (selected technology): ease of use, common mode of communication, can be easily connected with stick using Bluetooth or Wi-Fi, cost-effective.
   B. Braille (future): need an external device to give commands, need an interpreting medium, adds up weight and complexity to the stick, costly.
   C. Voice Command: Voice recognition can be unsuccessful sometimes, need a voice over interpreter

2. Communicating instructions to user
   A. **Bluetooth Speaker and earphones** (selected technology): ease of connectivity, do not shut completely the hearing senses, cheap and known technology
   B. Earphones and headsets: Connectivity with a jack is complicated, difficulties to use, risk of damage to tangible wires of earphone, bulky

3. Touch Sense
   A. **Vibrations** (selected technology): can be implemented easily and cheaply, easy installation and maintenance.
   B. Path Projections with vibration: difficult to implement, extra design and material, difficult for user to interpret the directions properly.

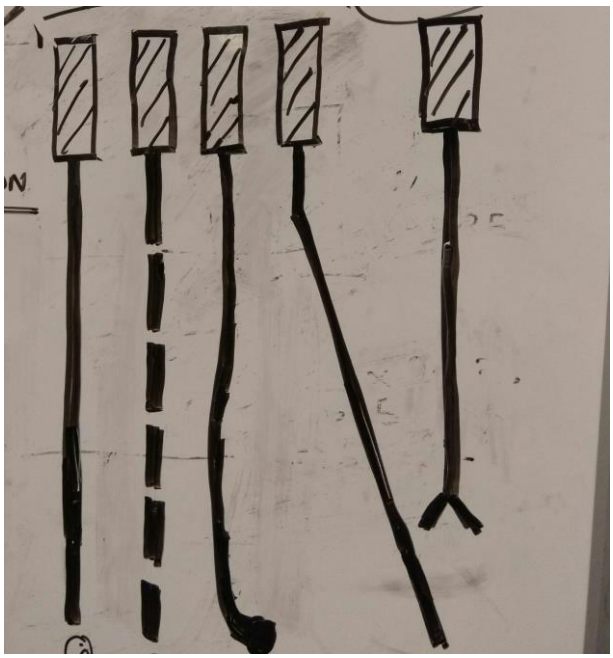
4. Shape and form of grip and cane (including placement of buttons)



Selected design is B

All the blind and visually impaired are straight (not curved), so that it reflects the ground vibrations correctly.

5. Ease of handling



Selected one is the 2nd foldable one

6. Power

   A. **Battery Power** (Selected technology): ease of installation, availability and light weight.
   B. Solar Power: expensive

Design for Manufacture Analysis

This analysis aims at reducing design and manufacturing changes, reducing time and costs linked to the production. It is one of the biggest importance in process planning.

There are different categories of manufacturing processes. We will use:

- Micro-manufacturing to assemble the internal components
- Joining to assemble all the components to the cane
- Finishing

As we will outsource all the components making, we don't need other processes, such as machining, forming and shaping.

The manufacturing cost represents around 40% of product selling price. It includes the cost of materials, tooling and labor and capital costs. It can be minimized by optimizing design, least cost material, while maintaining the intended function and characteristics, and materials substitution.

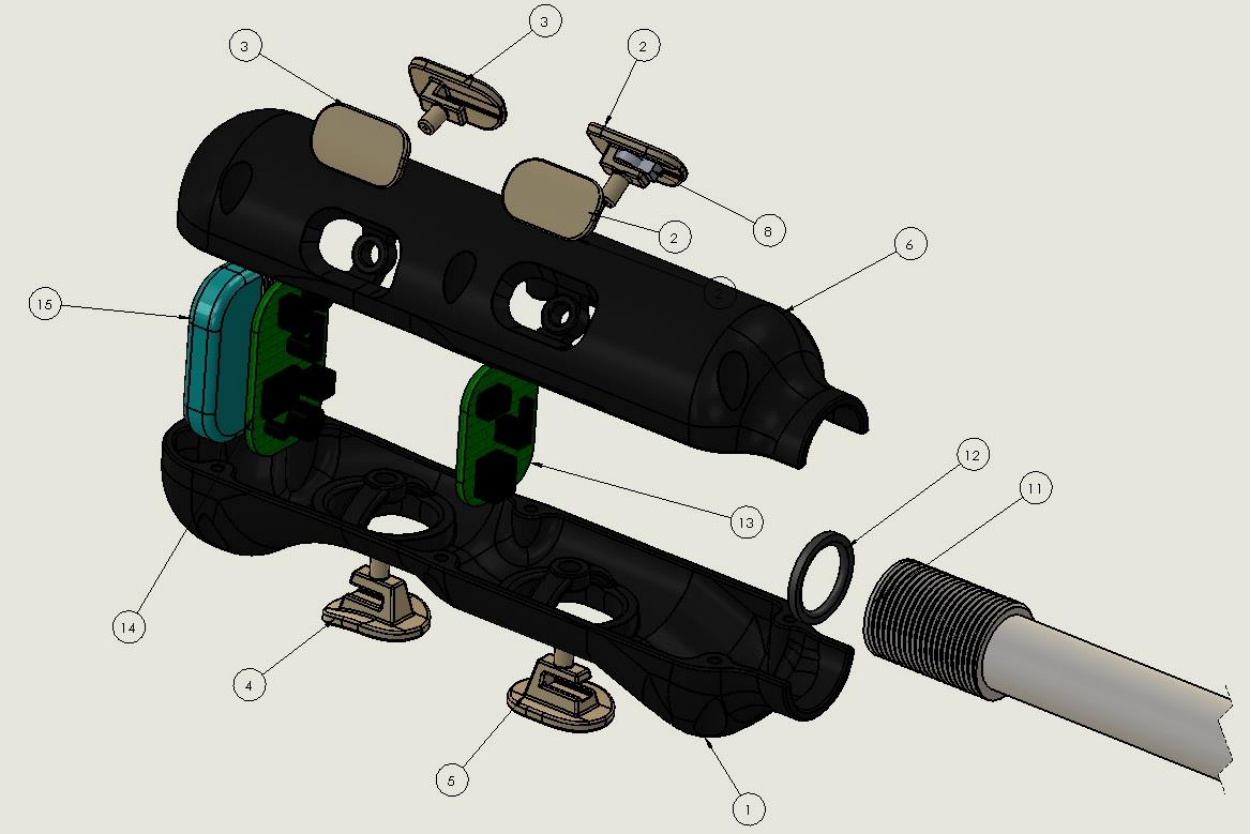
We will see more about the manufacturing cost in the Final Cost Estimates part.

For our structure, we will use a continuous process manufacture. It is specified for large batches, small assembling time and a reasonable demand. It includes a stocking plan to manage the different batches deliveries. It is designed only for a small range of product, which is our case because we only have one type of product to manufacture and assemble.

Thus, we will use a make-to-stock strategy. It deals with producing large quantities of a few standard products for which there is a predictable demand pattern. It allows a short delivery time, as defined in our final specifications.

Design for Assembly Analysis

The assembly analysis is depending on the first conception of the functional analysis:



The complete description of each component (diameter and length, material, shape, name and where to find them – 3D printed, bought, etc. - are also described in the functional analysis part).

The picture above is showing the axis of assembly of each component.

The design must simplify the assembly. There are a few keys to follow to insure a safe and simple assembling model of our object

- ➔ Minimize the number of small elements such as screws
- ➔ Minimize the reorientation of components during the assembly
- ➔ Simplify the object with symmetry
- ➔ Ease the insertion of small components
- ➔ Design the components so that each one has a different shape

Material Selection

Material selection is a step intended for the design of any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. Systematic selection of the best material for a given application begins with properties and costs of candidate materials. For example, a thermal blanket must have poor thermal conductivity in order to minimize heat transfer for a given temperature difference. Utilizing an "Ashby chart" is a common method for choosing the appropriate material. [15] We need a method for the early material selection: we will use the Ashby Methodology **[16]** .it is declined in four basic steps:

1. Translation: express design requirements express design requirements as constraints & objectives
2. Screening: eliminate materials that cannot eliminate materials that cannot do the job do the job
3. Ranking: find the materials that will do the job correctly and the materials that will best do the job
4. Supporting information: explore pedigrees explore pedigrees of top-ranked candidates ranked candidates

First Step: Translation [16]

Using design requirements, analyze four items:

- Function: What does the component do?
- Objective: What essential conditions must be met?
- Constraints: What is to be maximized or minimized?
- Free variables: Which design variables are free?
- Which can be modified? & which are desirable?

Summary of the above requirements for our specific case:

Function	Main housing to hold all the components
	Easy and economically viable to manufacture
	Should be lightweight and strong
Objectives	Accommodate the electronics and battery
	Cheap to produce/manufacture
	High stiffness
Constraints	Weight
	Density
	Reproducibility
Free Variables	Material
	Ease of machining

Second Step: Screening [16]

Here our main requirement was to have light weight material but with sufficient strength to sustain the intended operations. Based on this fact we could eliminate some materials as a possible option for our product. For example, natural materials like wood etc.

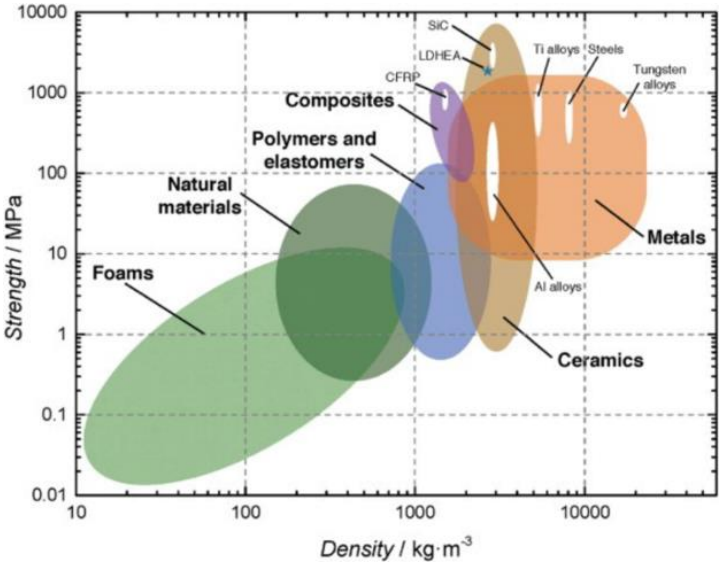


Figure: Ashby plot of strength vs. density for engineering materials.[1919. Budinski KG, Budinski MK. Engineering materials: properties and selection. 8th ed. Upper Saddle River, NJ: Pearson Prentice Hall; 2005.View all references]

Moreover our main edge over other products is the cost we are offering for a product in this category. So, the price has to be marginally cheaper than others. Hence we cannot opt for highly engineered material, for example- composites, ceramics, carbon fibers etc. Hence we are left with the only option of making the products out of engineering plastics i.e. Polymers.

