SMART CANE FOR THE VISUALLY IMPAIRED AND FOR PEOPLE WITH LOW VISION

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A Final Year Design Project (FYDP) submitted to the Department of Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of
Bachelor of Science in Electrical and Electronic Engineering (BSEEE).

Department of Electrical and Electronic Engineering
Brac University
September 2022

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Department of Electrical and Electronic Engineering
Brac University
September 2022

Declaration

It is hereby declared that

1. The Final Year Design Project submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

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Approval

The Final Year Design Project titled "Smart cane for the visually impaired and for people with low vision" submitted by

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of Summer, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering (BSEEE). on 1-9-22.

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Ethics Statement

We have maintained all the ethical approaches for this project. We have checked the plagiarism by Turnitin and the percentage of plagiarism is only 19%.

Abstract

This work introduces an affordable smart cane system to aid the visually impaired so that they can navigate their surroundings independently. In Bangladesh, around 1.5% of the current adult population is visually impaired or has low vision. However, despite making up such a significant percentage of the population, they often face challenges while navigating their surroundings due to a lack of sufficient resources and accommodation. Studies have found that this often leads to frustration, reduced autonomy, and physical safety risks among the people in the community. Thus, there is a dire need for better assistive technology. Currently, the most used assistive device for this community is the white cane and research also shows that users prefer it over other devices. Hence, this project incorporates the white cane with some basic electronic components to further enhance its usability so that it suits the users' requirements. The proposed device includes various subsystems including object detection system, water detection system, emergency response subsystem, etc.

Keywords: Visually impaired; assistive technology; navigation; Arduino Nano; emergency response system.

Acknowledgement

I would like to acknowledge and give my warmest thanks to our ATC panel and professors. This work would not have been possible without them. Their guidance and advice were crucial in the completion of this project. I would also like to thank them for their brilliant comments and suggestions throughout the process.

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Chapter 1

Introduction

1.1 Introduction

This work introduces a smart cane system that will allow the visually impaired to navigate their surroundings more easily. To do this, we have integrated electronic components into the smart cane so that the basic function of the cane can be modified to better suit the users' requirements. The device includes various subsystems which incorporate microcontrollers and different types of sensors to detect and notify the user when there is an obstacle in front of them. Other than this, we have also included an emergency response system among other subsystems. In this report, we have attempted to document the process step by step.

1.1.1 Problem Statement

The main motivation for choosing this project was the lack of resources available for the visually impaired community. According to recent statistics from the World Health Organization, approximately 314 million people in the world are visually impaired [1]. Visually impaired people include those who have completely lost their ability to see or suffer from a partial loss of vision. In Bangladesh, the total number of visually impaired people is around 750,000, or 1.5% of the current adult population [2].

Despite making up a significant percentage of the population, the visually challenged often face difficulties navigating their surroundings, especially when traveling alone. Navigating without the help of others is a major challenge for visually impaired individuals, and it leads to frustration, low confidence, reduced autonomy, and physical safety risks [3]. Thus, there is a need for better assistive technology. According to the work done in [4] by Bhowmick and Hazarika, the research sector related to assistive devices is rapidly evolving. Furthermore, due to increasing aging and blind populations around the world, projects like these will be more relevant in the future. It will also have a major impact on society and the industry for assistive devices.

1.1.2 Background Study

Recent research and surveys show that although the white cane is the simplest and most inexpensive device, it can still cause disruptions in certain situations, for example, in a crowded street since it can only detect objects through contact. Furthermore, ordinary canes and trained dogs fail to deliver the features that are required for safe movement. Another big issue with the traditional cane is that it cannot be used to detect overhead obstacles, which are quite common in our day-to-day lives. We found that more advanced devices have been implemented in other countries, such as those proposed by Chitra et al. which include using a TOF sensor and LiDAR attached to the cane [5]. Although the measurements made through this device are accurate, the technology used is quite expensive and would not be suitable for developing countries like Bangladesh. Aladren et al. have researched a device that helps in navigation, particularly in the indoor environment. The system uses an RGB-D sensor which uses the color and range information to detect obstacles [6].

Nakajima and Haruyama in [7] have produced similar devices which incorporate GPS modules and Android apps. In this design, a light ID is used by the visually impaired person. It is attached to the users' smartphones and aids in GPS communication. Al-Khalifa and AlRazgan in [8] developed similar systems using the spectacle. The user gets the latitude and longitude feedback via voice command through the headphones and Google Maps is used for tracking. H. O. Omoregbee (2021) proposed using convolution neural network algorithms to process and classify the images identified by cameras fitted in front of the cane [9]. The identified image is then given as an audio output. The problem with this method is that a huge amount of coding and training is required to design and implement the algorithm, which is again not cost-effective. Ahlmark et al. [10] used lasers for object detection. The system has a range of several meters and does not need the physical interaction of the cane and the obstacle. The response is then sent to the user through a haptic interface.

Several papers about wearable object detection and avoidance systems were also studied. Cosgun et al. (2014) proposed a vibrotactile belt, which uses a vibrotactile motor and haptic strap which notified the users through vibrations if an object was detected in front of them [11]. Pradeep et al. (2021) proposed a system where a microcontroller is fitted in the shoe and directions are sent to the user via a smartphone app [12]. We also found a plethora of literature reviews on devices fitted on smart walkers or harnesses with different kinds of sensors attached to them. However, most of these products proved to be bulky and too difficult to travel with according to most users' feedback.

Research shows that smart canes performed better than wearable devices. The work done by Sakhardande in [12] shows that a low-cost, user-friendly smart cane can be designed using ultrasonic sensors. The prototype was able to detect above-knee obstacles and alert the user in real-time through vibrations. Similar work was done by Palaguta where a GPS module was incorporated along with a mobile app [14]. In another paper, Prutha introduced a stick to guide blind people independently; raspberry pi and Arduino were used in this design [15]. Prudhvi and Bagani in [16] have introduced similar designs that use a microcontroller. Information about the time and color of objects can also be transmitted to the user. Furthermore, the design includes a touch keypad and an emergency button that sends SMS from the module of Global System for Mobile Communications (GSM) alerting the users' loved ones of their current location.

1.1.3 Literature Gap

In the context of Bangladesh, this technology is uncommon and sufficient research has not been done in this sector. According to a paper published by Rushton on access to assistive technology for people with disabilities in South Asian countries like Nepal, India, and Bangladesh, the number of assistive products available for this community is still limited and this sector is severely underfunded. Furthermore, there is still a large gap in the research that has already been done. This is largely due to a lack of awareness about such issues and a gap in research and development for assistive devices, particularly electronic cane [17].

Not only will research on people's visual impairments aid the ophthalmological society, but it will also lead to the production of better-suited devices for the community [18]. So, it is important to distribute sufficient research resources on such issues for the betterment of society. In conclusion, more research needs to be done to identify the problems faced by these individuals in their day-to-day lives, their concerns, and needs, and special emphasis needs to be given to developing mechanisms that can give the visually impaired people their right to travel safely and independently.

1.1.4 Relevance to current and future industry

In Bangladesh, the industry is still severely underdeveloped despite the rapid growth of the aging population and the increase in the number of visually impaired people. According to the study in [19], the proportion of older people in Bangladesh is expected to double to 21.9% in 2050 with 36 million people aged over 60. This means that for every five Bangladeshis, one will be a senior citizen. Among this population, a large percentage is likely to suffer from low vision. However, the technology available for their aid is still very outdated and as mentioned above, the research is limited. Even though a lot of companies have recently stepped forward with dedicated research and development departments, there is a dire need for advancements in the current industry and we hope our project will contribute to the growth of this industry in the future.

1.2 Objectives, Requirements, Specification, and Constraints

1.2.1. Objectives

- Design a smart cane for visually impaired people.
- Implement the system such that it meets the users’ requirements.
- Create social awareness about visually impaired people and the difficulties they face.
- Create community and support among visually impaired people.

Functional and Nonfunctional Requirements:

Requirements are identified from the perspective of the user, there are two types of requirements: functional and non-functional. Functional requirements are those requirements that are needed to achieve the project objectives and non-functional requirements are all about the comfort of being used, and the outer look of the device.

Functional Requirements:

SL	Requirement	Explanation
1	A cane	As we are designing and implementing a smart cane, therefore, the very first requirement will be a cane.
2	Object detection system	The device should have an object detection system. It should be able to detect any object if it comes in front of the user which can be an obstacle for him.
3	Elevated and lower surface detection system	The device should be able to detect both elevated and lower surfaces so that users can easily climb up and down any stairway.
4	Detection of wet surface	If there are any wet surfaces ahead of the user, the device should be able to detect that wet surface.
5	Notification/alarm system	The device should notify the user if there are any objects, elevated, lower, or wet surfaces ahead of him.
6	Emergency response system	In an emergency, if the user feels that he needs help, he should be able to send his location to some specific person using this device.

7	Low power consumption	As this is a mobile device and the user could use it all day long. Therefore, the device must consume a minimum amount of power so that the user can use it for a long time without having to charge it frequently

Table 1: Functional Requirements

Non-functional Requirements:

SL	Requirement	Explanation
1	Foldability	As the height of the device is almost 145 cm, it would be helpful for the user if the device is foldable
2	Light in weight	Users will carry the device all day long. So, if the weight is unbearable then it could be a burden to them. Therefore, the device should be light in weight.
3	White color	Color code is a vital part of this particular device. Internationally white color is being used for the canes of the visually impaired people. So, the color of this device should be white too.

Table 2: Non - functional Requirements

1.2.2 Specifications

Technical specifications:

Specifications come from the perspective of design. To achieve the above requirements, we need some components, and the requirements to operate those components can be considered as technical specifications.

System	System Requirement	Components	Specification
Object detection system & Elevated and lower surface detection system	Microcontroller Board	Arduino UNO	● Microcontroller: ATmega328P – 8-bit AVR family microcontroller ● Operating Voltage: 5V ● Recommended Input Voltage: 7-12V ● Input Voltage Limits: 6-20V ● Flash Memory: 32 KB ● Frequency (Clock Speed): 16 MHz
	Proximity sensor	HC-SR04 Ultrasonic sonar sensor	● Power Supply: DC 5V ● Working Current: 15mA ● Working Frequency: 40Hz

			● Ranging Distance: 2cm – 400cm/4m ● Resolution: 0.3 cm ● Measuring Angle: 15 degrees ● Trigger Input Pulse width: 10uS ● Dimension: 45mm x 20mm x 15mm
	Power source	Lipo Battery 3300mAh 11.1V 3S	● Voltage: 11.1V ● Capacity: 3300mAh ● Cell Type: Li-polymer ● Configurations: 3S ● Discharge (Output) Lead: T Plug Connector ● Charging (Balancing) Lead: JST-XHR
The wet surface detection system	Water Sensor	Water Sensor	● SEN-00235 Water Sensor ● Operating voltage: DC 3-5V ● Operating current: less than 20mA ● Sensor Type: Analog ● Detection Area: 40mm x 16mm ● Operating temperature:10-30 ● Humidity: 10% -90% non-condensing
Notification/alarm system	Speaker	speaker	0.25 W, 8 Ohm speaker
	Buzzer	Digital Buzzer Module	Operating voltage: 5V
	Vibration motor	Grove - Vibration Motor	Operating voltage: 5V
Emergency response system	GPS-GSM Module	GPS Module GY-NEO-6M V2	● Power supply: 3V-5V ● GPS Chip: Ublox Neo 6M ● Antenna: Ceramic antenna ● Data Backup: EEPROM saves the configuration parameter data when power down with data backup battery ● Default baud rate: 9600

Table 3: Technical specifications

1.2.3 Technical and non-technical consideration and constraint in design process

A constraint is something that imposes a limit or restriction that prevents something from occurring. In this project, there are some constraints that we have found.

1. As there are many features of this device, we have to add more components to achieve those features, but adding more components will increase power consumption.

2. Adding more power sources and components will increase the weight.
3. Due to the complex design, the device cannot have multiple-fold facilities.
4. We want the device to have a lot of features and facilities but we also have to make sure that we don't cross the set budget or else the device will not be affordable.

1.2.4 Applicable compliance, standards, and codes

Required Device/Technology	Standard/Code Number	Definition	The solution that the code dictates
Tactile stick or white cane	ISO 9999: 12 39 09	A white cane has two ends, one with a handle and the other with a tip or roller. When not in use, the cane can be hung up using a wrist loop built with the handle. To signify that the user is blind, the body of the white cane is wrapped with reflective tape at the tip. It is made of aluminum, fiberglass, or carbon fiber. It is 1.2 cm in outer diameter & 140 $\pm$5 cm in length for adults. Its handgrip's length is 20 cm and the handgrip's diameter are 2.5 cm. It can be straight, angled, or folded (up to five folds) [20].	According to the standard, our cane also has a handle and a tip with a roller. Standard measurements have been taken while making our prototype. It is made of aluminum & wrapped with reflective tape around the body and it is at least foldable by one-fold.
Global Positioning System (GPS)	WGS 84 or EPSG:4326	GPS is a global positioning system established by the US Department of Defense to provide important positioning capabilities to military, civil, and commercial customers. It makes use of the World Geodetic System (WGS), a global standard for cartography, geodesy, and satellite navigation.	This technology is used to detect the location of the user.
Global System for Mobile communication (GSM)	GSM 03.40 or 3GPP TS 23.040	The European Telecommunications Standards Institute established the Global System for Mobile Communications to describe the protocols for second-generation digital cellular networks used by mobile devices such as phones and tablets.	This technology is used to send the location data of the user via SMS.

Rechargeable Battery	IEEE 1625-2008	This standard specifies design standards for the certification, quality, and dependability of rechargeable battery systems for multi-cell mobile computing devices.	This standard is used to make battery functioning and end-user experience more reliable in mobile computing environments.

Table 4: Applicable compliance, standards, and codes

1.3 Systematic overview/summary of the proposed project

The proposed device will consist of sensors attached to different positions of the walking cane to detect elevated and lower-level ground, as well as any water surrounding the area of the cane. It will give vibration feedback to the person holding the cane so that they know which way to go to avoid obstacles. The lower and elevated surfaces will be detected by the middle IR sensor and the notification will be given via voice command. Other than this, a buzzer will ring wherever the water sensor detects a watery surface. Lastly, a communication module has been used so that the users' closed ones can be notified if the user is ever in danger or needs help. To alleviate the weight of the sensors, a single wheel will be attached to the cane at the bottom. The wheel will enable the cane to be dragged in terrain with minimum effort. There is also a power supply module to ensure that the device can be used for extended periods of time and does not require constant charging.