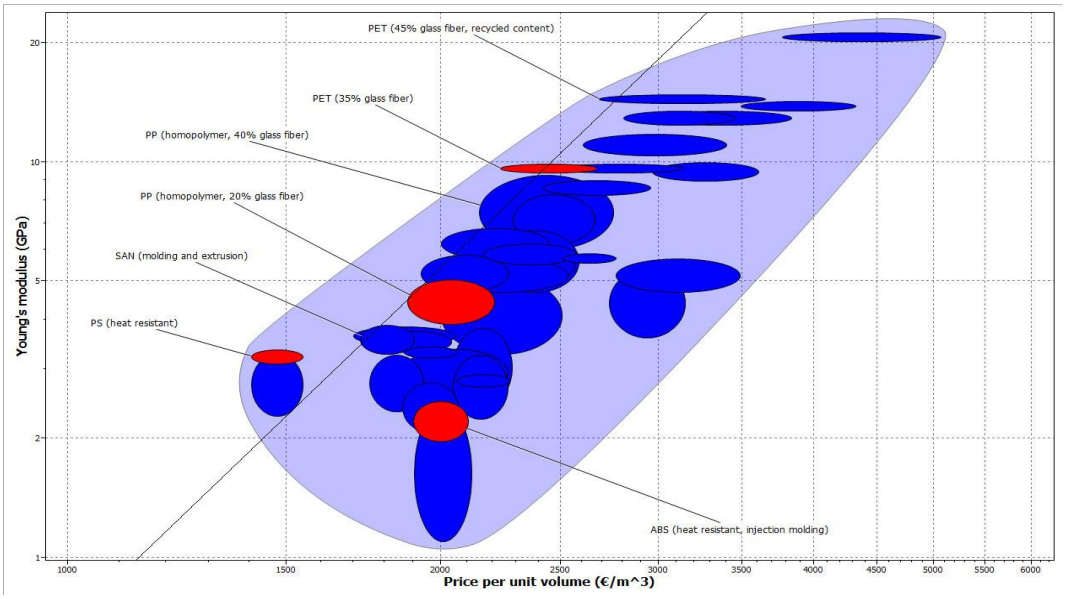


Figure: Graph from the Tecumseh case study, comparing plastics for an application in a ventilation unit. (https://www.grantadesign.com/images/ces/Tecumseh-large.jpg)

Third Step: Ranking

The following diagram shows the relative impact strength of commonly used plastics such as ABS, Polystyrene (PS), or Nylon.

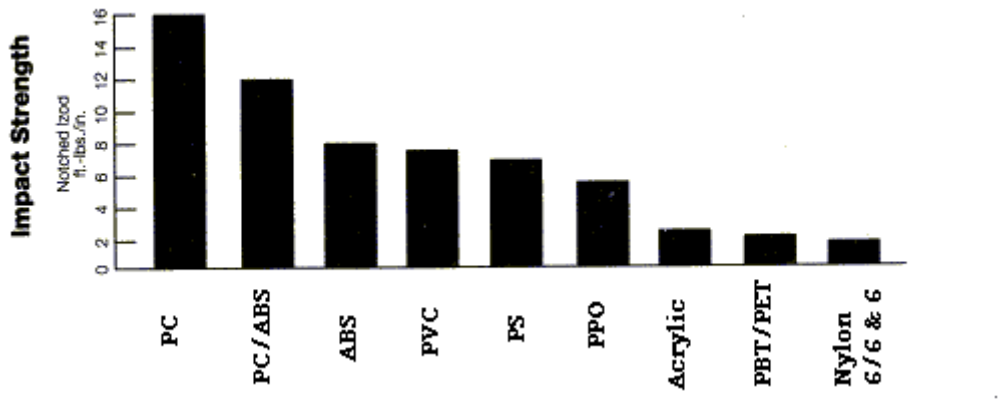


Figure: Relative impact strength of engineering plastics [17]

From the graph of the relative impact strength of commonly used plastics we found out the top plastics with higher impact strength. And considering their ranking we choose ABS (Acrylonitrile butadiene styrene) because even though Polycarbonate (PC) has got better impact strength it has some major disadvantages to our application like it is very susceptible to scratching. It can be protected by a coating, but this will increase the costs and majority of these coatings are toxic in nature.

Fourth Step: Supporting Information

Now that we have sufficient reasons to choose ABS we gathered more information to be sure of its application to our purpose. Here we present some of the facts that support ABS for our desired application:

1. ABS is easily machined. Common machining techniques include turning, drilling, milling, sawing, die-cutting and shearing. ABS can be cut with standard shop tools and line bent with standard heat strips [18].
2. It is a low-cost engineering plastic that is easy to machine and fabricate. ABS is an ideal material for structural applications when impact resistance, strength, and stiffness are required. It is widely used as it has excellent dimensional stability and is easy to paint and glue.
3. ABS is a widely used material for many consumer electronics like telephone handsets, keyboards, monitors, computer housings [20].
4. ABS is a two-phase polymer blend that provides good all-round performance for electronic enclosures. It can be used at low temperatures (-20°C) [21].

Final Design, Schedule

The final design of our project concerns all the last details that need to be discussed before deploying a project, such as the Supply Chain decisions, the final design, the tests or the control of quality.

Design Review

Design Review Process Overview [26]

Steps:

1. **Conceptual Design Review**

The intent of the concept review is to verify that the concept direction fits into the long term design planning of the product roadmap.

*Approval: Director of UI

2. **Design Standards Checkpoint**

This informal checkpoint is to confirm that the design meets required design standards. Should be done by the team.

3. **User Interface Design Review**

This stage requires two signatures for approval.

*Approval: Director of UI, client

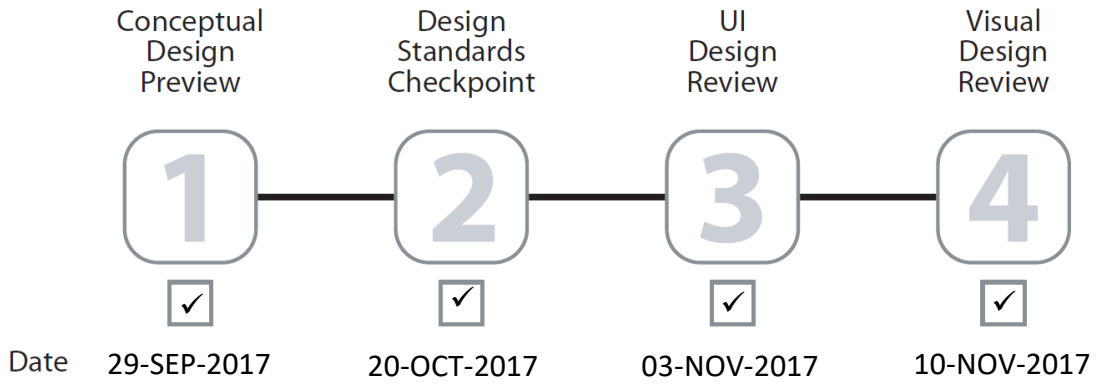
4. **Visual Design Review**

This stage requires two signatures for approval.

*Approval: Director of design, client

*Note: The approvals are listed for a standard design procedure. In our project we executed this aspect by the collective agreement of team.

Timeline



Purpose

The Design Review Process is a mechanism for ensuring standards, alignment, and diligence throughout the course of the product design process.

- Standards
  - Ensure that designs meet appropriate standards for consistency, accessibility & usability globally.
- Alignment
  - Ensure that designs meet business goals.
  - Minimize late-stage changes to product requirements and concepts.
- Diligence
  - Realize maximum value from early-stage design methodologies.
  - Increase accountability by keeping records of review sign-ins and design approvals.
  - Involve people outside the design team at appropriate junctures.

1. Conceptual Design Review

Goals :

- Review product for alignment with broader initiatives and possible integration.
- Ensure that the initial design direction maps to the business goals and user needs.
- Ensure that the designer employed an appropriate range of design tools and methodologies.
- Review resources & scheduling assessments.

Some questions to consider:

1. How did you reach this concept?

We started studying the ergonomics for hand and hand-held devices. Based on our literature study we came across some standard references [27] [28] based on which we considered some facts. There are three types of grips:

- Between thumb and fingertips
- Between base of thumb and finger tips
- Between thumb and knuckle joint

We studied some existing hand-held sticks and cane, and the various features of them.

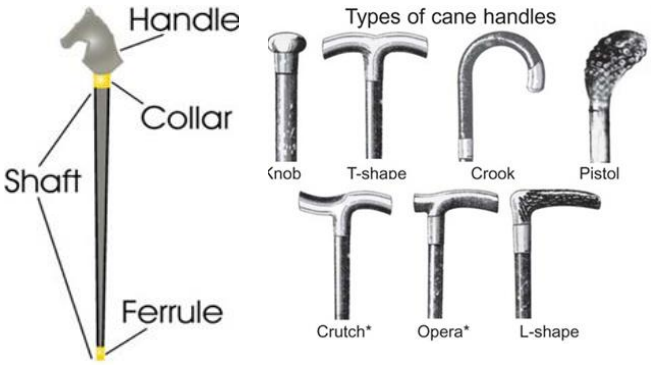


Fig. Basic parts of a cane & cane

To gather as many ideas as we can we studied all possible things that are employed to be used by hand such as handles of: tools, consumer products, shavers, toothbrushes, hand-held medical devices etc.

2. If you're using personas, what are the goals of the primary persona?

Our primary persona here is a visually impaired person. Hence our goals from that perspective are easy handling. Easy accessibility to controls, sensory difference between various controls, light weight and easy to grip design that allows for more comfort.

3. What are the business goals for this product?

Our main advantage here will be the price we will be offering for our product. Product in this category which are offered as an aide to visually impaired are priced at a very high rate and this limits their availability to masses.

4. How does this concept achieve the business goals?

The concept selection is done keeping in mind that we have to come up with a minimalistic design that serves all the desired functions effectively. The lesser the number of parts the easier it is to manufacture, maintain and use.

5. How did research help shape this concept?

With our research we decided upon one important factor that the cane design should be generic so as to be used by both right and left-handed people. This is important to minimize manufacturing, tooling and inventory costs as well.

7. Which stakeholders have given input into your concept?

Our main input came from online surveys which was answered by family, friends and the people that, in some way, interact with visually impaired persons on regular and irregular basis.

8. What are the guiding principles that will drive the rest of the UI design?

The guiding principles that will guide the rest of the user interface will be:

- -Usability
- -Generic design (i.e. commonality for right/left handed operation)
- -UI design should be such that it will user minimum number of parts to convey the instructions to users
- -Minimum controls

2. User Interface Design Review

Goals:

- Review interaction behaviors and provide guidance to designers on problematic interaction issues.
- Confirm utilization of the Interaction standards and best practices (where applicable)
- Confirm resolution of any outstanding issues in Design Standards checkpoint.

Some questions to consider:

1. How is the UI design tailored to the audience?

The UI design is based on the Principle of Least Astonishment (POLA). It is a general principle in the design of all kinds of interfaces. It is based on the idea that human beings can only pay full attention to one thing at one time, leading to the conclusion that novelty should be minimized [29].

2. How does this solution map to the guiding principles as identified at the Concept Review?

At the Concept Review stage we figured out that we needed to have the minimum number of parts so that we can achieve cost saving during manufacturing, as well as in the aftermarket support. Now our solution to guiding principle is in line with this consideration we made at concept review stage.

3. What are the most significant engineering concerns for this design?

The first engineering concern will be to generate the impulsions locally and not to have impulsions/vibrations that can be sensed in an area where it is not supposed to be detected. This engineering concern basically promotes the idea of having more number of individual parts which contradicts our idea expressed in the previous part.

4. Are there any recommended additions or changes to the style based on the solutions presented and approved?

No, there are few changes in the internal design to limit the number of parts but no changes in the style.

4. Does this design require ongoing maintenance?

Yes it will require preventive and predictive maintenance because of the induced vibrations.

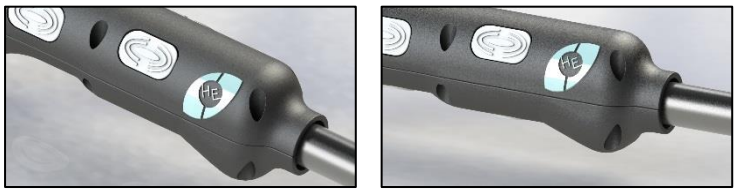
3. Visual Design Review Goals: [30]

- Ensure that the visual design maps to the initial art direction.
- Ensure that the objects (e.g. buttons, tabs, menus, etc.) follow style guide (as relevant and appropriate).
- Ensure that the visual design (colors, grid, typography, graphical style, icons, and logos) follows brand style guide (as relevant and appropriate).
- Determine if any style guide amendments are needed (then documented and changed within the style guide).

Some questions to consider

1. How did you reach this visual design?

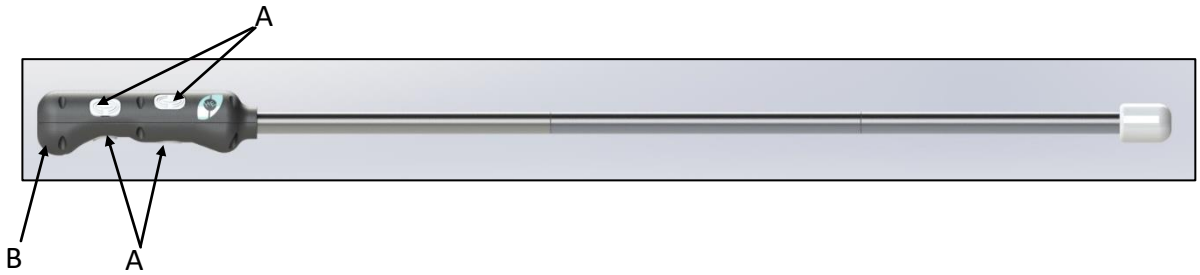
We kept the visual design to be curvy to follow the product style. It balances and creates the perception that there is equal distribution. Usually, items at the top are perceived as most important hence the placement of our logo is at the upper location of our product.



2. How did aspects of the visual design (layout, visibility of key elements) fare in usability testing?

It helps users perceive the overall design as opposed to individual elements. The styling of the product has been done keeping in mind the Unity aspect which promotes usability of a product. Unity has to do with all elements on a page visually or conceptually appearing to belong together. Some aspects of the form and visual design that has a positive influence on usability are as described in picture below:

A. Level difference and form variation between two button helps user sense the difference between two impulsions.
B. The bulky back of the product helps secure the cane properly also it acts as a fool proof mechanism to sense that the cane is not gripped at proper location



Structural Analysis

Structural analysis during product development is critical during the product design process. Design analysis can help identify the performance of a product before it even exists! Yet many companies tend to quickly sweep past this part of product development in a rush to get a product to market. Understanding what design analysis can truly do will save you both time and money [31].

Designers and engineers primarily use structural simulation to determine the strength and stiffness of a product by reporting component stress and deformations. The type of structural analysis you perform depends on the product being tested, the nature of the loads, and the expected failure mode [32].

Typically, products are creating in response to an issue or problem that needs to be solved. This could be anything from making a manual effort more automated, or expediting how long it takes to complete a function (think broom versus vacuum cleaner, dishwasher vs. washing dishes by hand, etc.). For effective design analysis we followed following approach :

1. Start with a problem statement
2. Create a list of questions to help guide the list of design requirements.
3. Take a step back and decide what is critical to solve the problem in the product we are trying to create.

This is a fundamental place to start. Product returns, recalls and other problems that occur once a product has been released can be prevented through careful product assessment early in a product's design lifecycle [31].

Software tool used for all Analysis studies: **Solidworks® 2016 SP03**

1. Start with a problem statement

Problem Statement:

A) With respect to manufacturing: Product looks too complicated with intricate features which may not be accomplished by molding process.

B) With respect to functionality and service environment: Because the product will be handled by visually impaired individual, it's natural that it will be dropped frequently. Moreover, the product will be subjected to low frequency vibrations generated from a motor that is used in cellphones. The vibrations generated are in the range of 7 to 20 m/s^2 peak-to-peak [33]. Hence, we can evaluate the vibration effects through Vibrational Analysis.

2. List of questions to help improve the design through structural analysis

a) Can we achieve all the feature geometry that is there in the product through our desired manufacturing technique?
b) Can the product be simplified to minimize the mold tooling cost?
c) Can the product sustain the drop from a certain height?

d) How dropping the product onto a floor will affect its structural integrity?
e) How can we locate critical weaknesses or failure points, as well as stresses and displacements?
f) How can we verify performance, material selection, component shape, and fixture methods to ensure that critical components stay together?
g) How to visualize the stress wave propagating through the system so that the correct assembly methods are used?
h) Are we consistent with Design for Manufacturing methodology?

Summary of the analysis tests performed:

Sr. No.	Test / Check criteria	Purpose	Questions addressed
1	Draft Analysis	In order to facilitate component removal from the mold and hence reduce cycle time, a design should incorporate appropriate draft angles.	a, h
2	Thickness Check	Parts with different thicknesses suffer from distortion, because the different thicknesses exhibit different degrees of shrinkage [34][35].	b
3	Drop Test	Study the effect of dropping the product on floor to its structural integrity	c, d, e, f
4	Random Vibration Analysis	Identify trouble spots that could cause problems (such as, resonance, fatigue, and assembly techniques) and avoid costly rework and delays during the prototype phase.	g

3. Decide what is critical to solve the problem

We will answer this question with respect to various findings from our analysis and simulation studies in the following part.

Analysis tests results:

Draft Analysis

Draft is the amount of taper for molded or cast parts perpendicular to the parting line. It can be measured in degrees or mm/mm (in/in). It will allow for an easy, non-damaging release from the mold when the expected shrinkage of the plastic material occurs.

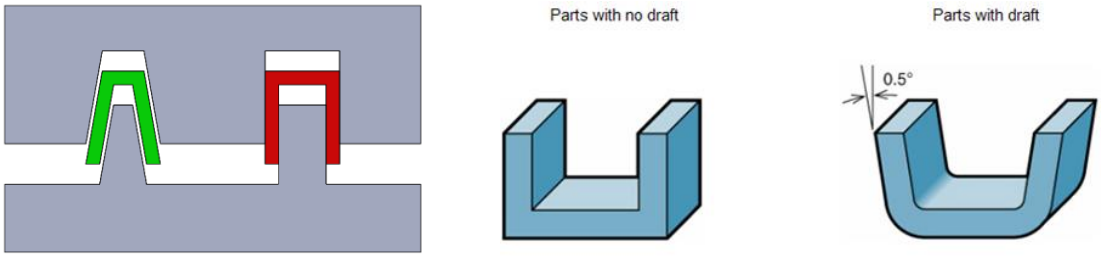
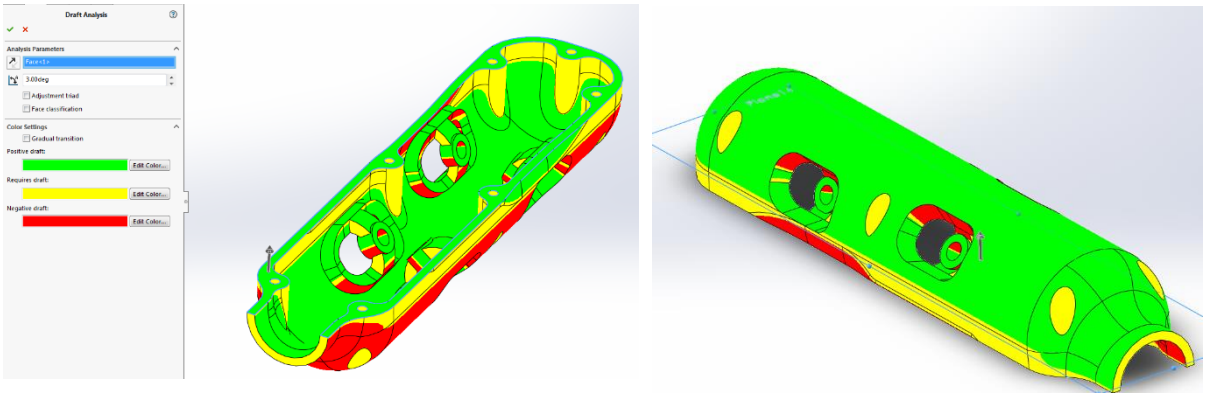