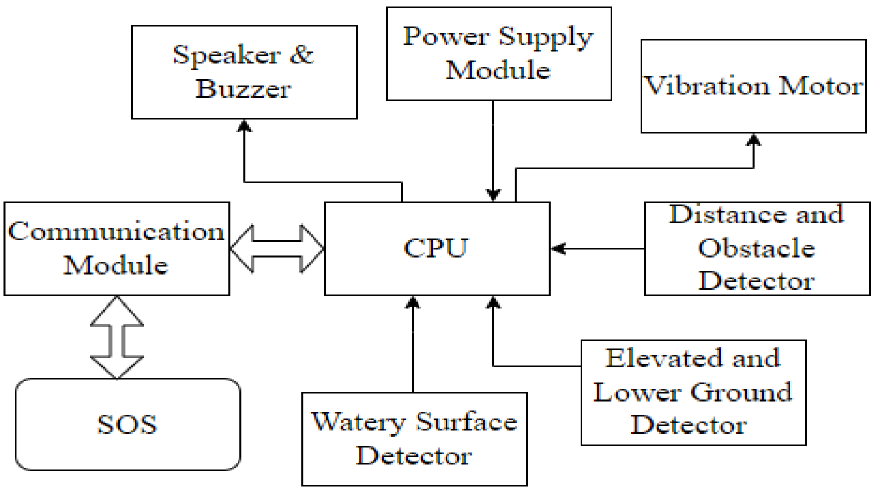

Figure 1: Overview of the proposed system

Knowledge, Skills, and Resources Required:

Apart from research skills that we learned during the initialization and designing phase, we also had to conduct extensive research on advanced technologies and concepts. To do so we reviewed relevant technical literature and documents on related engineering topics. Some of these learnings have been mentioned here.

During the design part of the project, we needed a 3D model to visualize the design. For this, we first compiled a number of different software that could do the task and finally decided on using Blender as it was the optimal tool to use. Blender is a free and open-source 3D modeling and animation software. It comes with a robust toolset capable of producing professional-quality 3D models. Since this software was completely new to us, we used professional tutorials and technical documents to develop our skills and learn how to use the software. We also got a lot of support from the well-established online community. Furthermore, we learned about the different types of file formats and how to import them, and how the mechanics worked. Lastly, we used some of the latest features to make our design accurate and appealing.

For the implementation part of the project, Arduino IDE was used to write and upload the code to the Arduino motherboard. A lot of trial and error had to be done while compiling the code which was definitely a learning experience. To produce a viable code, we had to revisit our knowledge of the C programming language and also read about some advanced in-built functions. For example, we had to learn how to make use of AT commands in order to establish communication between the GPS and GSM modules.

Proteus was used to validate the proposed design. Even though we had prior knowledge about the software, we still had to work out how to add external libraries such as for water and ultrasonic sensors which were not already available with the software. Apart from this, interfacing had to be done with the Arduino IDE and Proteus. Also, we had to read up on how to simulate the GPS and GSM module on Proteus and how to display the VGPS screen with the GPS coordinate as well. Lastly, a virtual screen was used to mirror the phone screens while simulating the communication modules.

Other than this, some practical skills were also acquired. We had to learn how to read and extract data from the datasheet for each component to ensure the safe operation of the subsystems. For example, there was an issue with the power supply subsystem where we designed the entire system to work with a 12 V supply but later found out from the datasheet that the communication modules could handle a maximum of 3V supply. In the end, we used only one of the three cells of the Lipo battery for the communication system and kept the rest of the design as it was with a 12V supply to the main device.

In order to complete this project, we conducted independent research and literature surveys on relevant topics by reviewing articles, documents, reports, and conference papers. Furthermore, we had to familiarize ourselves with new concepts and technologies during the testing and validation process. For example, we had to learn how to use Blender, which was completely new to us. We also had to compile the necessary information, materials, and resources needed to complete this project. Through this project, we recognized the need for independent learning and acquired skills that will hopefully be useful to us in the future.

1.4 Conclusion

In this section, we identified a complex engineering problem that could be solved using our learned knowledge and skillset. Then, the next task was to do a background study and identify existing solutions and assess how well they were combating the issue. At this stage, we found out the alternative solutions and their lacking. Next, we found out the literature gap and areas where improvement could be done. We also analyzed how relevant this project would be to the current and future industry. Lastly, we found out the objectives, functional and non-functional requirements, specifications, constraints, and applicable compliance, standards, and codes associated with our project. This was a crucial first step as it helped us gain a more in-depth idea about the topic.

Chapter 2

Project Design Approach

2.1 Introduction

Project design is an early phase of the project lifecycle where ideas, processes, resources, and deliverables are planned out. A project design comes before a project plan as it's a broad overview, whereas a project plan includes more detailed information. After determining the problem, we tried to determine how many ways we could fulfill our requirements for the problem. Here we tried to find the most suitable designs for our project.

2.2 Identify multiple design approach

<u>Design approach 1: Obstacle Detector</u>

Sensors will be attached to a walking cane and those sensors will scan the surrounding area and upon detecting an obstacle it will buzz to give feedback to the person holding the cane.

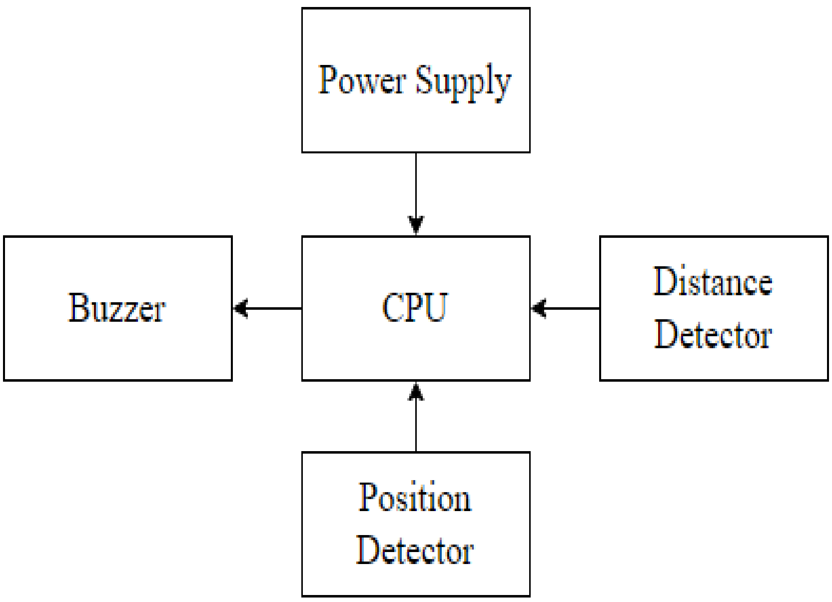

Figure 2: Block Diagram of Obstacle Detector

Design approach 2: App-Based Obstacle Detector

Sensors will be in the box and the vibrator will be attached to the handle of the cane to alert the user. There will be an app to smartly and remotely control the cane over Wi-Fi or Cellular data.

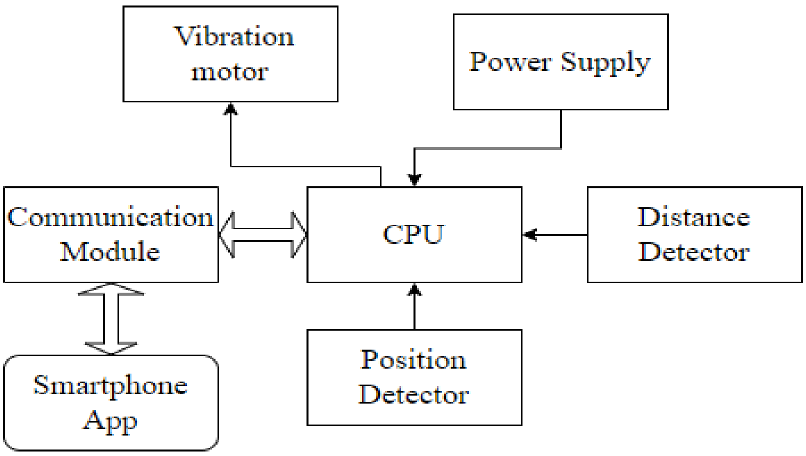

Figure 3: Block diagram of App-Based Obstacle Detection

Design Approach 3: Automated Obstacle Detector

Sensors will be attached to a three-wheel-based small trolley system. The trolley system will be attached to the bottom of a cane. The whole weight of the cane will lie on the trolley and will be run by a motor driver connected to DC motors. All the sensors will be placed on the wheels like a toy car system. Upon detecting an obstacle, it will automatically stop and will go left or right after scanning the safest route.

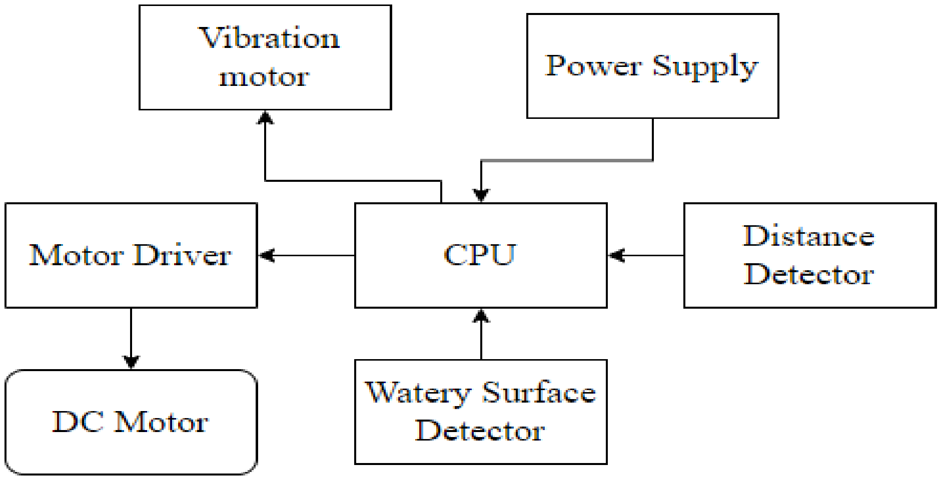

Figure 4: Automated Obstacle Detector

<u>Design Approach 4: Obstacle, Elevated, and Lower Ground Detector</u>

Sensors will be attached to different positions of the walking cane to detect elevated and lower-level ground, as well as any water surrounding the area of the cane, and will give vibration feedback to the person holding the cane. To alleviate the weight of the sensors, a single wheel will be attached to the cane at the bottom. The wheel will enable the cane to be dragged in terrain with minimum effort.

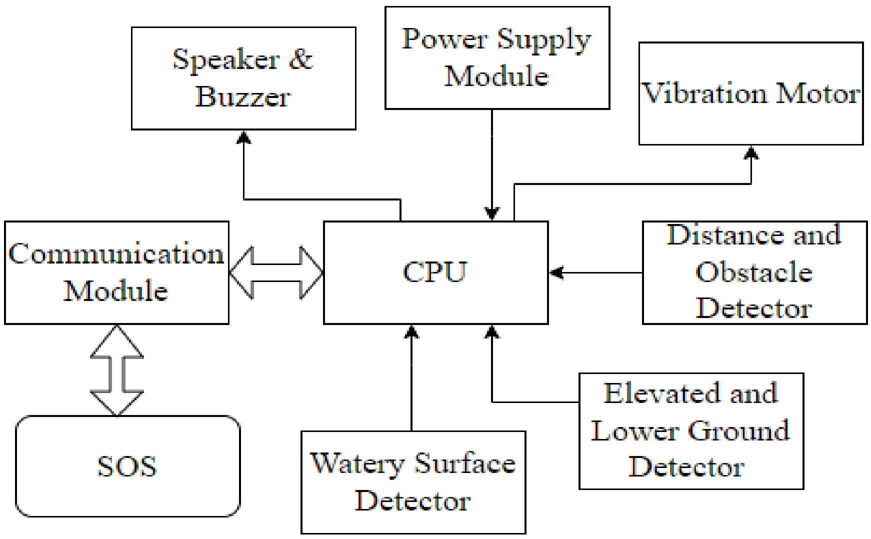

Figure 5: Obstacle, Elevated, and Lower Ground Detector

2.3 Describe multiple design approach

Design Approach 1: Obstacle Detector

This design approach fulfills the requirements of detecting an obstacle in front of the user. After detecting the obstacle, the device will notify the user by using the buzzer of the notification system. Besides, it is quite cheaper and simple to build. Troubleshooting is also easy. Although it cannot detect the obstacle to its left or right side. The flowchart is also given to understand the working algorithm of this design.

Flowchart:

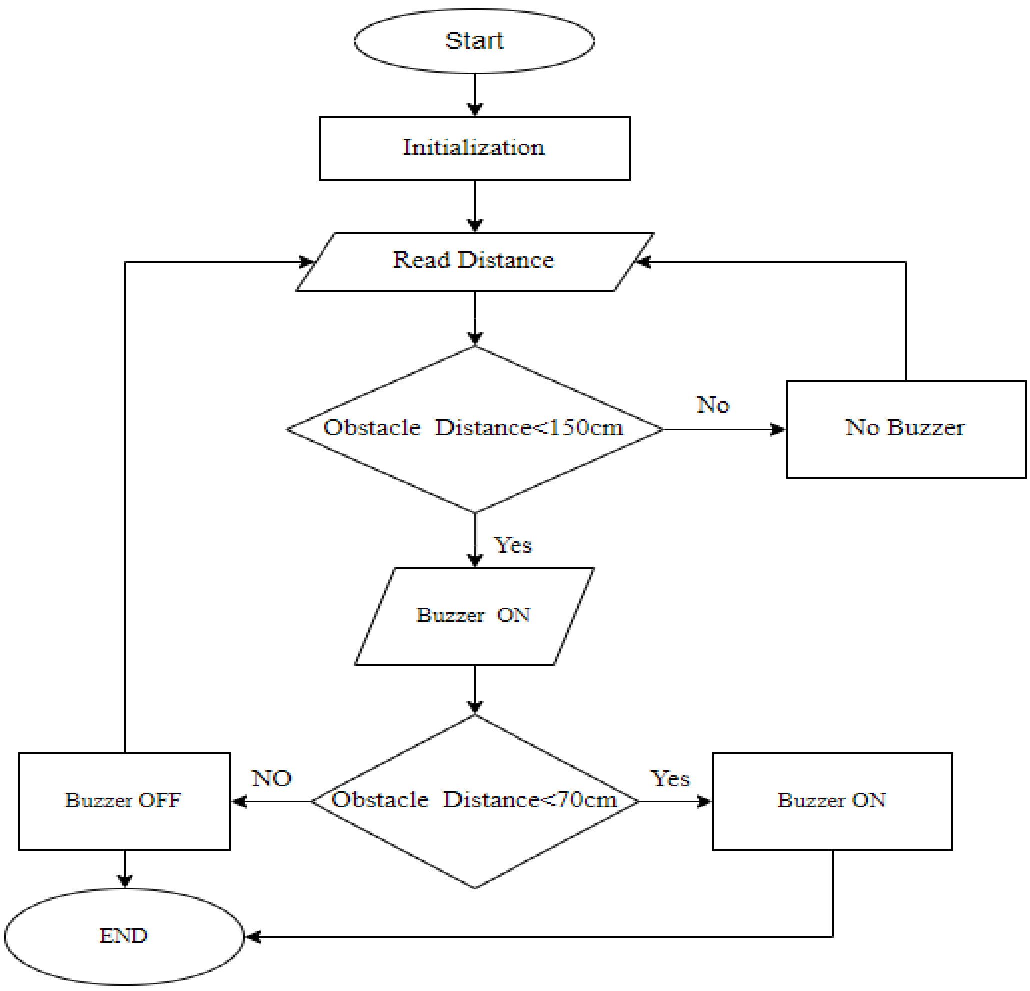

Figure 6: Design process of approach 1

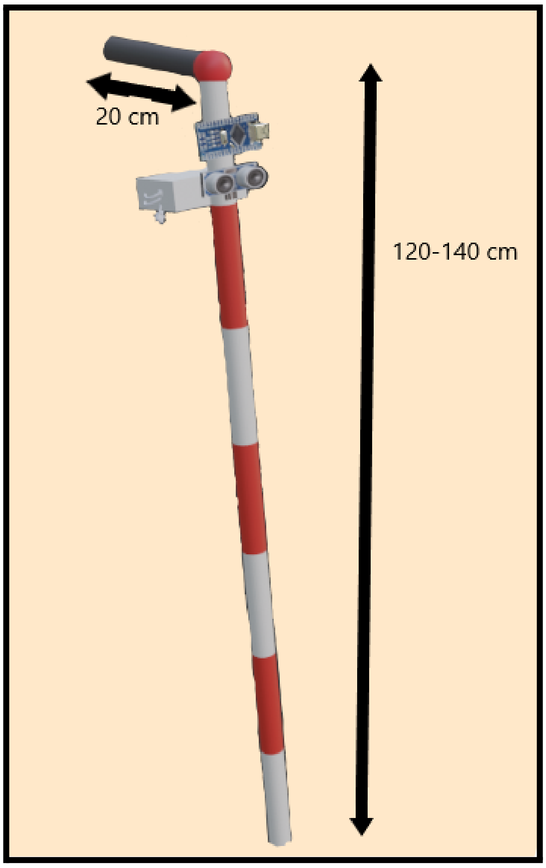

Figure 7: 3D model of approach 1

Design Approach 2: App-Based Obstacle Detector:

Sensors will be attached to the upper half of a walking cane and those sensors will scan the surrounding area and give vibration feedback to the person holding the cane. The criteria for identifying a barrier in front of the user are met by this design strategy. When an obstruction is detected, the gadget will alert the user by buzzing the notification system. In addition, it is

easy and cheap to construct. Identifying problems is also simple. Despite the fact that it cannot see the obstruction to its left or right. There is an emergency system in this device. To comprehend how this design's working algorithm works, a flowchart is also provided. A flowchart is furthermore supplied to help users understand how this design's working algorithm operates.