Fig.: Draft angle illustration (Source: https://www.solidsmack.com/design/design-fundamentals-draft-angles-part-1/)

- Original casing design:

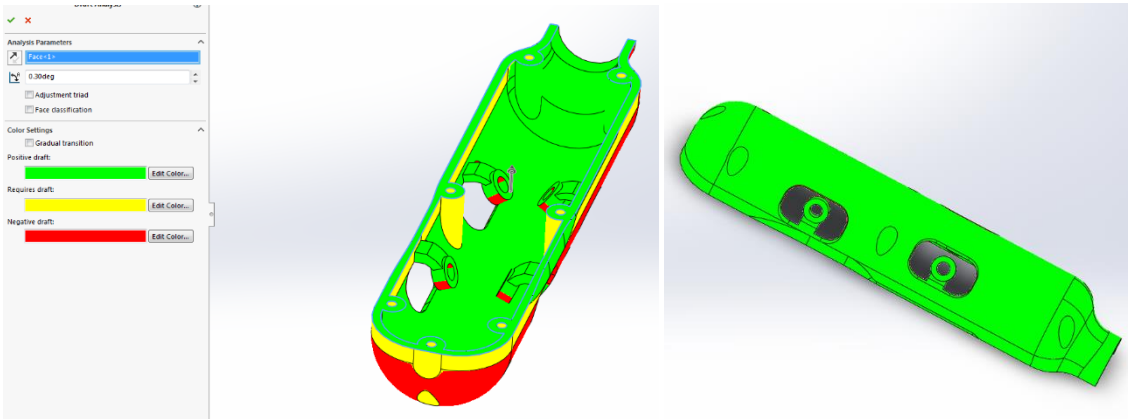


Observations: The red zone shows the negative draft area which should be avoided
Possible solutions: Reducing unnecessary geometry in part and giving proper draft angle wherever necessary.

- Improved new design

For untextured surfaces, 0.25 degrees to 2 degrees per side for both inner and outer wall is usually sufficient [34] [35]. We implemented a draft angle of 0.3° as it is used as standard by many companies.

Observations: Internal Geometry simplified. No undercut detected, and sufficient draft angle exists**.** The casing can be molded with a three pieces mold.



Thickness Check

Parts with walls of uniform thickness allow the mold cavity to fill more easily since the molten plastic does not have to be forced through varying restrictions as it fills.

If the walls are not uniform the thin section cools first, then as the thick section cools and shrinks it builds stresses near the boundary area between the two. Because the thin section has already hardened, it doesn't yield. As the thick section yields, it leads to warping or twisting of the part, which, if severe enough, can cause cracks [36]. In thickness check we made sure that as far as possible a uniform thickness is maintained throughout the part. The nominal thickness in this case is 0.12 inches.

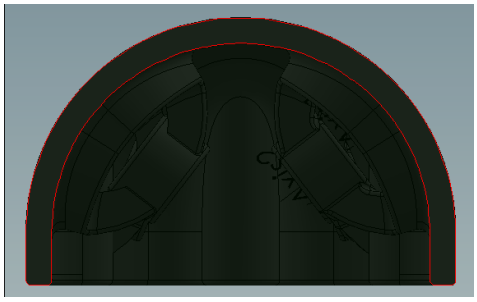


Fig. Uniform thickness of the product

Drop Test

Will the Part break?

The study does not answer this question automatically. It also does not predict the separation of bonded components due to impact. We can use the results to assess the possibility of such events to occur. For example, you can use maximum stresses to predict material failure and contact forces to predict separation of components [32].

We simulated a drop from three different heights 4.5 feet, 8 feet and 10 feet. For the first two drop heights the test did not provide evidence of any kind of deformation or damage to the product. At 10 feet drop we observed some deformation and high concentration of stresses. The graphical results from drop test with a drop height of 10 feet are as shown below:

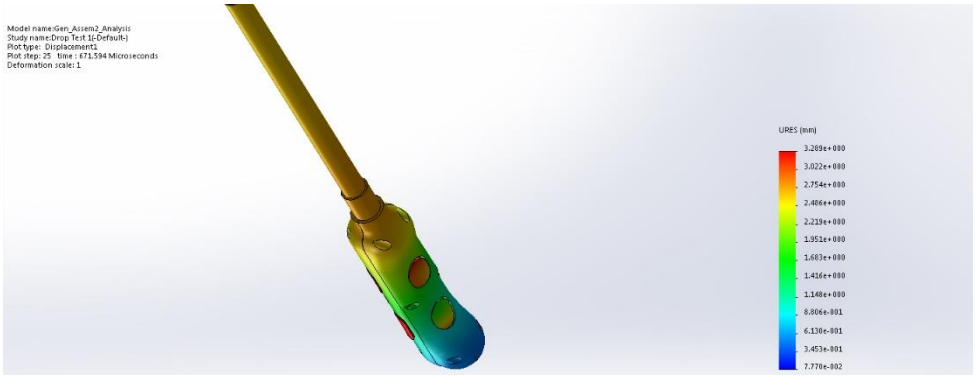


Fig. Displacement plot of drop test (Drop height: 10 feet)

Fig. Strain plot of drop test (Drop height: 10 feet)

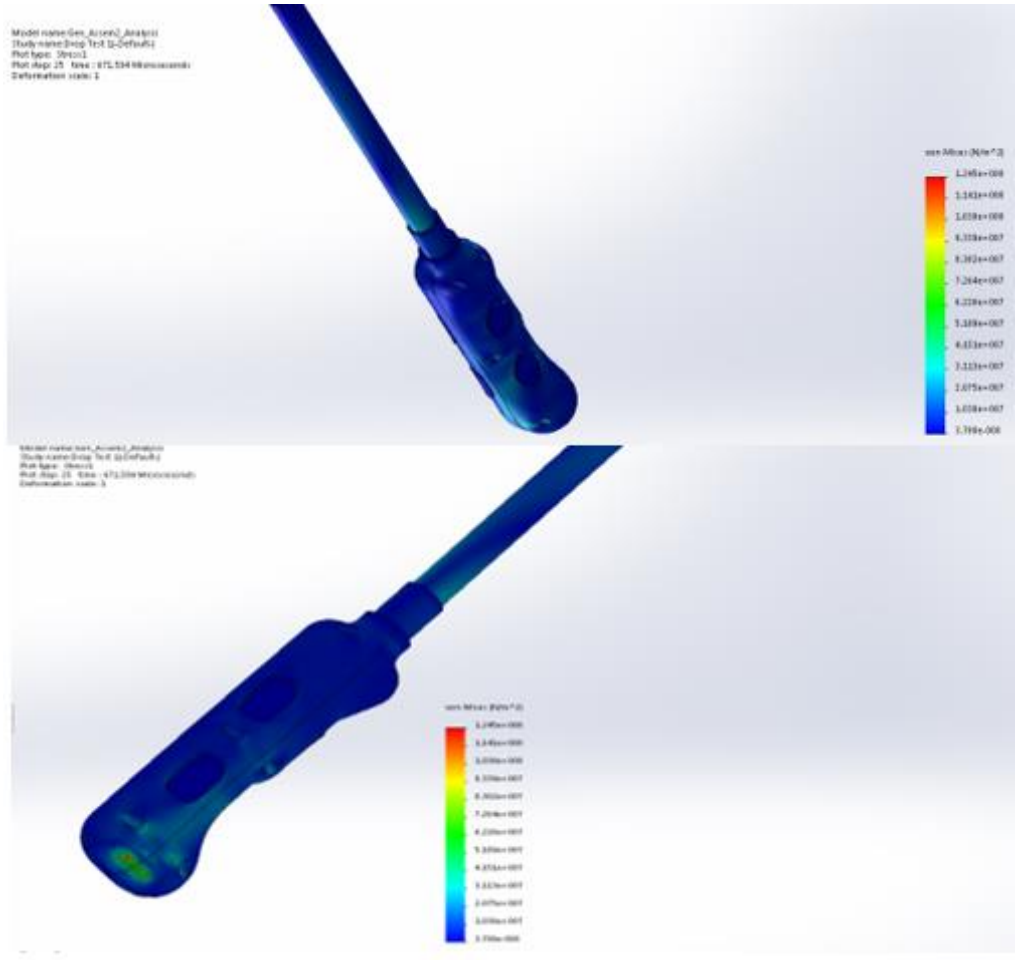


Fig. Stress plot of drop test (Drop height: 10 feet)

Random Vibration Analysis

A random vibration analysis provides the likely structural response to a spectrum of random excitations. The randomness is a characteristic of the excitation or input, not the mode shapes or natural frequencies. Structural response to random vibration is usually treated using statistical or probabilistic approaches.