Flowchart:

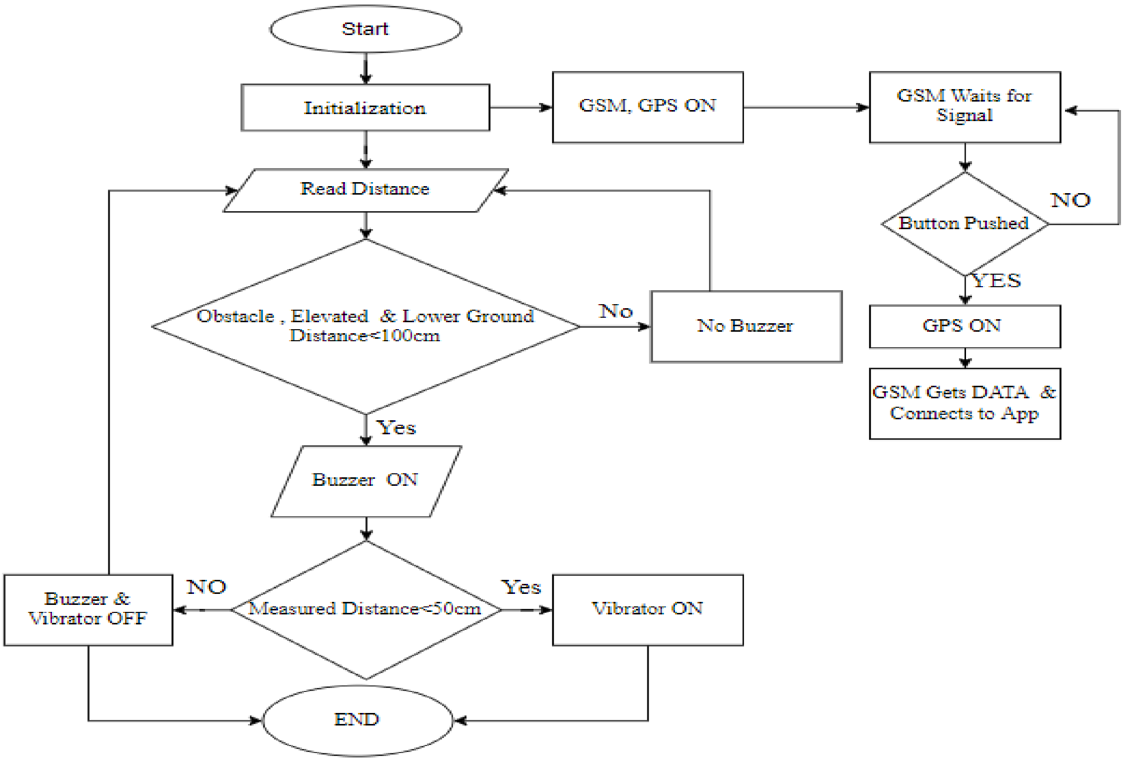

Figure 8: Design process of approach 2

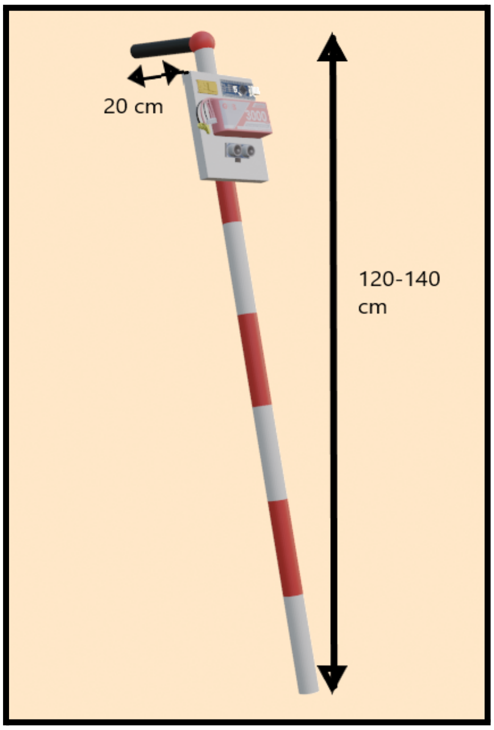

Figure 9: 3D model of approach 2

Design Approach 3: Automated Obstacle Detector

A tiny robot system with three wheels will be equipped with sensors. The bottom of a cane will have the robot system linked to it. The robot, which will carry the whole weight of the cane, will be propelled by a motor driver linked to DC motors. All the sensors will be mounted on the wheels. It will automatically stop when it encounters an impediment and then choose the safest course by turning to the left or right. It can also detect the water surface. Flowchart:

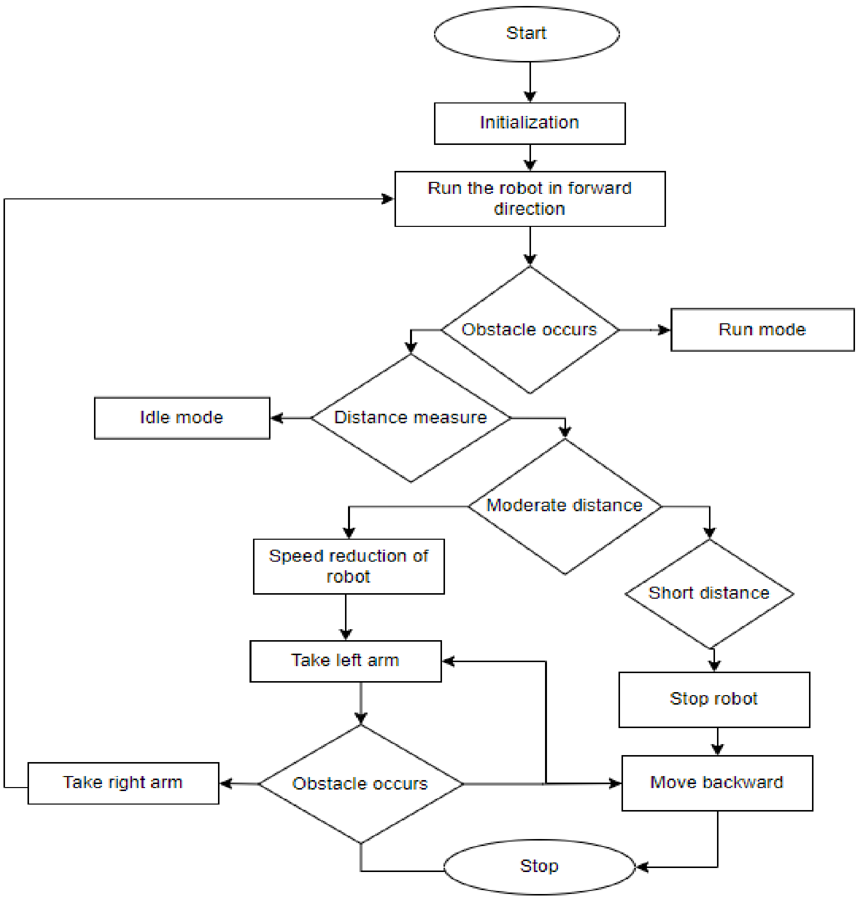

Figure 10: Design process of approach 3

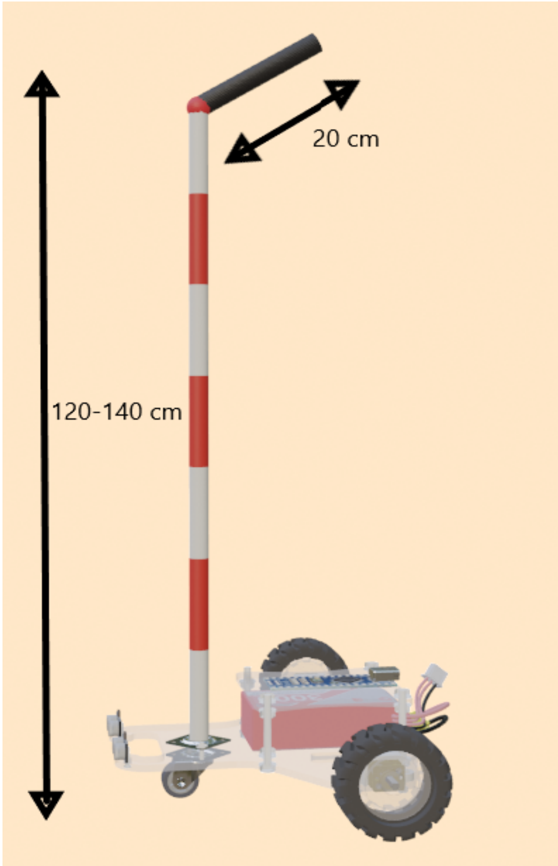

Figure 11: 3D model of approach 3

Design Approach 4: Obstacle, Elevated, and Lower Ground Detector

The criteria for identifying an obstacle in front of the user are met by this design strategy. When an obstruction is detected, the device will alert the user by buzzing the notification system. In addition to that, it will also notify the user if there are any stairs or elevated surfaces and lower surfaces. This will also identify if there is a watery surface in front of the user. There is also an emergency system in this device. Identifying problems is a little bit complex. This device can see the obstruction to its left or right to notify the user. To comprehend how this design's working algorithm works, a flowchart is also provided.

Flowchart:

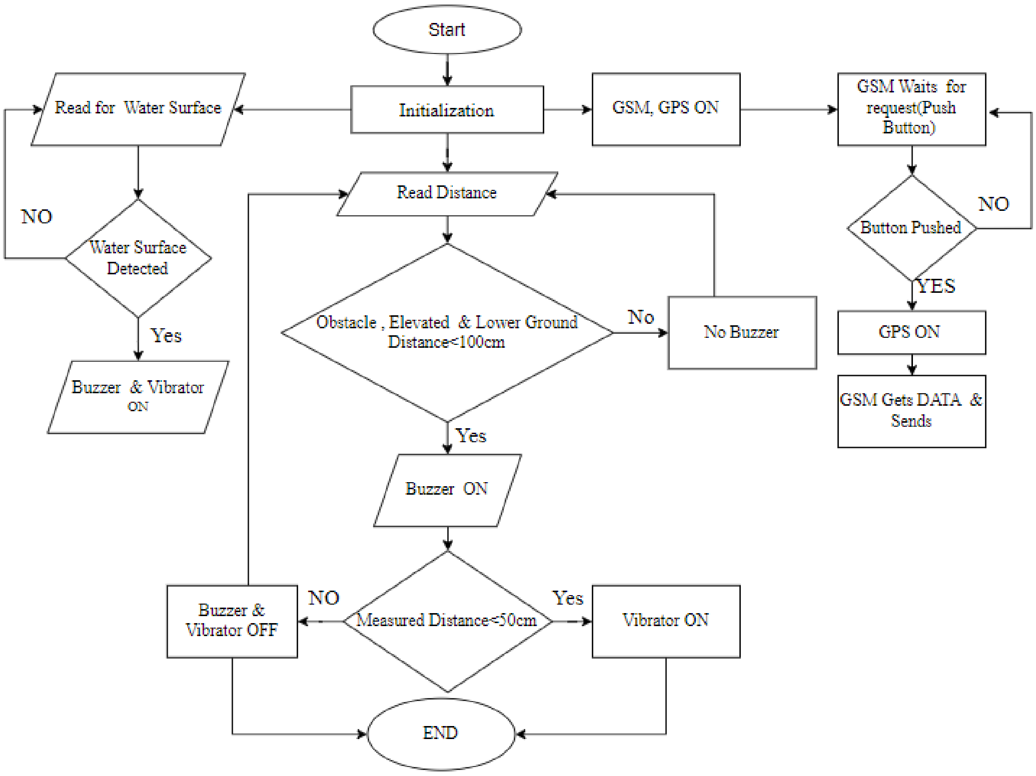

Figure 12: Design process of obstacle, elevated, and lower ground detector

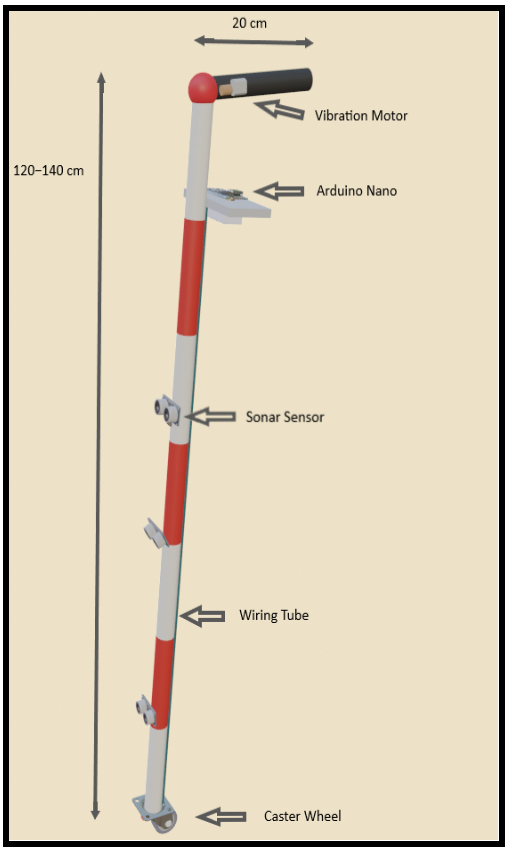

Figure 13: 3D model of obstacle, elevated, and lower ground detector

2.4 Analysis of multiple design approach

In this section, a comparative analysis of the four design approaches were done based on cost, efficiency, usability, manufacturability, maintainability, etc. The following table shows how each of these approaches was evaluated based on these criteria.