The vibration motor that we are using generates vibration in the range of 100 to 200 Hertz. The product is subjected to these vibrations throughout its life cycle. In our case in simulated the test with induced random vibrations from 100 Hz to 200 Hz. As expected (from low frequency vibrations) the design sustained these conditions and showed no sign of any structural deterioration. The results of the test are shown in figure below:

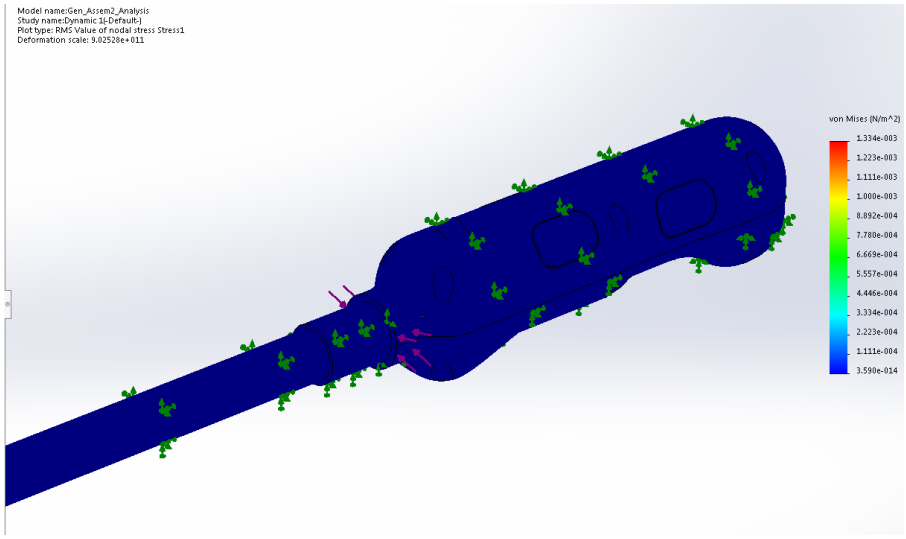


Fig. Vibration Analysis Plot (Vibrations induced: 100 – 200 Hertz)

Supply Chain

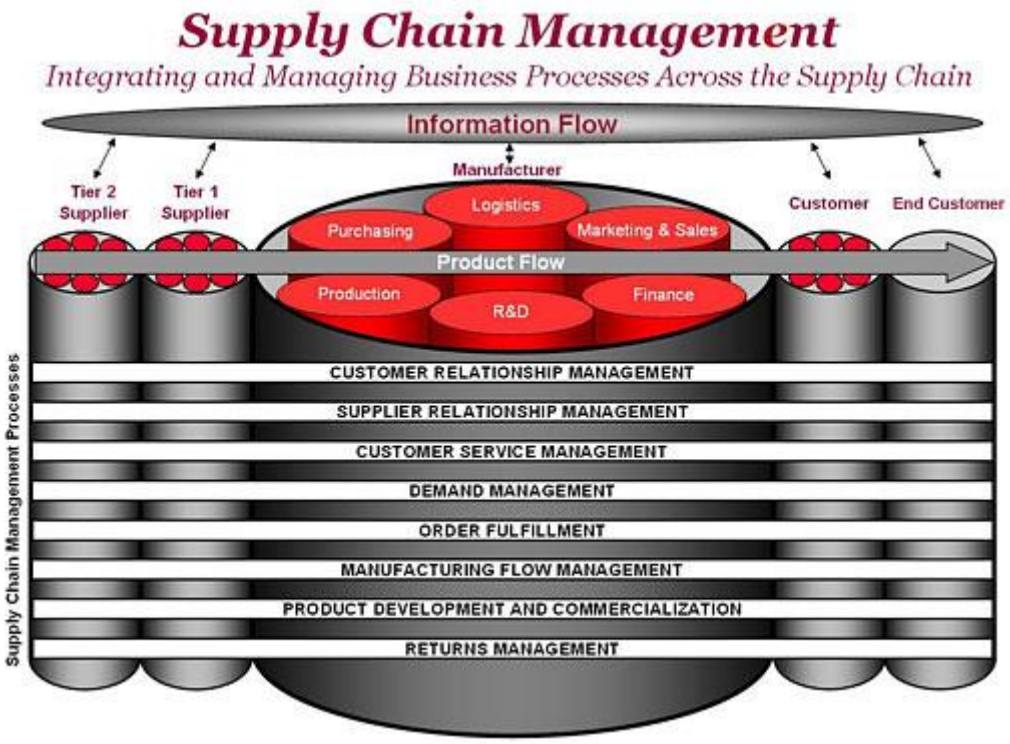


Figure 1: Supply Chain Management, Source:https://scm-institute.org/relationship-based-business-model/the-supply-chain-management-processes/

Supply chain includes all the activities from the purchase of raw materials to the distribution of the finished product to the customer. In this project we will be concentrating more on the Supplier-Production-Distribution side of the supply chain. The project focuses to meet an estimated annual demand of five hundred thousand per annum across Canada and USA. All the components of the product is planned to be sub contracted from the suppliers and the assembly is done in the Company Production house.

The Company is focusing on a Just In Time (JIT) inventory model with a Lead-time of 1 week and follows a continuous manufacturing assembly layout.

Supplier

Being a startup company, we do not want to hold too much inventory and also did not want to fail in meeting our customer demands. The main inventory models that were on our minds were MRP model and the JIT model. Finally, purely on the inventory aspect, we selected the JIT model of Inventory Management.

Just In Time Inventory model (JIT)

It's an inventory management model wherein one orders when you have shortage of raw materials. By using the above model, one can save a lot on the holding cost of inventories. However, JIT is not easy to achieve, as you need a zero defect and zero delay production line with a zero-lead-time supplier to achieve its main objective of zero inventory, which in practical terms is hard to meet. Thus, taking the above aspect into consideration, we have also calculated a basic EOQ model to determine order quantities of each sub-assembly.

Figure 2: Just In Time Policy, Source: https://www.contalog.com/blog/wp-content/uploads/2016/04/just-in-time.jpg

The smart cane in our project has following components. All the parts are ordered from a set of local suppliers:

- USB Charging port- $2/piece
- Cane- $ 25/piece
- Motors- $10/6 piece
- Chipset- $10/piece
- Button - $1/6 piece

			ORDER QUANTITY OF PARTS						
SL NO	ITEM	C ($)	I (%)	H ($)	A ($)	D	EOQ	TBO(WEEKS)	LT (days)
1	USB PORT	2	15	0.3	100	500000	18257.4186	1.89877153	2
2	CANE	25	15	3.75	100	500000	5163.97779	0.53705369	2
3	MOTORS	10/6piece*	15	1.5	100	500000	8164.96581	0.84915644	2
4	CHIPSET	10	15	1.5	100	500000	8164.96581	0.84915644	2
5	BUTTONS	1/6piece*	15	0.15	100	500000	25819.889	2.68526845	2

*1 unit of both motors and buttons come in a pack of 6 pieces.

EOQ= Economic Order Quantity; LT= Lead Time; C=Unit Cost; H=annual Holding Cost/unit/year; D=Annual Demand; TBO=Time Between Orders; I= Holding Interest %; A=Fixed ordering cost

EOQ= ((2*A*D)/H)^0.5; H=I*C; TBO= (EOQ/D)*52

Production and Assembly

The only area we will be concentrating here is the assembly as all components of the smart cane are being sub contracted.

The estimated time for assembling a single smart cane is approximately estimated to be 4 minutes (manual assembly) with the factory working 8hrs across 300 days. We focus on a continuous manufacturing layout (product layout) using 3 different assembly lines. In the initial phase we target a small proportion of demand later the production line is planned to be made automatic with many assembly lines.

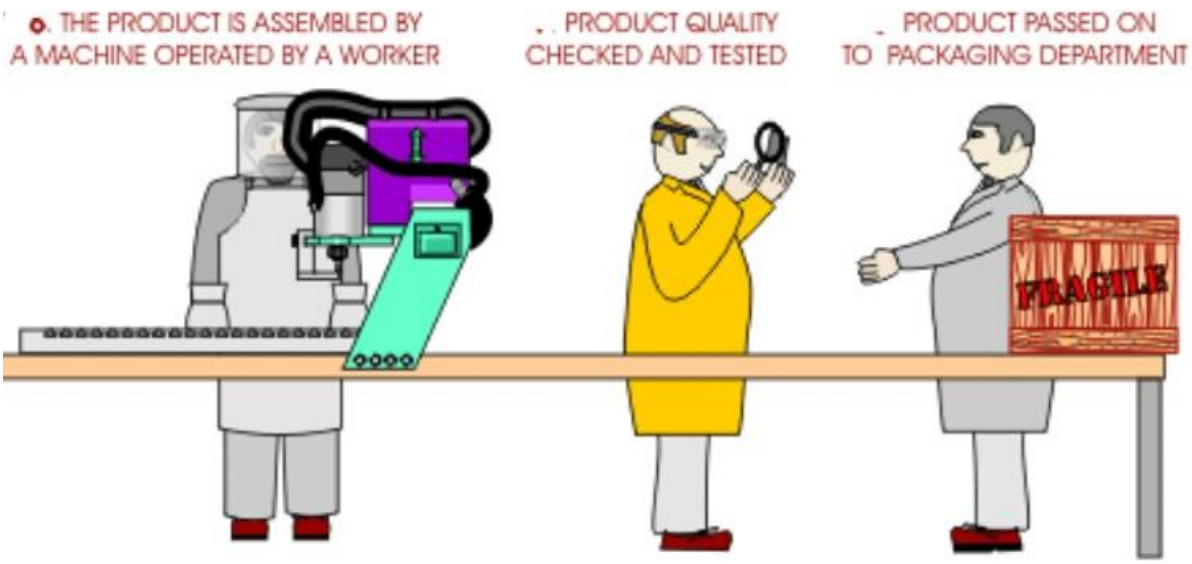


Figure 3: Assembly Line, Source:http://www.technologystudent.com/images4/bat2a.gif

Distribution(Logistics)

The product is introduced in the market both online and offline. The online purchase can be made from the drop shipping websites such as Amazon and eBay whereas the offline market will be controlled by a using a set of retailers.

The customer will have to bear with the shipping cost for online purchase whereas the offline purchase will be free of shipping charges. We will be following Drop Shipping distribution model here for online purchase and In-Transit Merge network model for offline purchase.

Drop Shipping Model

In this logistics model the customer orders the cane in a drop shipper website and the drop shipper gives us the information about the order and shipping details. The only responsibility of the manufacturer is to ship the item directly to the customer. The figure below will give a detailed idea on drop shipping.

Figure 4: Drop Shipping Model, Source:http://workathomepros.net/2017/03/14/10-outfits-inspired-by-famous-works-of-art/

In Transit Merge Network Model

In this logistics model the company sells the product using retailers in different parts of North America. Here the retailers order the quantities according to the customer demand and the manufacturer has to ship it directly to the retailer:

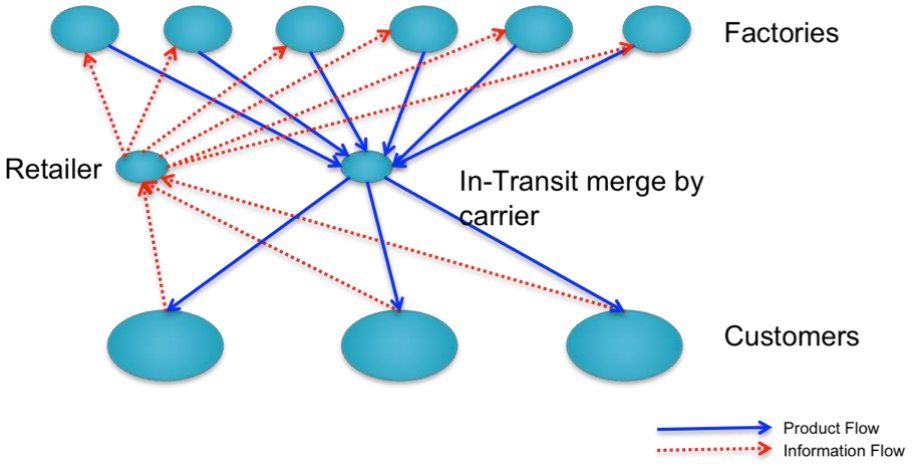


Figure 5: In Transit Merge Network Model, Source:http://www.thinksimpletoday.com/blog-30/files/dnd2.png

Final Cost Estimates

Prediction of Demand per year

Forecasting is an essential step before proceeding to the model. Although there will be errors in the prediction we can estimate the quantity of product Q expected to be sold during a time period by the equation given below which could be correlated to the actual demand.

$$Q = N * A * P$$

From the market analysis and the WHO estimates there are about 285 million people who are blind and visual impaired. Out of this 8 million people are from the western countries. From the survey done we estimate that number of people who could buy the cane is around 40% of the 8 million people. Therefore,

$$N = 8000000 * 0.40 = 3200000 \sim 3.2\ million$$

In the case smart blind cane market, it is estimated that 70% of potential customers would be aware of the product, due to marketing strategy. Also, due to the distribution challenges initially, it is estimated that 75% availability would be achieved. These data were also collected from the market research to support our statistics.

$$A = awareness \times availability\ (fractions)$$

$$A = 0.70\ x\ 0.75$$

$$A = 0.525\ or\ 52.5\%$$

To estimate the quantity of product being sold, we need the statistics of how many customers would definitely buy the product and how many may buy the product. To estimate this, we are employing a calibration constant $C_{definitely}$ and$C_{probably}$. The purchase probabilities associated with the responses C is 0.4 for definitely and 0.2 for maybe.

From our customer survey, we have

$$F_{definitely} = 0.67\%$$

$$F_{probably} = 0.25\%$$

P = Probability of purchase

$$P = (C\text{------}_{definitely} * F_{definitely}) + (C_{probably} * F_{probably})$$

$$= (0.4 * 0.67) + (0.20 * 0.25) = 0.318$$

Therefore, the expected sales can be predicted by the formula:

$$Q = N * A * P$$

$$= 3200000 * 0.525 * 0.318 = 534240\ units/year$$

From the market research, customer analysis and surveys, we could estimate that around 534,240 units are expected to be sold per year.

The MAKE vs. BUY decision

The make-or-buy decision is the action of deciding between manufacturing an item internally (or in-house) or buying it from an external supplier (also known as outsourcing). Another way to define make-or-buy decision is that it is a decision to perform one of the activities in the value chain in-house, instead of purchasing externally from a supplier.

To come to a make-or-buy decision, it is essential to thoroughly analyze, all the expenses associated with in addition to expenses associated with buying the product. The assessment should include qualitative and quantitative factors.

Factors favoring for in-house manufacturing

- Cost considerations (costs less to make the part)
- Improved quality control
- No competent suppliers and/or unreliable suppliers
- Quantity too little to interest a supplier
- Design secrecy is necessary to protect proprietary technology
- Control of transportation, lead time, and warehousing expenses
- Political, environmental, or social reasons
- Productive utilization of excess plant capacity to assist with absorbing fixed overhead (utilizing existing idle capacity)
- Wish to keep up a stable workforce (in times when there are declining sales)
- Greater guarantee of continual supply

Factors favoring purchase from outside

- Suppliers' specialized know-how and research are more than that of the buyer
- Lack of expertise
- Small-volume needs
- Cost aspects (costs less to purchase the item)
- Wish to sustain a multiple source policy
- Item not necessary to the firm's strategy
- Limited facilities for a manufacture or inadequate capacity
- Brand preference
- Inventory and procurement considerations.

Environmental factors are also a factor to consider for Make or Buy. Choice has to be made considering both aspects of short term benefits and long-term sustainability

In our case it is likely that the business may buy better grade products than those it can manufacture in-house. It is better to buy the cane to integrate with our designed handle. The handle we are making is unique to our product. We can outsource our design and simply assemble our product and sell it which would be better rather than making. If we are to make our handle and cane the initial investment cost will be very high and the cost of the dies and casting materials have to be taken into account.

Since our product is on the verge of developments and lots of companies are striving to produce more technologically advanced product, we would be spending our investment R&D. A firm spending on R&D is more likely to have the desire to outsource than to make a product.

An industry or a business operating on a constant change is more like to outsource their product. For us the best option is to buy the components for our product and assemble them which would be more profitable rather than making all the individual parts. By doing this, we calculate our product cost:

The white cane would cost around - 25 $/piece.	-	Buy
Motor cost would be for a set of six – 10 $/ 6 pieces	-	Buy
Chipset -10 $/piece	-	Buy
USB female port – 2 $ /piece	-	Buy
Power source kit – 5$/kit	-	Buy

The total outsourced components cost per unit would be 52$ CAD.

Analysis to make or buy

Manufacturing Cost:

Manufacturing costs are the costs incurred during the production of a product. These costs include the costs of direct material, direct labour, and manufacturing overhead. This is in the case if we are going to make the Handle.

To make the handle (Rough Estimates), 1kg of plastic pallet would cost around 1 USD which is equal to 1.27 CAD (price as on 11/11/2017) (From here on all calculations would be done with CAD).

For our handle the plastic that would be consumed would be around 100 grams per unit.

Taking scrap value of 5% of the material weight, then we get

$$= 0.100 + (0.100 * 0.05)$$

$$= 0.105 \text{ Kg}$$

So the unit material cost would be,

$$= 0.105 * 1.27$$

$$= 0.13\$ \, CAD$$

The total material costs

The total material cost = 52 + 0.13 = 52.13$

Therefore, the total material cost that would be incurred for our demand is,

$$= 52.13 * 534240$$

$$= 27849931.2\$ \, CAD$$

Then there is the tooling and machining cost involved in the molding process.

The tooling cost for a 1000 handle pieces is around 5$ CAD (Estimated from a similar product manufacturing process). Therefore, the tooling cost for our demand would be around 2671.2$ CAD. The machining cost is determined from the equipment cost, original machine cost, cycle time. For an injection molding machine cycle time is 30 seconds and could produce 250 parts

per hour. In which case the hourly rate would be 25$ if done by manual operator and 15$ if its automatic.

If we going to produce a quantity of 1000 units then

Machining Cost would be

$$= 25 * 534240/250$$

$$= 53424\$ \text{ CAD}$$

If the handle is made by our company, then the cost of one molding machine set would cost around 30000$ CAD on the average. Then there is the price for the mold which would be 3000-5000$ CAD and materials cost 0.13$ /part. There is also labor cost for personal handling the machine which is around 816,000$ CAD. When a manufacturing facility is build initially a company has to save a certain amount in case of emergencies in the facility.

Total cost = Total Material cost + Equipment cost + Machining cost + Tooling cost + Mold cost + Total labor cost + overhead cost + Emergency cost.

$$Total\ cost = 278{,}499{,}31.2 + 30000 + \ 53424 + 2671 + 4000 + (508996 + 816000) + \ 153{,}500 + 50000$$

$$= 29{,}468{,}522.2\ \$\ CAD$$

So the cost of the individual part becomes,

$$= \frac{29468522.2}{534240}$$

$$= 55.16\ \$\ CAD$$

If we were to outsource it then for making 1000 units the cost of injection molding would be the molds will cost around 3000-5000$ CAD and the each part would cost 0.10 $ CAD. Then the documentation and other miscellaneous cost are taken in to account, the cost of buying the components would be more profitable than the cost of making the components by ourselves. Cost of outsourcing the designed handle,

$$= 4000 + (0.10 * 534240)$$

$$= 57424\$\ CAD$$

Cost of the other parts,

$$= 534240 * 52$$

$$= 27{,}780{,}480\$ \text{ CAD}$$

Total cost of the material,

$$= 27{,}780{,}480 + 57{,}424$$

$$= 27{,}837{,}904\$\ CAD$$

Assembly and Packing cost

According to our sales forecast, we must manufacture 534240 units per year. The monthly production should be 44520 units and therefore, we should assemble 2226 units per day and roughly 250 units per hour. (Assuming that our company works 8 hours for 5 days a week).

The labor required for assembling 250 parts. If one-unit assembly would take around 4-5 min, we would require 17 workers.