Multiple design Approach	Design Approach 1: Obstacle Detector	Design Approach 2: App-Based Obstacle Detector	Design Approach 3: Automated Obstacle Detector	Design Approach 4: Obstacle, Elevated, and Lower Ground Detector
Efficiency in fulfilling Requirements	Obstacles detection & Notification systems.	Obstacles detection, Notification systems & can be controlled remotely via Wi-Fi	Obstacles detection, Notification systems and will guide the user elsewhere	Object detection, Elevated, and lower surface detection, Wet surface detection, Notification system, and Emergency response system.
Cost	Low	Medium	Very high	High
Usability/how easy it is to use	1. Very easy to use. 2. Users will have to carry the device.	1. Takes a little time to learn to use. 2. Users will have to carry the device.	1. Takes a good amount of time to learn to use. 2. Users will not have to carry the device.	1. Easy to use. 2. Caster wheel will compensate for the weight.
Weight	Light	Light	Heavy	Medium
Size	Compact	Compact	Bulky	Compact, with a wheel attached
Manufacturability	Easy to mass-produce.	A lot of time and resources are needed to develop and release an app.	Easy to mass produce but a lot of components are required.	A decent number of components and time are required.
Maintainability	Is easily maintained and takes less time to troubleshoot.	Comparatively easy to troubleshoot.	Easily maintained and takes a moderate amount of time to troubleshoot.	Complex and takes a good amount of time to troubleshoot.

Upgradability	Basic level design so hard to implement new/ more advanced features	Difficult to implement as adding new features will mean bringing changes to the app.	Easy to implement new features.	Easy to add on new features or customize according to the user.

Table 5: Analysis of multiple design approach

Weighted Average

A quantitative comparison was done here using a weighted matrix. For this, we studied research papers, articles, and surveys that analyzed similar products and found out which of these eight features were most important for the users. Then, as a group, we assigned a weight to each feature and rated each design approach based on how well it met the criteria. Finally, the ratings were summed up and compared to determine the best approach.

Different parameters	Assigned weight	Design Approach 1	Design Approach 2	Design Approach 3	Design Approach 4
Meet Requirements	25	10	15	18	22
Affordability	15	14	12	8	10
Usability	15	12	8	10	13
Weight	15	13	12	8	11
Size	10	13	10	8	12
Manufacturability	10	8	7	4	7
Maintainability	5	4	3	2	3
Upgradability	5	1	3	2	3
Total	100	75	70	60	81

Table 6: Weighted average

We have prepared a weighted average chart to find the optimal design. From this chart, we have found out design approach-4 is the best solution. As mentioned above, the ratings for each individual design were given as a group through a brainstorming process, after studying reports and research papers on similar devices.

2.5 Conclusion

In this section, we identified the multiple approaches that could be taken to achieve the desired goal. Four such designs were selected based on the research we had done. During the selection process, we had to make sure that the objectives, needs, and requirements of the system were met and that the identified constraints were taken into account. Further research was conducted to work out the details of each design and analyze how it could work, what requirements it met, and its limitations. In the third section, both quantitative and qualitative analyses were done to determine the optimal design approach. For the qualitative approach, eight criteria were chosen based on the users' feedback. Lastly, based on the research that was done during the previous sections, we, as a group, evaluated how well each of the four designs performed on these given criteria. Later, this comparison was reflected in the weight matrix which ultimately helped us to determine the optimal approach for our system.

Chapter 3

Use of Modern Engineering and IT Tool

3.1 Introduction

Once we finalized the optimal design approach, the next task for us was to select appropriate tools for the development, and validation of the final prototype. The tools were divided into two groups according to their use: software and hardware tools. Software tools were required for simulation, interfacing, and visualization tasks such as 3D modeling, code compilation, and functional verification. In order to choose the appropriate software, we first listed down all the available resources, and then through comparative analysis, we determined the optimal tools. During this process, we took into account the limitations and benefits of using each of the different software tools. For example, for simulation and functional verification, we had the option to choose between Eagle, MATLAB, Proteus, and Multisim. So, we set six different criteria including cost of usage, availability of microcontroller libraries, availability of simulation tools, ease of use, etc. to compare them and finally determined that Proteus would be the best option for us. A similar analysis was also conducted for the hardware tools. In this case, the analysis was done for each of the different subsystems.

3.2 Select appropriate engineering and IT tools

Simulation software: For simulation and functional verification.				
Basis of comparison	MATLAB	Proteus	Autodesk Eagle	Multisim
Component library	Limited library. Add-ons are required	Numerous libraries. External libraries can be added	Library lacks components. Difficult to create custom components.	Several components are unavailable.
Usage	Testing / Data visualization	Schematic/ Verification, especially for digital circuits	For printed circuit board designs.	Educational institutes (research / teaching)
Availability of microcontrollers in library	Add-ons or extra packages are needed.	Arduino boards are available.	Arduino boards are available.	Microcontrollers and ICs missing in the library.

User interface	User-friendly interface.	User-friendly interface.	User-friendly interface.	Outdated interface, not user-friendly.
Availability of simulation tools	A lot of tools for analysis.	Variety of tools for analysis.	Limited features in the free version.	Tools are available online.

Table 7: Simulation software tools

We found that the optimum software to use was proteus since it has numerous libraries and external libraries that could be added and it also has a user-friendly interface among other facilities [21].

3D designing software: For design visualization.				
Basis of comparison	Blender	AutoCAD	Maya	TinkerCad
Strength	Excels in developing sophisticated 3D designs.	Harder to design organic shapes.	3D animation and modeling for cinema or animation projects.	3D designs for general purposes.
Software	Open source.	Paid service.	Paid service.	Open-source.
Availability of advanced features	Has most of the popular features, easy to customize.	Has a lot of features that other products do not have.	A comprehensive set of features.	Few advanced features are available.
Learning curve	Moderately easy to learn, user-friendly interface.	Difficult to learn, training is required.	Moderately difficult to learn.	No training required, very easy to learn.
Supported file types/ formats	Blender supports more file formats such as .stl. gltf. .obj. fbx. AVI and JPEG formats.	Support limited file formats.	.OBJ, .EPS, .Image, and .DAE_FBX file formats.	STL, OBJ, and SVG file formats are supported.

Table 8: 3D designing tools

From this table, we found that Blender was the best option for us since it was easy to learn and an open-source software. Also, it was extensively documented and offered a supportive online community [22].

Distance detection sensors			
Features	Ultrasonic sensor	IR	LiDAR
How it works	Measures distance through reflected sound waves.	Measures distance through reflected light waves.	Measures distance through reflected light waves.
Power consumption	Tends to consume lower current/power. Operating current 8 to 15 mA.	Low power consumption. The operating current is 30mA.	The average power consumption is 0.6W.

Long Range sensing	3cm – 350cm	10cm to 80cm	0.3m-12m
Cost	Low	Low	Higher cost

Table 9: Distance detection sensors

We chose the ultrasonic sonar sensor as our distance sensor as it had the appropriate range and was also low cost [23].

Communication System (GSM module)			
Features	SIM900 Modules	SIM300	SIM900A
Quad Band module.	Yes, the GSM module can support 4 bands- 850/900/1800/1900 Mhz.	No, the GSM module can support 4 bands- 900/1800/1900 Mhz.	No, the GSM module can support 4 bands- 900 and 1900 Mhz. (SIM900A can only be used in Asia, as it is region locked to Asian markets)
Version and price	Newer version, medium price range	Old version, lowest price.	Latest version, a medium price range.
Operating voltage ranges	3.4V to 4.5V	3.4V to 4.5V	3.2V to 4.8V

Table 10: GSM modules

SIM 900 was the best option for us since it was one of the newer models and supported all 4 bandwidths (support 4 bands- 850/900/1800/1900 MHz) [24].

Wet surface detection: Sensor			
Features	Water sensor: Sen 00235	Rain sensor	Soil moisture sensor
Size/Weight	3g	8g	larger/heavier
Price	250 Tk	470 Tk	97 Tk

Table 11: Wet surface detection sensors

We chose the Water sensor Sen 00235 for our project due to its small size and low cost [25].

Communication module: (GPS module)			
Features	U-Blox NEO-6M	U-Blox NEO-M8U	NEO-M8P
Accuracy	Few meters	0.9 meters	25mm
Cost	Low	High	High
Power consumption	3-5V	2.7 V to 3.6 V	3.0-3.6

Table 12: GPS modules

U-Blox NEO-6M was chosen as it has good accuracy and has a low cost. Thus, it is the best option for our project [26].

3.3 Use of modern engineering and IT tools

Software tools

Proteus: For simulation and functional verification

Proteus was used to validate the proposed design. This was chosen since it had numerous libraries and external libraries could easily be added when needed. Furthermore, Arduino-based boards were already available in the software which was a big advantage for us. To validate the chosen design, we had to use external libraries. So, even though we had prior knowledge about the software, we still had to work out how to add external libraries such as for water and ultrasonic sensors which were not already available with the software. Simulations for each of the different subsystems were done separately to verify that the system worked. Later, while combining all the subsystems into a single file, it was found that the Arduino boards did not have enough capacity to run all the subsystems on a single board. Thus, modifications were done and the communication module and water sensor were brought under a second microcontroller. In this way, we verified that our design was valid and it could be implemented on hardware.

Blender: 3D modeling and visualization

Blender is primarily used to construct three-dimensional objects and situations using a 3D viewport and a collection of modeling tools that let users design any kind of item or situation they desire in a 3D space. Mesh objects made from three different forms of geometry may be used to build simple objects and surroundings. We used this software because it was free for all. Besides, we could build any object as it was less complicated than other software. Here, we built all the different approaches for this project and the 3D models were able to give us an understanding of the physical appearance of the different approaches. This helped us figure out where each of the components could be placed in order to maximize comfort for the user and also to improve the overall look of the design. Furthermore, producing the 3D design on Blender gave us a rough idea of how much space the individual components would take and that proved useful in reducing bulkiness.

Hardware tools

To implement the different subsystems, we used Arduino nano and modules. For example, for the communication subsystem, we used the GPS and GSM modules. For the notification subsystem, buzzers, speakers, and vibration motors were used. For object detection and wet surface detection subsystems, sensors such as water, ultra-sonar, and IR sensors were utilized. Since a lot of these components were new, we had to learn about them through technical documents and data sheets so that we could use them properly.

For the object detection subsystem, we had to detect objects within 50 m of the cane. So, we used four ultrasonic sensors at the bottom of the cane to detect objects from the sides as well as in front. We first tested the sensors and then programmed the device such that the user would be notified through vibration motors. If there were obstacles in front and on the left of the user, the right vibration motor would vibrate indicating that the user should go right. The same method was followed in case there were obstacles in front and on the left side of the user. An IR sensor was also added in a tilted position to measure the hypotenuse, whenever this distance was greater than a set value, the voice command for the lower surface was given as output and when the measured value was less than the reference value, the voice command for the elevated surface was given as output. We had to conduct testing to determine this reference value. For this, it was found that using a range instead of a specific value gave the best results.

A water sensor was used to determine whether the cane was in the presence of a wet surface. Testing was done to determine the reference value and a buzzer was used for notification. As for the communication module, both GPS and GSM modules were tested separately and then interfaced with the Arduino nano. The program was written using the Arduino IDE and it took the current coordinates from the GPS module and stored them as a variable. Later, that variable was sent as text through the GSM module.

The power supply subsystem consisted of a Lipo battery, a B3 pro charger, and DC buck converter LM2596. Rechargeable batteries were used instead of disposable batteries in our project since they are more environmentally friendly and light in weight. The design called for a 12 V supply but later we found out from the datasheet that the communication modules could handle a maximum of 3V supply only. Thus, we had to modify the system slightly to ensure that we do not damage the GSM. For this, a DC buck converter LM2596 was also used. A B3 pro charger was used so that the user could charge the device and use it for an extended period.

To ensure that the device functioned properly, we had to study various components that could be used to implement the different subsystems. Furthermore, it had to be ensured that the different subsystems could work together as a whole to achieve the user's requirements.

3.4 Conclusion

In this section, we learned the usage of modern engineering and IT tools for designing, developing, and validating solutions. For this, we had to collect information about the software and hardware that could be used to achieve our goal. So, we first divided the tasks into two groups: software and hardware. Then, for each task, we identified the tools we could use. As before, we chose the best one through comparative analysis. However, this time, the different tools required different criteria on which we could base our comparison. So, we chose the criteria according to our research, depending on what we found to be important factors. These criteria were different for the hardware and software group as well as for each subsystem. While conducting the comparative analysis, the different limitations were also considered for the tools and we also tried to find out ways to deal with them. The selected tools were used for the development and evaluation of the solution. Furthermore, certain techniques had to be learned to complete the tasks and for this, we took help from resources such as manuals, tutorials, documents, and online communities.

Chapter 4

Optimization of Multiple Design and Finding the Optimal Solution

4.1 Introduction

In this section, we identified multiple solutions to our design approach and chose the optimal one. While deciding on the solutions, we had to consider the specifications, requirements,

and standards associated with the design. To determine the best solution, we found a few different ways in which we could implement each design approach and then, as before, conducted a comparative analysis. For this, we had to consider factors such as usability, cost, manufacturability, etc. The next task was to evaluate the performance of the chosen solution. For this, we used Proteus to simulate different test cases. The test cases consisted of different scenarios where the device could be used. The process was repeated for each subsystem, the response was noted down and findings were summarized in a tabular format. If the action taken by the subsystem for a particular situation was the same as the expected action, we said that the system was working properly and it had been functionally verified.

4.2 Optimization of multiple design approach

After determining the optimal design approach, we had to find out the optimal solution. This was necessary since there were multiple ways to achieve the same goal. So, a comparative analysis was needed to find the best possible way. To do this, factors such as cost, effectiveness, ease of installation, and troubleshooting were considered. Thus, comparative tables were made for each of the four subsystems consisting of the different solutions that could be used to implement it.

4.3 Identify optimal design solution

Multiple design Solutions of Optimal Approach

Subsystem 1: Obstacle detection System

The device has to sense any obstacle that is present in front of the user.

Obstacle detection System	Design Solution 1: infrared rays	Design Solution 2: sound waves	Design Solution 3: light waves from laser
Method	Using infrared rays and measuring distance based on the angle of the reflected beams.	Sending high-frequency sound waves and calculating the time taken for the sound wave to return.	Measuring the range through light waves from a laser.
Cost	Moderate	Moderate	Very high
Range	Obstacles can be detected from a moderate distance.	Obstacles can be detected from a moderate distance.	Obstacles can be detected from far away.

Table 13: Obstacle detection System

Subsystem 2: SOS System

In case the user is in danger, they can push the panic button to notify their close ones about their current location.

SOS System	Design Solution 1: Call/Email	Design Solution 2: Text with google Maps link	Design Solution 3: Saving users' data on web server
Method	Users' closed ones will be notified via direct call or email.	Sending a text with a google maps link to a closed one.	Saving all users' locations on a private cloud server.
Effectiveness	Immediate action can be taken but calls or emails may go unnoticed.	Immediate action can be taken and users' live location is easily available.	There is a risk of losing data in case of a server crash or hacking.
Usability	Some people may not check emails regularly. Also, some areas may not have stable cell connections for a call.	Live location will be displayed on the google map when the link is clicked. So, it is very easy to use.	High maintenance cost. A lot of resources will be needed to run the server.

Table 14: SOS System

Subsystem 3: Notification System

If an obstacle or water surface is sensed in front of the user, the device will have to notify the user.

Notification System	Design Solution 1: Voice through speakers.	Design Solution 2: Different beep sounds	Design Solution 3: Vibration motor on both sides.
Method	Using human voice through a speaker.	Different patterns of a beep sound indicate different notifications.	Vibration motor on both sides, so that the user can feel which side the motor is vibrating on and go in that direction.
Effectiveness	Users may fail to properly hear the voice in a noisy environment.	Maybe an inconvenience to people who are in the users' vicinity.	No disturbance will be caused.
Usability	Users might not prefer getting instructed through speakers.	The user may find it difficult to remember the different beeps.	The user does not need to remember the instructions.

Table 15: Notification System

Subsystem 4: Elevated/Lower ground detector System

If an obstacle or water surface is sensed in front of the user, the device will notify the user.

Elevated/Lower ground detector System	Design Solution 1: Servo motors.	Design Solution 2: 4 - 5 sonar sensors	Design Solution 3: Changing placement of sonar sensors.
Method	Using servo motor and sonar sensors. The motor will rotate continuously so that the surroundings can be monitored.	Placing sonar sensors on the right, left, top, and bottom to detect obstacles from different sides.	Placing the sonar sensors so that different leveled surfaces can be detected.
Effectiveness	This can affect the foldability of the cane	Circuitry will be complicated.	The circuitry is not complex, strategic placement means we can achieve the same result using fewer sensors.
Cost	Moderate	High	Moderate

Table 16: Elevated/Lower ground detector System

4.4 Performance evaluation of developed solution

Simulation was done on Proteus for different test cases based on real-life scenarios and the performance was evaluated based on the systems' response.

Test case 1 (a): Elevated surfaces are present but no water surface is present in front of the user.

Here, elevated surfaces are present in front of the cane but no water surface is detected in front of the cane. So, the LEDs for the middle and bottom sonar sensors are on. We will use buzzers during implementations, LED is used for demonstration purposes.

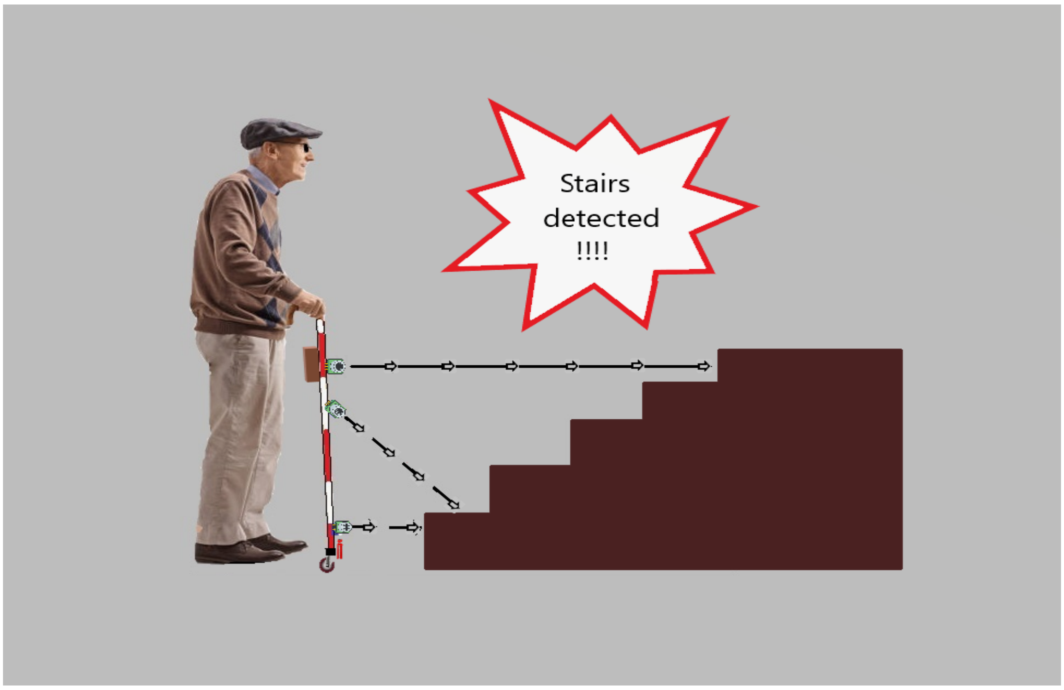

Figure 14: Stairs Detected

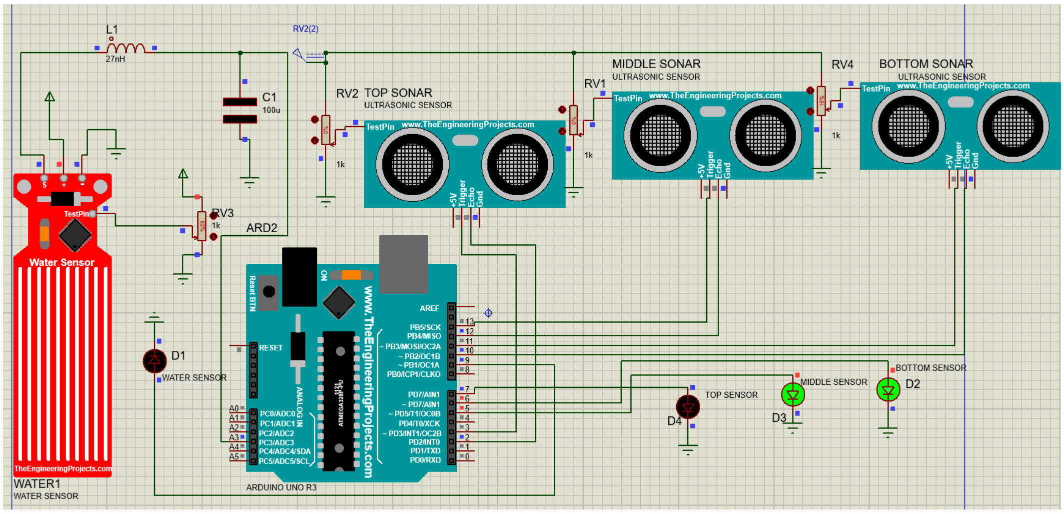

Figure 15: Simulation for Stairs Detection

Test case 1 (b): Lower surface is present but no water surface is present in front of the user.

There are lower surfaces in front of the cane but no water surface is detected in front of the cane. So, only the LED for the middle sonar sensor is on. We will use buzzers during implementations, LED is used for demonstration purposes.

Figure 16: Lower Ground Detected

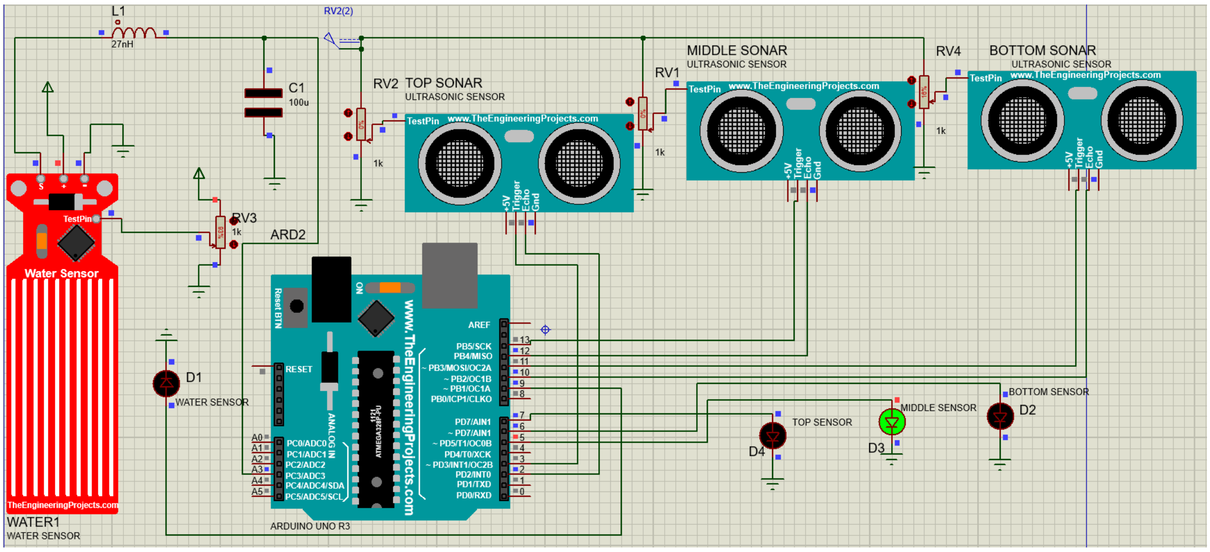

Figure 17: Simulation of Lower Ground Detection

<u>Test case 2: Water surface detected in front of the cane but no obstacle is present in front of the user.</u>

The water surface is sensed but there are no objects in front of the cane. So, only the LED for water surface detection is on. We will use buzzers during implementations, LED is used for demonstration purposes.

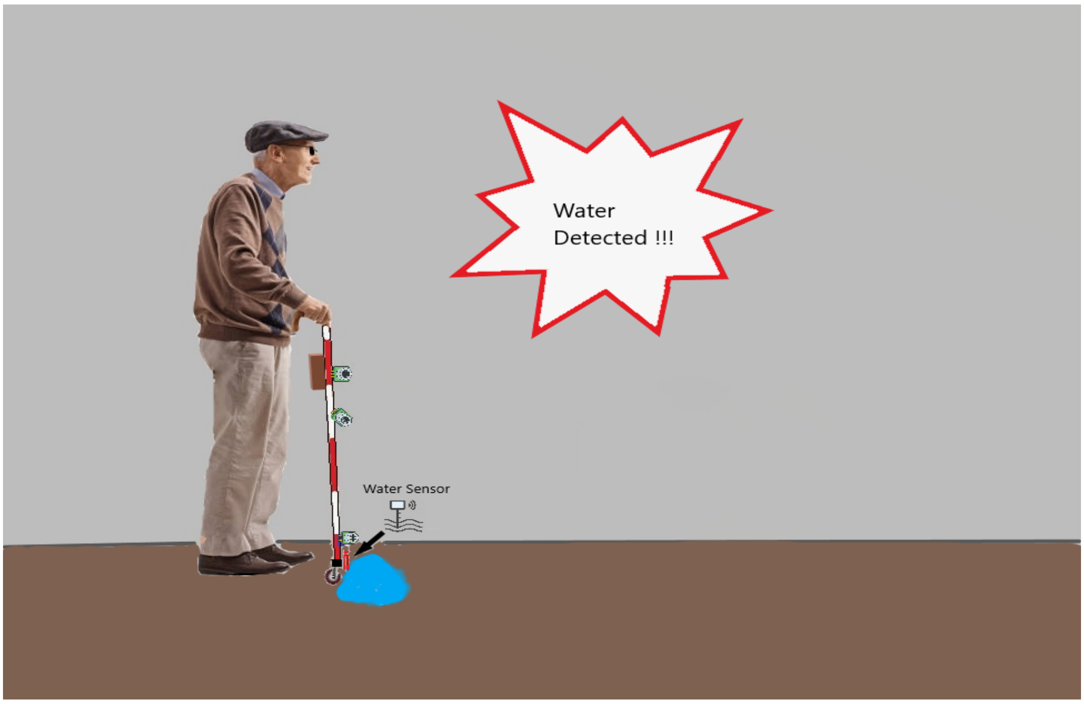

Figure 18: Water Surface Detected

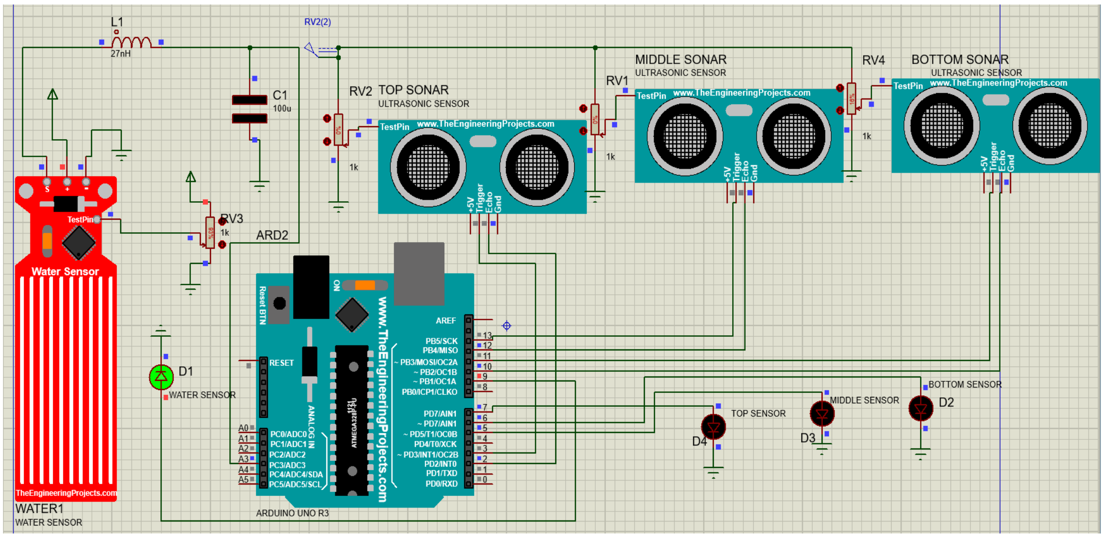

Figure 19: Simulation of Water Surface Detection

Test case 3: SOS system, the user is not in danger.

Since the button was not pressed, the user is not in danger and so no text was sent to their closed ones. The GPS and GSM modules are in standby mode.

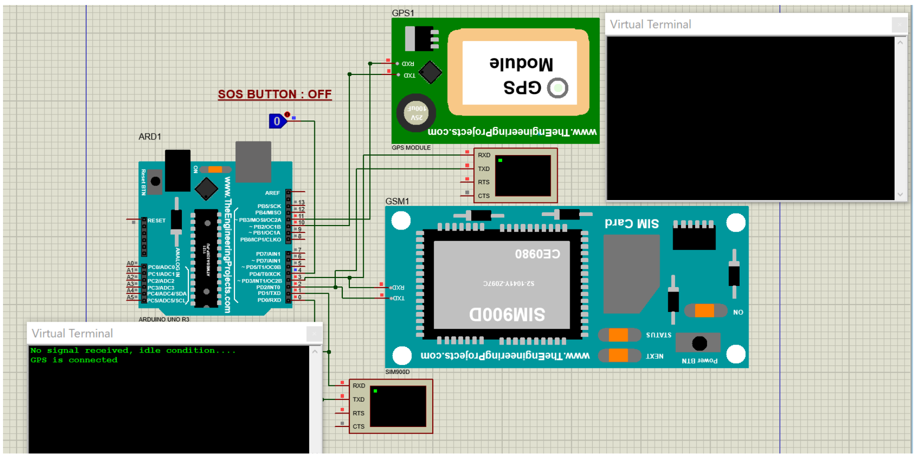

Figure 20: GPS, GSM modules

Test case 4: SOS system, the user is in danger.