The labor cost for the workers would be,

$$= 17 * 8 * 11.3$$

$$= 1536.8 \$ CAD$$

Labor cost for a year would be,

$$= 1536.8 * 20 * 12$$

$$= 368836\$ CAD$$

	Wage per hour(CAD)	Working hours in year	Cost per year CAD
Manager	25	8*20*12 = 1920	48,000
Floor supervisor	18	8*20*12 = 1920	34,560
Sales & inventory officer	15	8*20*12 = 1920	28,800
Quality inspector	15	8*20*12 = 1920	28,800
Total			140,160

The total labor cost for one year

$$= 368,836 + 140,160$$

$$= 508,996\$ CAD$$

Manufacturing and Assembly Overhead

For assembly of the product, a separate facility is required. There would be some cost associated with the assembly plant.

Overhead	Cost incurred in CAD
Rent	12000$
Electricity	30000$
Maintenance	1500$
Marketing	25000$
Development	10000$
Website	10000$

For our product, we are interfacing the product with a mobile application. Android developer charge, for developing an app, around 50$/hr. Assuming the application development time as 100 hours, we incur a cost of 50000$. Once the product is out for market, all the cost regarding the product is laid out. Now the product has to be introduced in to the market. Thus, a product

introduction to the market at the right time at the right place has a huge impact on the sale of the product. For this reason, we must indulge some money in product launch. Product launch cost would be around 15000$ CAD (Article by Ken Gallie-website-smallbusinessbc.ca)

Total overhead cost $= 153{,}500\$\ CAD$

Total cost of the product based on the buy strategy would be,

$$= direct\ material\ +\ direct\ labour\ +\ overhead\ cost$$

$$= 27{,}837{,}904\ +\ 508996\ +\ 153{,}500$$

$$= 28{,}500{,}400\$\ CAD/year$$

$$= 28.5\ million\ CAD/year$$

The cost of an individual product would be,

$$= \frac{totalcost}{\frac{units}{year}}$$

$$= \frac{28500400}{534240}$$

$$= 53.35\$/unit$$

Profit margin

In our case, the expected manufacturing cost is found out and then the profit margins are added to the cost. The approach employed here is a cost plus approach. A profit margin for a retailer is set as 5% and the manufacturer is 25%.

$$C = P_i \sum_{i=1}^{i=n} (1 - M_i)$$

Where,

C = Manufacturing cost,

P_i = sales price,

M_i = profit margin.

Manufacturer selling price,

$$53.35 = M_{manufacturer}(1 - 0.25)$$

$$M_{manufacturer} = 71.13\$$$

Retail price,

$$71.13 = M_{retail}(1 - 0.07)$$

$$M_{retail} = 76.48\$$$

Payback Analysis / Return on Investment Analysis:

To estimate the payback of the initial investment and to decide if the product could be successful in the market, a payback analysis is necessary for any company. From this the company must make the financial plan to determine the initial production volume. A longer payback is not desired by any manufacturer.

The cost of the products produced per year is 28,500,400. Therefore, consider the company invests 28.5 million initially and the cost of a HECATE cane is 71.13$ on the manufacturer end.

Payback

$$= \frac{28500400}{71.13}$$

$$= 400680.4\ products$$

Approximately 400000 products have to be sold to get the payback of the initial investment. But we estimated that our demand per year would be 534240 products.

Breakeven analysis

Once the company reaches the sales of 4000000(approx.) break even sales point is reached. It is the point where the company has no profit and no loss.

Payback period

Therefore for the cost of 71.13$ CAD payback period would be,

$$= (534240 - 400680) * 71.13$$

$$Cash\ flow - first\ year = 9500091\ \$\ CAD$$

$$Payback\ period = \frac{28500400}{9500091}$$

$$= \boldsymbol{3\ years}$$

Net Present value

Net present value of the company after a period of three years is calculated for cost of capital - 10%

Year	0	1	2	3
Cash flow $	2,85,00,000	95,00,091	95,00,091	95,00,091
PV factor	100%	91%	83%	75%
PV of cash flow $	2,85,00,000	86,36,446	78,51,315	71,37,559
Cumulative PV $	2,85,00,000	3,71,36,446	4,49,87,761	5,21,25,320
Net Present Value $	5,21,25,320			

In-Service Support Analysis

As our targeted community needs to be supported and assisted when they discover and first use our product, we need to have a strong In-Service Support.

Firstly, for an extra fee, the customer can have an external kit with Bluetooth earphones, headphones or loud speakers. We will also produce some external battery kits that can prevent the cane from being out of charge. At any moment, the customer can charge it during its activities thanks to the external battery.

We also wanted to include a first 30-minutes assisted training to all our customer. It will include:

- Taken-in-hand – directions to use the product
- How to configure an itinerary
- How to charge the cane

HECATE will be available directly online but also through retailers such as pharmacies and specialized stores. Thus, we will provide an online training and notices for specialists to make them discover our product and make them able to help the customers.

Our software will be free and available on all platforms: it will be available on the Apple Store, the Google and Android Play store. We will also provide a version for computers and especially for computers that use Braille inputs and displays. Thus, a special attention must be provided to the aspect of the software: it should be simple to use, with a few number of categories such as:

- direction input
- itinerary type: single or round-trip.
- Language: English of French
- The cane percentage of charge

As a continuous training, we will upload simple online notices and videos to assist the customers. As we're focusing on visually-impaired people, we must also provide simple descriptions of the contents and the video. This will help them understand the video.

The last In-Service category aims at assisting the customers when they have an issue related the use of our connected cane. For each cane purchased, we will assure a 5-year warranty. During this period, the user can ask the reparation of any broken component.

We will add a calling center to provide a continuous help and support to our customers.

Quality Control

Quality Control is used in all phases of business but is extremely relevant in engineering and manufacturing in developing systems to ensure products or services. It is used to meet or exceed customer requirements and is vital in the manufacturing part of all businesses.

There are five types of quality control methods:

- **Quality Assurance:** this method covers activities such as development, design, production, servicing, and production. Quality assurance can also cover areas of management production, inspection, materials, assembly, services and other areas related to the quality of the product or service.
- **Failure Testing**: this method involves testing a product until it fails It can be placed under different stresses such as humidity, vibration, temperature, etc. This method will expose the weaknesses of the product in question.
- **Statistical Control:** almost all manufacturing companies use statistical control. This process involves randomly sampling and testing a portion of the output.
- **Company Quality:** with management leading the quality improvement process and other departments following, a successful product or service will emerge
- **Total Quality Control:** measure used in cases where sales decrease despite implementation of statistical quality control techniques or quality improvements.

Quality Assurance and Failure Testing are relevant for our project.

Quality Assurance Method will help us cover most of the phases of the project where quality is predominant such as materials and assembly. We decided to provide an attention to the quality of our product through each step of its development: studying the behavior and the needs of our customer, knowing what is prevalent for them and according importance to quality when choosing our suppliers and materials were our first thought of quality.

We also increased the targeted quality of HECATE when defining our final specifications. The aim was the increase the minimum value of bending strength, speaker maximum sound volume, maximum UV exposition time and the maximum average number of cycles to failure.

Then, we added a Quality Function Deployment to analyze our quality response regarding our customers, markets and competitors.

The failure testing method is important for our product because it will insure that it is safe enough for our customers to use it. As they will rely on our product to walk and go to their destinations, we must make sure that the safety rate is the highest possible.

Finally, we will also do a statistical control to increase the precision of our testing and make sure that the product has the maximum-possible degree of safety.

Testing Definition

The testing phase of product development ensures that the product operates as expected. This phase is linked to the final specifications that are explained in the Analysis of the general environment of our product. There are two testing methodology when developing a product, depending on the way we developed our project.

The Waterfall methodology: aims at testing the product once all the development parts of the product are completed. The Agile methodology aims at testing the parts of the product separately every time a functioning requirement is met.

Regarding our product, the agile methodology seems preferable.

We will firstly do unit tests during the product development before testing the complete product. The simple cane will be bought separately, and our suppliers will already have tested it. We will require from them a review of each batch tests such as the bending strength limit, the mass and the minimum number of cycles to failure.

Then, we will produce test cases. These cases are all the possible scenarios that can happen to the cane when a customer use it. We can also ask the customer through a survey to test the cane and see how they handle it and see what could happen. This method can highlight some scenarios that we haven't thought about.

Some of the scenarios are listed below:

- Fall of the cane from a human height
- Division of the cane: the handling and the foldable parts are divided
- The handling opens during utilization and make some of the components move
- The Bluetooth connection isn't configured correctly, and the cane can't interact with the software nor the speakers/earphones
- The software isn't working correctly
- One of the vibrating buttons is blocked in the cane or is being divided from the rest of the handling

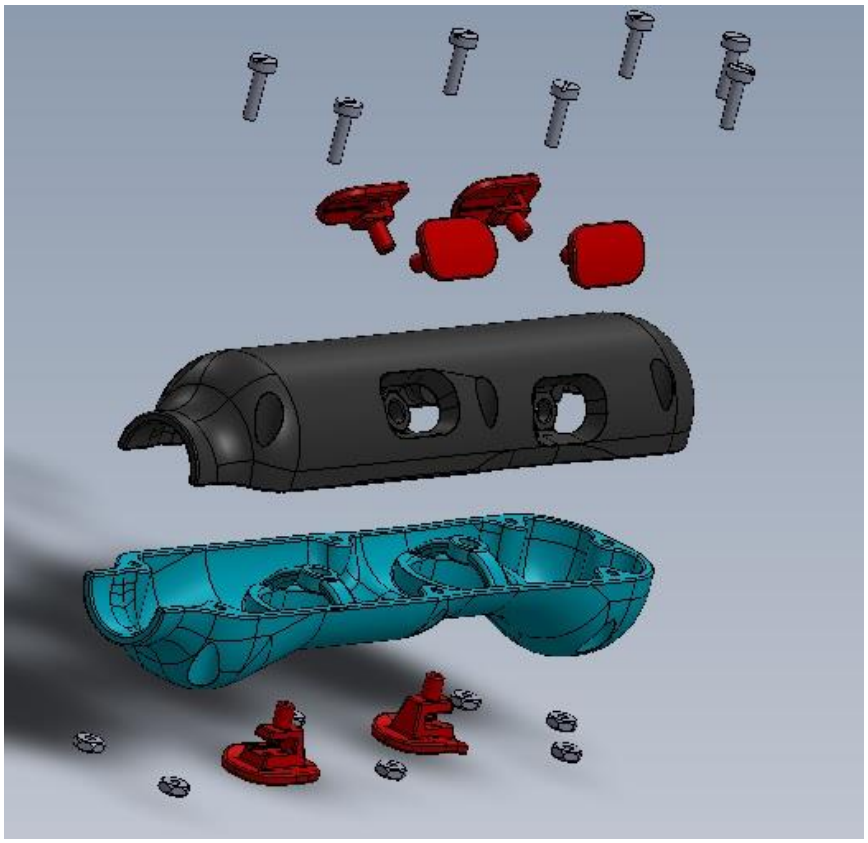
We will then test all these scenarios on different environments:

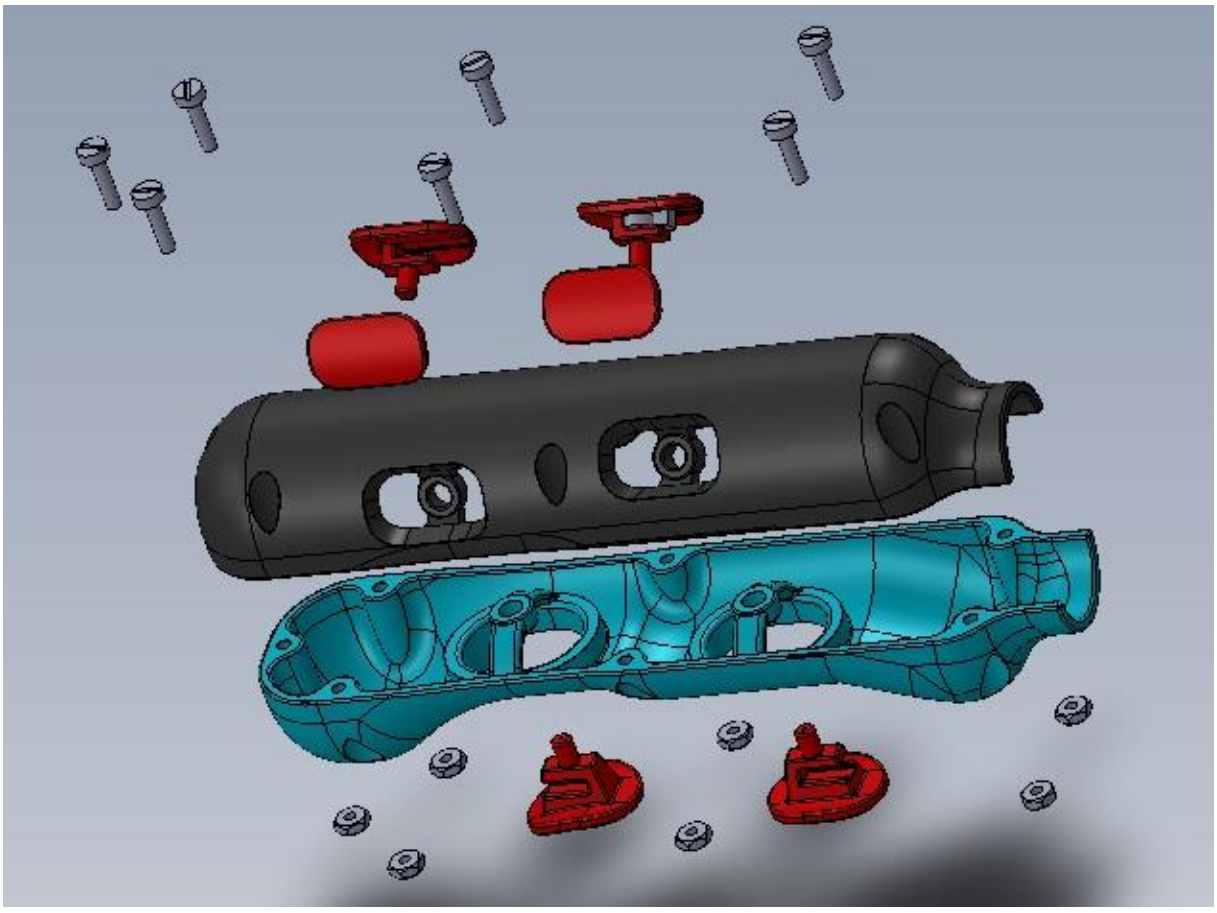
- Software environments may include different browsers, or operating systems
- Hardware environments may include different configurations such as type of ground, crowd, weather conditions

As we are a start-up, all these testing is sufficient and is the most cost-saving method at a short term. When our business will exceed the return on investment period, we will install an automated testing. It consists of executing regression tests each time a developer creates new functionality: it will ensure that they did not break old functionalities. This might also be a long process.

Drawings

We finally have the following 3D drawings of our product:





Deployment Plan

A deployment plan is a step-by-step guide on what needs to happen in the final stage of a project to get it into production. This plan needs to have every little detail included no matter how small it is. It should include items such as a resource calling another to complete the next step in the deployment. The deployment plan should be put together by the project manager and reviewed with the entire project team prior to the deployment. It should be done before the deployment. Once the deployment plan has been reviewed, it needs to be distributed to all project team members to use as a reference during the deployment.

Using excel, the deployment plan can be explained into two worksheets. The firs one deals with all the steps in time order and their description:

Deployment and Implementation Plan Project Name	HECATE
Implementation Date	DD/MM/YYYY
Implementation Time	XXX days
Estimated Completion Time	XXX days

Deployment Steps	Functional Are	Task Description	Duration Dat	Time Assigned	Status Comment

On the second worksheet, include contact information of anyone involved in the deployment, including escalation contacts:

Team Member Nam	Work Phone	Cell Phone	Alternate	Email	Notes
André Dupont	514-334-6789	+33 6 82 34 55 99	-	andredupont@hecate.ca	Team Manager
John Smith	514-226-1627	514-341-1524	514-212-1234	john.smith@gmail.com	Cane Supplier / work at night
Tom Marshall	514-334-4576		-	tommarshall@hecate.ca	R&D Researcher
Alexandra Barns	514-334-9078		-	alexandrabarns@hecate.ca	Financial

Finally, we will follow an application readiness checklist to make sure no steps are missed. Following these steps will enable the project manager to stay on top of what is going on during the deployment and ensure a seamless and successful launch. The application readiness checklist ensures that the application is ready and fully supportable once deployed. In a project that deals with implementing new applications for users to use, it is important to have the following:

- Name and General Description of the Application- this includes the purpose of the application and the number of users that are going to use the application.
- Software
- Hardware
- Operating Systems and Patching Requirements
- Installation and Configuration Guidelines- includes runbooks
- Application Design- includes flowchart and dependencies
- Monitoring and Systems Management
- Key Support & Maintenance Items
- Back-up, Data Retention and Data Archiving Policies
- Issues Logs
- Security Plan
- Service Level Documentation

Review and Future Market Opportunities

Future Growth Opportunities

After the production of our cane and its appearance on the market, we thought of different opportunities to make our industry grow.

Our first growth opportunity can be to expand our HECATE production to another continent. Many under-developed countries can be interested by our smart cane. If we decide to do answer to this demand, we will have to meet their needs. They might need different types of itinerary indications.

Once the first HECATE cane will be on the market and once we will have meet our payback period, we want to increase the range of HECATE products. For instance, we want to develop canes with different ranges of hand size. We also thought of developing straight cane so that the customer can choose between a straight and a foldable one.

Our next development step will be to include sensors to the cane to detect objects on the road (or infra-red cameras) to increase the safety degree of our product. This will also give a new function to our product.

We also want to integrate a vocal input function to delete an external need to program a path. Consequently, we won’t rely on smartphone’s platforms.

Lessons Learnt

Each member of the team had a different experience during this project. We all wanted to produce the best out of us.

“The tight schedule for completing the project helped me to produce the best out of me. The overall project activities helped me in understanding real life product development. Each gate in the project outline gave me a fair idea about the modular approach that is used in creating a new product. The project overall gave a clear picture about the hassles in the product development field and showed the importance of leadership and team work for the successful completion of the project. Further it refined my knowledge in MS word and Excel Spreadsheet making me much comfortable with this software. Overall it was a wonderful experience for me.”

“This project has helped me to work in a different language than my mother language. I discovered that the management must be different for each different way of working. It is difficult to meet all the needs to a product, you must make compromises to meet the deadlines and the budget. I appreciated to put in practice the notions seen in class: the key success factors, the QFD, efficient customer surveys, and how to make a manufacture and assembly analysis.”

“This project made me learn a lot about how a company functions while developing a new product by employing concurrent engineering principles. Made me learn a lot about managing my schedule since my work also influences the work of others since the information flow from one member to another is crucial while using concurrent methodology. “

“Design and research activity should have been more engaging with the feedback process as we came to notice some critical issue at a very later part in the design process. We found, after the first prototype, that the scale we considered for the model is not appropriate. The ergonomic studies should have been at a more detailed and practical level. This would have helped in identifying the most appropriate scale for the model. We could have made the prototype at a very early phase even before design detailing to feel the form of the product and make necessary improvements. For the structural analysis of components, we spent too much time at the concluding phase of design. This could have been avoided if we have start structural analysis parallelly at early design phase and improve the design side by side. The design guide to the desired manufacturing process should be referred before proceeding to detailed design of each of the functional features. This could have saved a lot of time spent in corrected the feature geometry. Our prototype concepts were based on insights and hypothesis. We could have spent more time to validate and iterate progressively.”

Conclusion: Project Review

Our product HECATE was developed to meet the customer needs by following the concurrent methodology. Since time to market plays a crucial role in a product success, this was kept in mind and our team set milestones and goals so that we could launch the product on to the market in a short period.

From the Market analysis customer needs were determined and competitor analysis was done to set the target specification based on both. Then the best possible concept was developed and designed according to the standards, at the same time provide maximum comfort to the customers. It was also tested for safety and quality. Then supply chain methodology and logistics were selected according to our business needs. Finally, cost estimations were done according to the predicted demand and the payback period was determined.

As the concurrent principles were followed, we were able to see the importance of the parallelization of the tasks.

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