The user is in danger so the button is pressed, the GPS and GSM modules are activated and the user's closed ones are notified of their location via text messages. Here, the virtual screen on the right represents the closed one's mobile screen and we also verified that the GPS was sending the correct coordinates via the VGPS facility on Proteus.

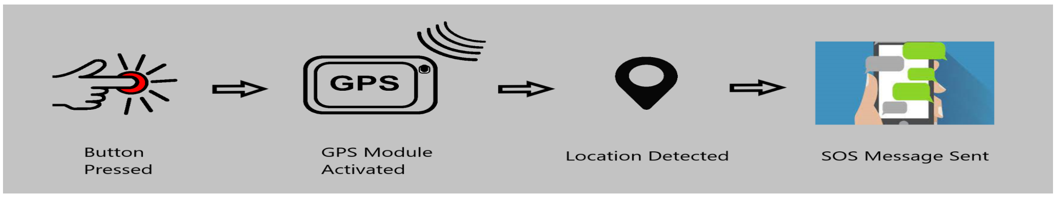

Figure 21: SOS system activated

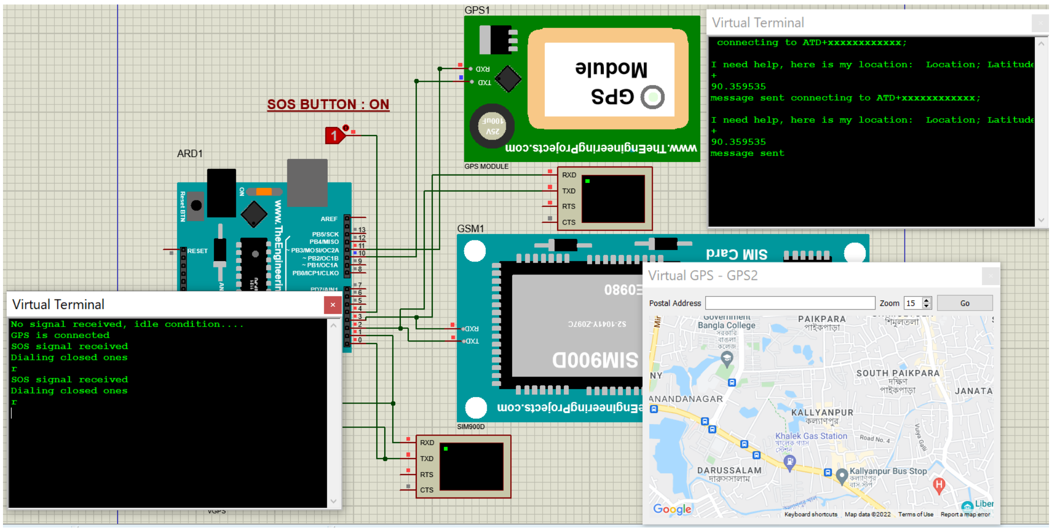

Figure 22: Simulation for SOS system

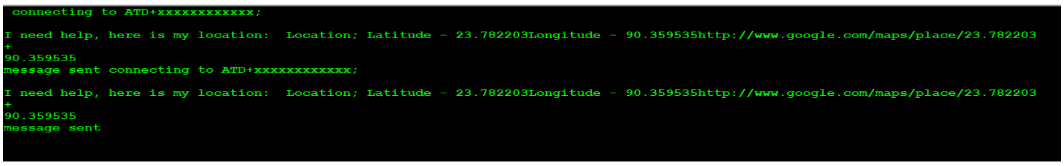

Figure 23: Message shown on virtual window

Functional verification of Optimal Approach

Test case	Situation	Action required	Action taken	Verification status
1 a	Stairs or lower surfaces are present	Middle and bottom sonar sensors will detect obstacles and vibration motors will notify the user.	LEDs for the middle and bottom sonar sensors are on. After implementation, vibration motors will notify the user.	✓
1 b	Elevated surface is present	Only the middle sonar sensor will detect obstacles and the vibration motor will notify the user.	Only the LED for the middle sonar sensor is on. After implementation, vibration motors will notify the user.	✓

2	Water surface present	Water sensor will detect the water surface and notify the user.	Only the LED for water surface detection is on. After implementation, vibration motors will notify the user.	✓
3	User is in danger; SOS system needs to be activated.	Activate GPS and GSM modules and send users' locations to their closed ones.	The GPS and GSM modules are activated, and Users' closed ones are notified of their location via text messages.	✓

Table 17: Functional verification

4.5 Conclusion

In this section, we identified multiple engineering solutions to the design approach to meet the desired objectives, needs, and requirements within the given constraints of the problem. Then, a comparative analysis was done to choose the optimal solution. While deciding this, we had to consider the usability, cost, manufacturability, etc. Lastly, simulation was done on Proteus for different test cases based on real-life scenarios and the performance was evaluated based on the systems' response. If the action taken by the subsystem for a particular situation was the same as the expected action, we said that the system was working as expected and it had been functionally verified. The findings were summarized in a tabular format. Through this section, we verified that the design would work when implemented. This was an important part of the project as it ensured that resources were not wasted unnecessarily and also ensured viability.

Chapter 5

Completion of Final Design and Validation

5.1 Introduction

Now that we have verified our design, the next task for us would be to implement the design. For this, we have to consider the sensor placements, constant parameters, and also the overall look of the project. Certain adjustments have to be made in the design to account for practical scenarios and the systematic and logical approach to these decisions has been described below. Lastly, we have to evaluate the device and determine whether it achieves the users' requirements.

5.2 Completion of final design

During the implementation process, we faced a few problems. The first problem that we faced was that the communication modules could only take a maximum of 3V supply according to the datasheet. However, the design asked for a 12 V supply. As a result, we had to make a little change to the design and power system to protect the GSM module. Additionally employed for this was a DC buck converter, the LM2596. The user was able to charge the gadget and use it for a long time thanks to a B3 pro charger.

As planned, the sonar sensors were placed at the bottom of the cane, one on each side and one in front. However, we had to determine the angle of tilt for the IR sensor. If the angle was too low, then there was a chance that the stairs would be detected too late and if the angle was too high, then the stairs would be detected too soon. Thus, we needed to determine an appropriate angle that would detect the stairs at an acceptable distance. To solve this issue, the first thing we did was look at similar products and find out what angle they had used. However, this was not very useful for us since the design was different, and unlike most white canes, our smart cane was meant to be held vertically. Thus, we had to use a different standard. For this, we looked at the standard angle of stairs in Bangladesh. The standard angle of a staircase depends on its use case and application. For most stairs in residential buildings or offices, the stair angle varies between 30 degrees and 45 degrees and we base our value on this. The next issue was the placement of the IR sensor which would detect the stairs. If the sensor was placed too high, the tilted distance would have to be set at a larger range (i.e, more than 75cm). This could reduce the accuracy of the IR sensor since the percentage of error increases with the distance for these types of sensors. Thus, placing the sensor at the lower end of the cane seemed to be the best option here.

Next, we verified the system by measuring the horizontal distance at which the cane detects the stairs. According to our design, the user will be notified that there are stairs at an appropriate distance away from the stairs. So, to determine the appropriate angle, we measured the horizontal distance at different angles. We found that a 1.5m distance was an appropriate horizontal distance for the users to be notified according to the surveys we had previously read. Furthermore, placing the IR sensor near the ultrasonic sensors would have benefitted us when making the housing for the system. These two factors along with the fact that the hypotenuse distance range had to be around 70 cm for optimal results, were used to determine the angle at which the sensor was to be tilted. Therefore, the IR sensor was placed 28cm above the ground level on the cane.

Lastly, housing was added to improve the overall look of the cane and to make sure that there were no wires visible from the outside. The buttons used were of different types so that the user could easily identify which button was for which functionality. The power button was an SPDT-type button and the emergency response button was a push button. There were a few ways in which the vibration motors could have been attached, for example, we could have used gloves or haptic belts. However, we decided to keep it simple and place the vibration motor on the side of the cane. Components such as the Arduino board and battery were placed in a protective casing. The rest of the design remained as planned with the sonar GSM and GPS module and vibration motors and an emergency button placed near the handle.

5.3 Evaluate the solution to meet desired needs

After the implementation process was completed, we had to evaluate the performance of the design. For this, we tested the smart case under different test case scenarios. These have been shown below.

Test case 1 (a): Obstacle detector

If an obstacle is present in front of the user the buzzer rings and the frequency of the ringing increases as the object comes closer.

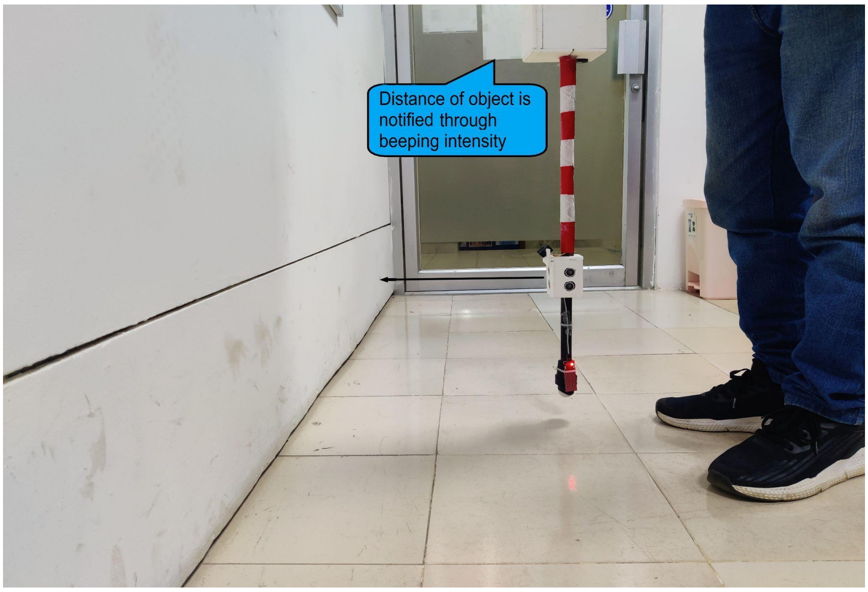

Figure 24: Object detected in front of the user

Test case 1 (b): Object detected in front and to the right

If an obstacle is present in front of the user as well as on the left. So, the right vibration motor is vibrating indicating that the user should go to the right.

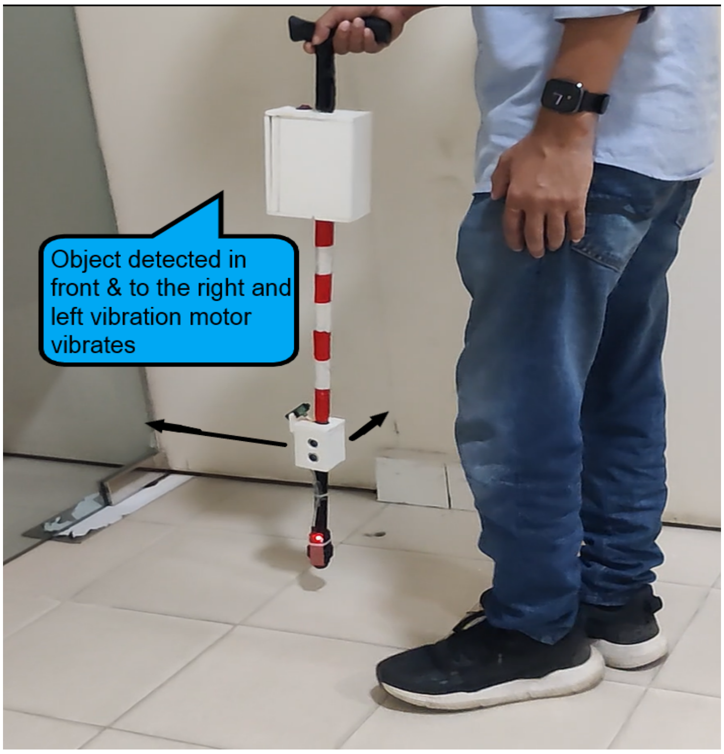

Figure 25: Object detected to the right and left of the user

Test case 2 (a): Elevated surface is present in front of the user

Here, an elevated surface is present in front of the cane. So, the user is getting a notification via voice command for "upper surface".

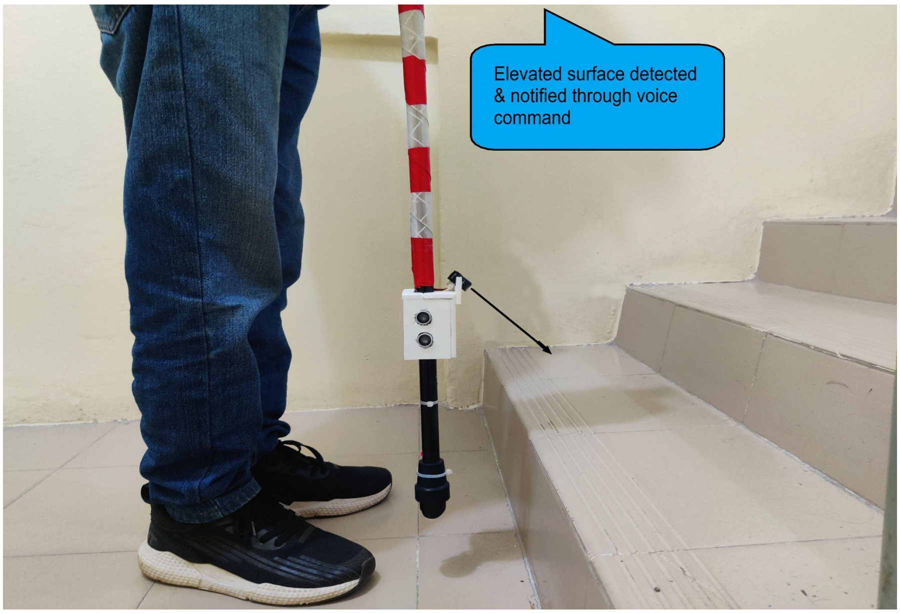

Figure 26: Elevated surface detected

Test case 2 (b): Lower surface is present in front of the user

Here, a lower surface is present in front of the cane. So, the user is getting a notification via voice command for "lower surface".

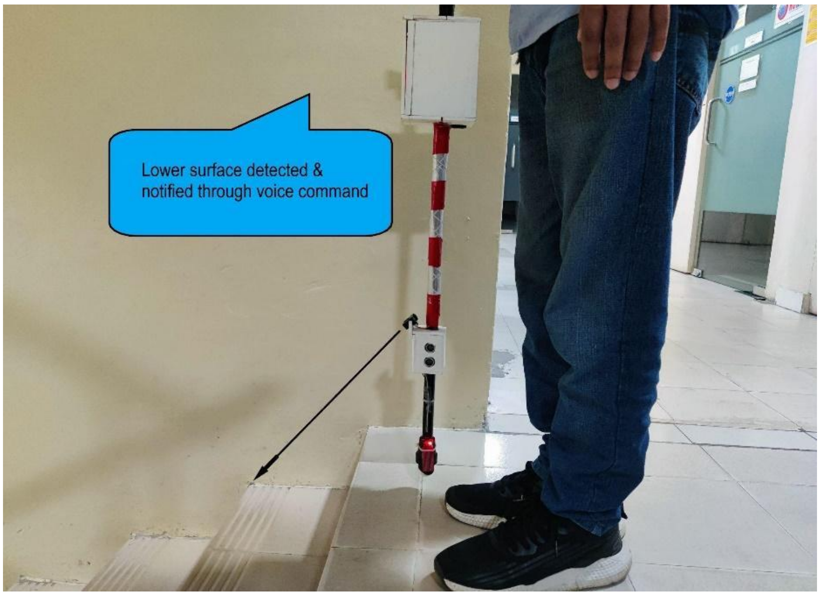

Figure 27: Lower surface detected

Test case 3: Water surface detected in front of the cane

The water surface is sensed. So, the buzzer buzzes.

Figure 28: Water surface detected

Test case 4: SOS system, the user is in danger

The user is in danger so the button is pressed, the GPS and GSM modules are activated and the user's closed ones are notified of their location via text messages.

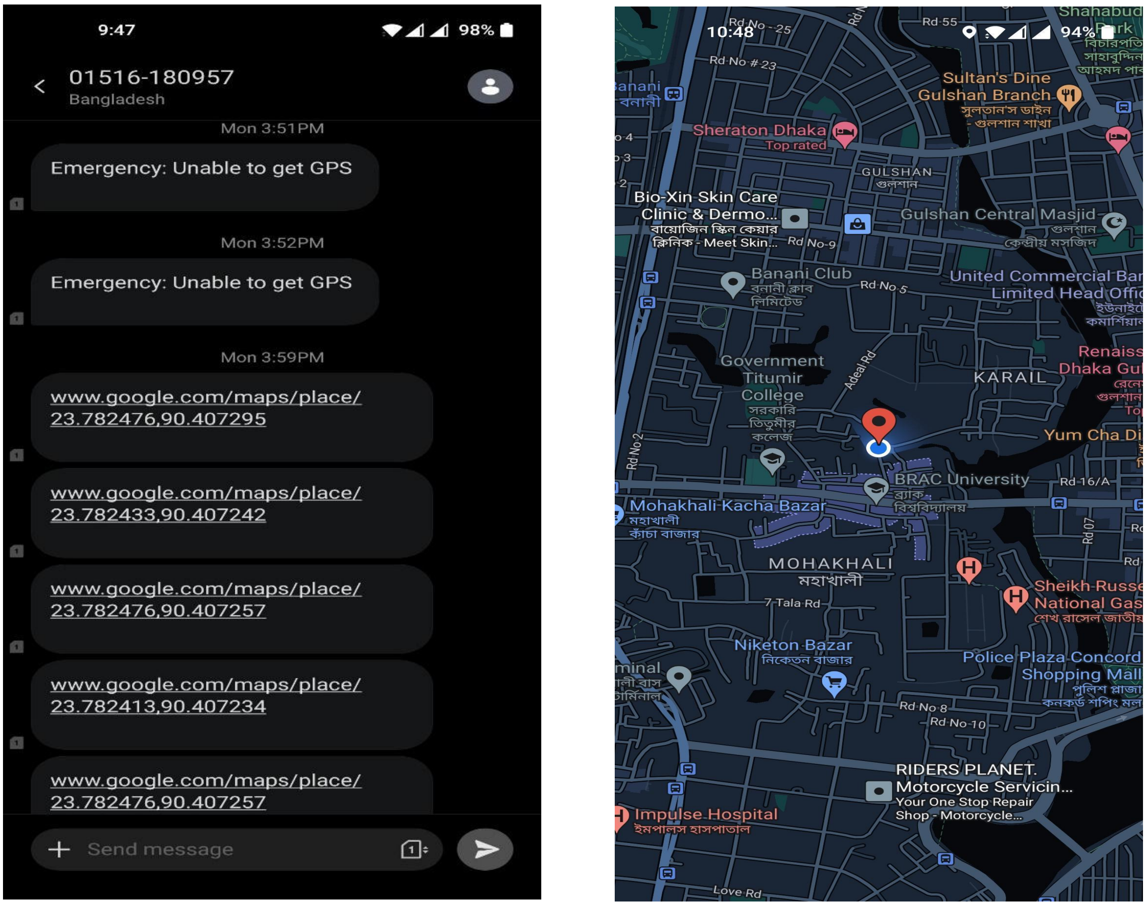

Figure 29: Message with location

5.4 Conclusion

While implementing the design, we faced some problems that required modifications. After solving those issues and modifying the design we finished our implementation. Then, we started verification of our device. We started testing our individual subsystems to see if they are giving us the required result. After that, we started testing multiple subsystems together to see if they are able to communicate with each other. Finally, we tested the device as a whole. In every step, we saw if the systems were giving us our expected result or not.

Chapter 6

Impact Analysis and Project Sustainability

6.1 Introduction

By impact, we mean the 'influence' of research or its 'effect on an individual, a community, the development of policy, or the creation of a new product or service. It relates to the effects of research on our health, social, legal, and cultural lives. Due to this project, there can be many impacts like social impact, legal impact, impact on health, economic impact, etc. Here, we are discussing some of them.

6.2 Assess the impact of the solution

<u>Social Impact</u>

Social impact can be defined as the net effect of an activity on a community and the well-being of individuals and families. We should make sure that the positive aspects outweigh the negatives and also that we can mitigate the negative aspects as much as possible.

- Visually impaired persons will feel more empowered and they will not feel incompatible anymore.
- The outlook of society will change towards visually impaired people.

<u>Cultural Impact</u>

The term “cultural impact” refers to the consequences to human populations of any public or private policies and actions that significantly change their norms, values, beliefs, practices, and institutions as well as the way they live, work, socialize and organize themselves as part of their cultural life.

- At present, a normal scenario is that visually impaired people are using a normal foldable white cane, if they start to use smart canes then it will be a huge cultural change for that particular community.

Impact on Health

In our project, we are maintaining all the standards given by ISO (International Organization for Standardization). Despite all these things, this smart cane has some negative impact on human health. That is,

- As we are installing a GPS System into our cane, there will be radio frequency. We all know that exposure to very high radio frequency intensities can result in the heating of biological tissue and an increase in body temperature. However, 1575.42 MHz radio frequency will be used which is quite low and this will not harm the human body.

Legal Impact

Legality, in respect of an act, agreement, or contract is the state of being consistent with the law or of being lawful or unlawful in a given jurisdiction, and the construct of power. As this is medical equipment, therefore, we need to take permission and place a registration for the device to “The Ministry of Health and Family Welfare”. We need to follow the “Registration Guidelines for Medical Devices-2015, Bangladesh” in [27]. This guideline is based upon the guidelines of the Global Harmonization Task Force (GHTF). The GHTF is a voluntary group of international regulatory affairs experts for medical devices that were established to harmonize the regulation of medical devices internationally.

6.3 Evaluate the sustainability

Environmental sustainability is the responsibility to conserve natural resources and protect global ecosystems to support health and wellbeing, now and in the future. Because so many decisions that impact the environment are not felt immediately, a key element of environmental sustainability is its forward-looking nature [28].

We will be using aluminum for the main infrastructure of the cane. Aluminum is called green metal because it is a very environmentally friendly metal. Recycling this material saves 95% of the energy required to produce aluminum from raw materials [29]. This means it plays a key role in human ecology.

However, there are some bad impacts of producing aluminum on the environment. Aluminum is hidden in an ore called Bauxite. It’s a red dirt and clay mixture commonly found in Australia, Brazil, and India. Bauxite is collected from the ground in an open-pit mining operation. Once collected, the bauxite has to be refined and needs some chemical processes to get Aluminum. Turning Bauxite into Aluminum requires a lot of energy and has a variety of environmental impacts. Both open and underground mines affect the plant and animal life immediately surrounding an area and beyond for multiple generations. Clear-cutting trees and grasslands contribute to biodiversity loss, habitat loss, carbon emissions, and erosion. Mining operations have taken this damage into account more and more in recent years, incorporating plans to restore and regrow natural habitats once mining is completed. All refining processes use varying levels of electricity and water, which can cause higher carbon emissions, create air and water pollution, and even noise and heat pollution [29].

Moreover, to provide power to the system we need a power source, for that, we have to use a battery. According to Mario Grosso, who is a professor at the Polytechnic Institute of Milan and part of a team of researchers studying the environmental impact of different types of batteries, “the greenhouse gasses generated from manufacturing rechargeable batteries look lesser than disposable batteries. We can reuse them, so we don’t need to make as many”. Grosso also said that if a battery is recharged about 50 times, its overall benefit is significant. But if a battery is used for only a few months and thrown away, its impact is worse on the environment [30]. Therefore, we will use rechargeable batteries instead of disposable batteries in our project. Compared to other rechargeable batteries Lithium batteries are more environmentally friendly and light in weight. This characteristic offers them the advantage for application in such portable devices as cordless power tools, wearable devices, and cordless medical diagnostic tools, among others. They are also designed to last longer, which makes them find widespread application in high-tech smart devices and electronic devices for which changing the batteries causes inconveniences [31]. Therefore, we will use Lipo batteries for this project.

We must prevent pollution. Pollution prevention reduces both financial costs (waste management and cleanup) and environmental costs (health problems and environmental damage). Pollution prevention protects the environment by conserving and protecting natural resources while strengthening economic growth through more efficient production in industry and less need for households, businesses, and communities to handle waste [32]. To prevent pollution, we can take some necessary steps, such as:

- Use of environmentally benign fuel sources.
- Increasing efficiency in energy use.
- Protection of sensitive areas.
- Modifying a production process to produce less waste.
- Using non-toxic or less toxic chemicals like cleaners, degreasers, and other maintenance chemicals.

We will be using SWOT analysis to observe the sustainability of our project.

SWOT Analysis

	Beneficial	Harmful
Internal	**Strength** ● Reliable and durable product at a reasonable price. ● Having advanced features. ● Low power consumption. ● Foldability ● Light in weight	**Weaknesses** ● Not fully water-resistant. ● Expensive - can isolate several potential buyers.
External	**Opportunity** ● A new thing to the Bangladesh market. Therefore, no competitors. ● Can easily grab the attention of visually impaired people.	**Threats** ● Foreign competitors can enter the market easily. ● It will take time for the users to get used to the product.

Table 18: SWOT Analysis

6.4 Conclusion

In this section, we analyzed the impact and sustainability of the project. This was crucial in order to determine what effect our device would have on the society and environment. Also, we analyzed the impact in terms of societal, health, safety, legal and cultural issues. The most prominent impact was on society; as our project directly affected the well-being of individuals and families. There is also a major cultural effect as it would help change the way we thought about the visually impaired community. We also found out that we would need to work closely with different groups and organizations and follow the regulations. Next, we analyzed the environmental impact of the solution and modified our design to reduce the harmful effects. For example, we found that a huge amount of greenhouse gasses were generated from manufacturing rechargeable batteries. So, lithium batteries were used. They are more environmentally friendly and light in weight; they are also designed to last longer, which makes them widespread in application of electronic devices for which changing the batteries causes inconveniences. Lastly, a SWOT analysis was done to identify the strengths, weaknesses, threats, and opportunities our device would have in the current market.

Chapter 7

Engineering Project Management

7.1 Introduction

The field of engineering is sophisticated and constantly evolving, so aside from the knowledge of engineering, engineers need to learn and adapt management skills to properly manage any project as it plays a critical role in their professional career. Most engineers consider themselves technical specialists in their respective fields but in the professional environment budget, deadlines and people have to be managed which requires a basic understanding of project management skills.

7.2 Define, plan and manage engineering project

An engineering project management means systematic planning and implementation of that plan by a group of engineers. It focuses mainly on engineering projects and uses the same methods and processes just like any other project management. It involves finding out the project goals and creating different scenarios with their contingency plan. Project management for engineers is an important step as unexpected problems may arise at any time which hinders the work of many people and may hinder the progress of the project.

Our engineering project was divided into three stages which are initialization, development, and implementation. These three stages are assigned to three different courses which are EEE-400P (initialization), EEE-400D (development), and EEE-400C (implementation). To manage our project, a logbook has been maintained to keep track of the meetings and agendas. In each stage, work responsibilities were divided equally among the group members. To keep on track of our project progression, Gantt charts were made for all three different stages. Our project progress against the project plan has been evaluated using the

Gantt chart and the logbook. During our EEE-400P course, we made tentative Gantt charts for 400P,400D, and 400C. The timeline and task proposed in those Gantt charts were based on our estimation. Previously, the Gantt charts for 400P and 400D were revised and the project progression was evaluated accordingly in their respective courses. Currently, the project progression of the implementation stage is managed and maintained through a Gantt chart for 400C which was revised according to the timeline. During this semester due to different factors, some of our tasks or the timeline for 400C may have been changed, shifted, or delayed on the Gantt chart.

7.3 Evaluate project progress

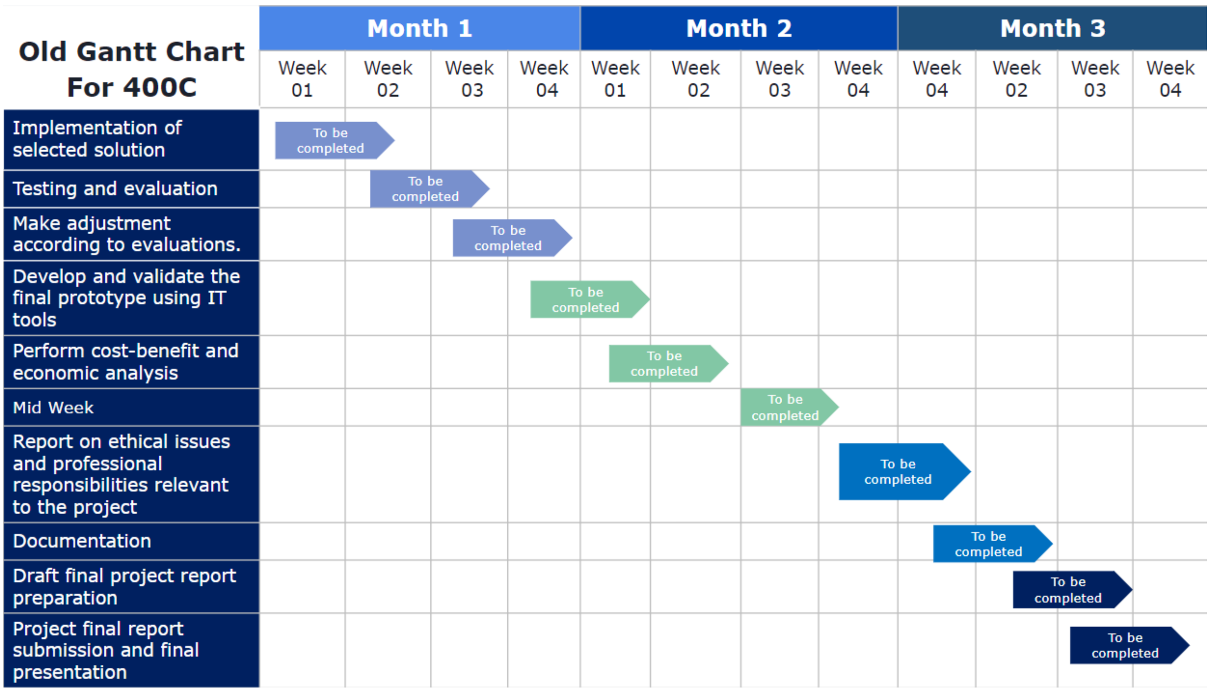

Figure 30: Old timeline for 400C

In our previously made tentative Gantt chart for EEE-400C, we planned on implementing our selected solutions within the first two weeks. Then we were to test and evaluate the solution to make adjustments according to it within the next two weeks. From the first to the second week of the second month, we were to validate our final prototype using appropriate IT tools.

Then, we were to perform cost-benefit and economic analysis. Previously, we estimated that our mid-term exam week would be on the third week of the second month, and during the mid-week, our project work would be kept on hold. Next, by the last week of the second month, we were to prepare a report on ethical issues and professional responsibilities relevant to this project. Lastly, we were to make documentation of the final project report and prepare for the final presentation within the third month.

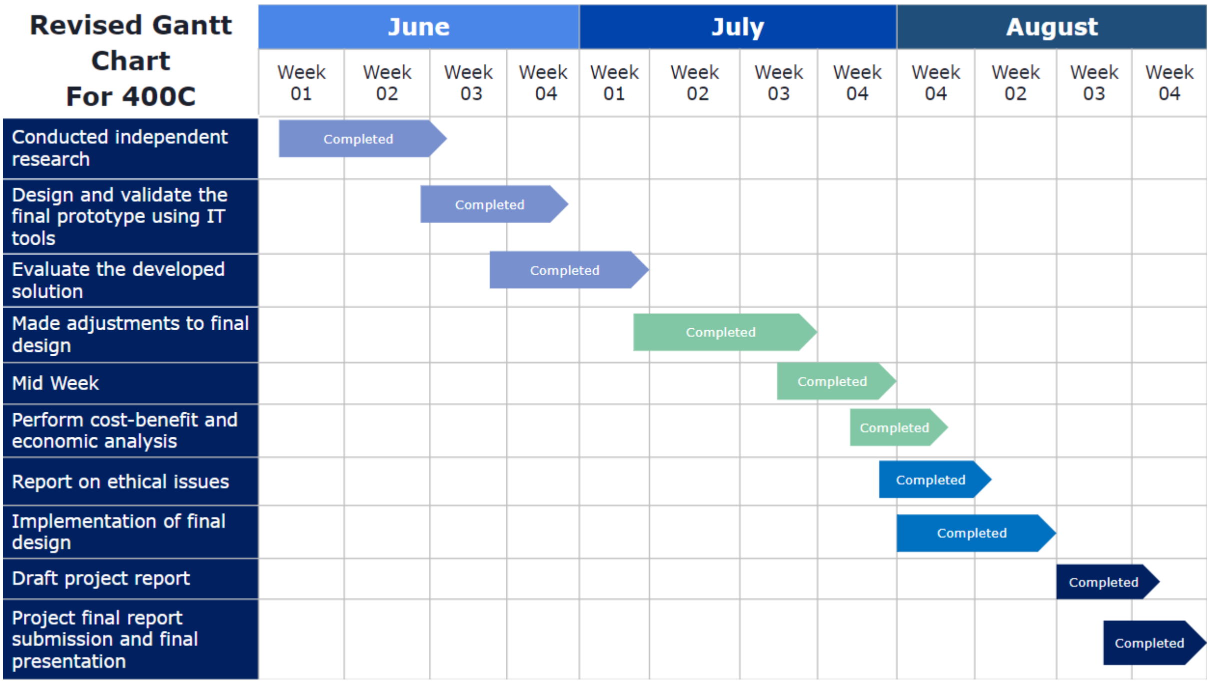

Figure 31: New timeline for 400C

In our revised Gantt chart for EEE-400C, some tasks were changed based on the curriculum objectives (CO), and also the timeline has been slightly rescheduled or replanned according to our semester schedule and also due to the conflicting time/class schedule of our classmates. The Gantt Chart for EEE-400C spans the months of June, July, and August. We have planned our project work time with the help of the Gantt chart. The first two weeks of June were assigned to conduct independent research. From the third week to the fourth week of February were assigned to design and validate the final prototype design using IT tools.

Next, the developed solution was evaluated within the next two weeks of July. Last two weeks of July, due to mid-term week, our project was kept on hold. After mid-term, the cost-benefit and economic analysis and report on ethical issues were prepared within the first two weeks of August. Finally, by the end of August, the final design report was prepared and submitted and the final presentation was given.

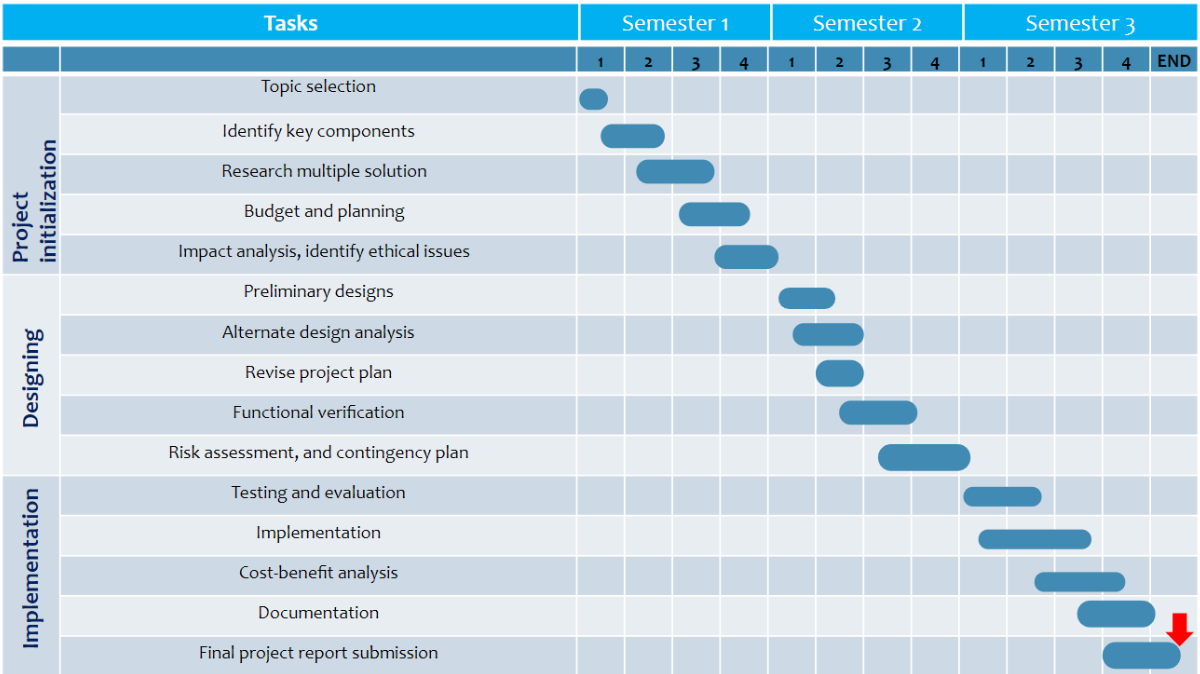

Figure 32: Yearly timeline of the project

Our project progress throughout the year has been shown through a yearly Gantt chart. As for our project progress, we have completed all of our project tasks in the initialization stage throughout the first semester (EEE-400P) and all of our project tasks in the development stage throughout the second semester (EEE-400D). In the third semester (EEE-400C), we tested and evaluated our selected solution, implemented the selected solution, performed a cost-benefit analysis, and finally prepared documentation and submitted the final project report. Thus, our implementation phase has been completed in EEE-400C.

Moreover, work responsibilities for each task were distributed equally among the group members. Cost-benefit analysis, testing, and 3D design models were done by Aditto. Research on modern IT tools and implementation of a final design done by Ifrit. Testing and evaluating the performance of implemented solution for functional verification were done by Atib. Lastly, revised project planning, reports on ethical considerations, and 3D design models were prepared by Fyaaz.

7.4 Conclusion

A logbook to keep track of meetings & agendas and the Gantt chart for all three stages of the project to evaluate our project progression has helped us to manage our engineering project within the deadline with little to no hassle.

Chapter 8

Economical Analysis.

8.1 Introduction

Economic analysis is the assessment of costs and benefits associated with a project. It is used to find out the economic viability, we can determine a rough estimate of the profit, i.e., the return, that can be reasonably expected from the project with respect to the investment. This will also aid in better allocation of resources and in analyzing the welfare impact of a project. The economic analysis of our project has been discussed below.

8.2 Economic analysis

To conduct an economic analysis, we have to first estimate the cost that will be incurred, then the benefits that will be obtained from the project when it comes to fruition, and lastly, compare the costs and benefits to determine whether it is appropriate to invest.

Cost is a major factor for consideration in economic analysis. It is the expenditure required to create and sell the product. Here, we have considered the following costs associated with this project:

Direct cost

Direct costs are the expenses a business incurs directly to make a product or service. In our case, this would be the cost of the components or materials/ resources, manufacturing expense, etc in producing the device. This cost has been quantified in the next section.

Contingency cost

This cost is the estimate to account for conditions that can lead to uncertainty and aggregate the initial cost. So, for example, it may happen that the sensors malfunction after the project has been implemented. In that case, we have to consider the extra cost that will be incurred. Here, we have included a rough estimate of how often there may be such malfunctions and added it to the current cost. Other costs include intangible costs of a decision, such as an impact on users or in production. This can include the machinery that would be needed to manufacture the smart canes on a large scale.

Life cycle and depreciation of device

Depreciation relates to the cost of using a product or asset with the benefit gained from it during the time that it has been used. It is calculated by dividing the cost of the asset by the estimated number of years it will be in use. Frequency of usage, environment, and maintenance are some of the factors that affect the useful life of a product. So, it is difficult to calculate an absolute value. However, from our literature review of similar products currently available in the market, it can be said that the device has an approximate lifespan of 6-7 years, after which it will require a replacement due to the availability of more advanced technology or deterioration in performance.

Cost reduction

Our goal during the designing phase was to keep the cost of the product as low as possible without sacrificing the quality. For this, we searched numerous competitive suppliers for our materials and chose the one that could ensure us the best products at the lowest cost. Furthermore, we restructured the product to reuse certain components for different purposes without incorporating new, more expensive technology. For example, we could have used LiDAR for object detection, but it would have made our product extremely expensive and uneconomical.

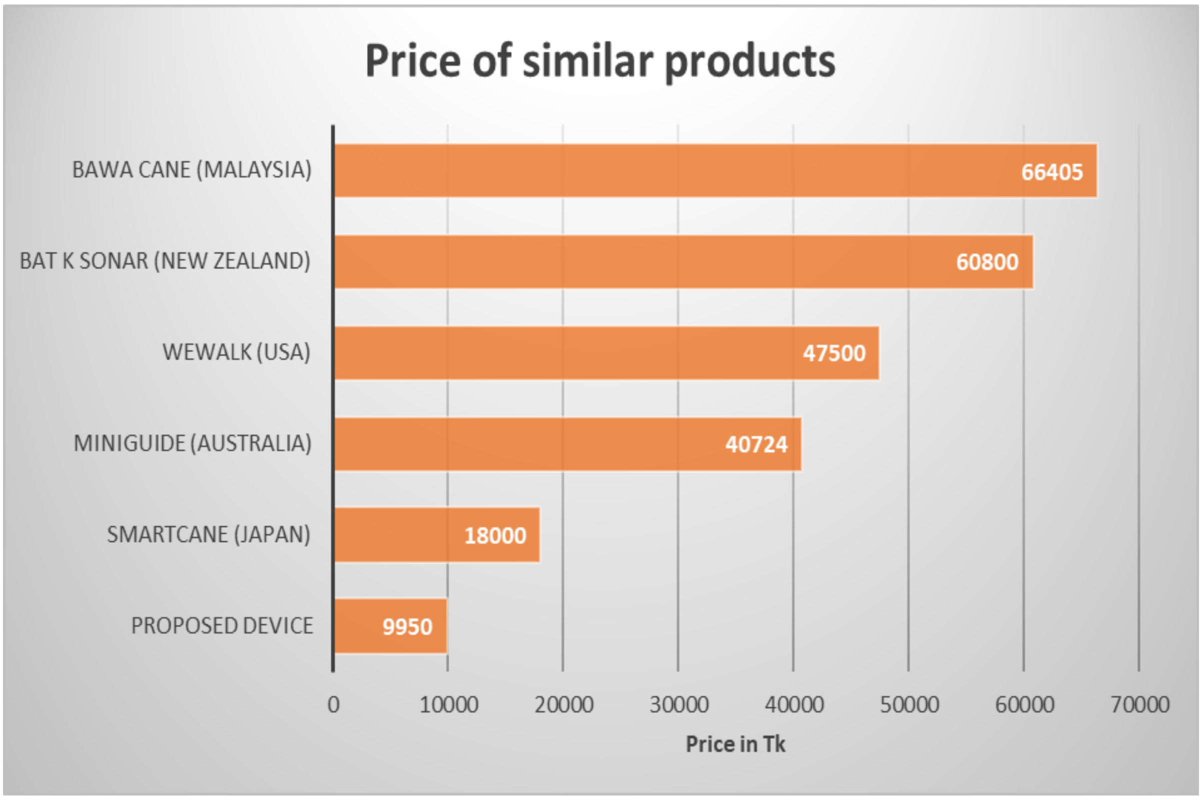

Figure 33: Price of similar products

<u>Benefits of implementing such projects</u>

Now that we have discussed the costs associated with this project, let us look at the benefits that might come from the implementation of such a device. Firstly, this will be a great initiative in terms of social welfare as we will be providing affordable assistive devices to a huge group of people who need such aid through this project. According to a study on the provision of assistive technologies in Bangladesh, lack of affordability was the main reason for not possessing assistive technology in both rural and urban areas. The research also concluded that certain vulnerable groups, such as young adults and the uneducated population, could not obtain basic assistive technologies unless the cost of such technology was marginal [33]. We hope that we can provide help to these communities at an affordable rate.

Another issue faced by the visually impaired community is that despite having the necessary academic requirements, they are often not given the same opportunities in the workforce. As a result, blind people are often excluded from employment and feel like a burden to their families. Thus, disability tends to reduce the economic output of a country by reducing or eliminating the economic contribution of the members with disabilities and the people surrounding them. There is an economic cost of disability. A study on this shows that there were four cost components of this phenomenon: costs due to lack of access to employment; costs due to children with disabilities losing out on school; costs due to adults helping people with disabilities; and costs due to children helping a family member with disabilities. The cumulative cost of the four components is approximately US $1.18 billion per year, which is about 1.74 percent of Bangladesh's GDP [34]. Access to opportunities and the latest technologies is the only way to move forward and visually impaired people and other persons with disabilities in society. There are a lot of institutions that help visually impaired persons in this regard, by providing specialized schools and training; the Employment Rehabilitation Center for Physically Handicap (ERCPH) has had the biggest impact in this regard. More devices like the smart cane will fill the gap of awareness that exists and make it easier for the visually impaired to integrate into the workforce.

In addition to this, there are also certain intangible benefits of this project. Intangible benefits are benefits that cannot be directly or solely attributed to the results of the project. For example, while it may not directly affect people's perception of the visually impaired community, it can help create awareness and thus make people more empathetic towards the hardships faced by the community. Open and honest communication by government and nongovernmental associations will result in reduced stigmatization of issues surrounding impairments. This will also lead to more people viewing impairments in a less condescending way. An article exploring the relationship between assistive aid use and the perceived attitudes of others reports that the use of such aids is directly related to the perception of the attitudes of others [35]. Thus, raising awareness about disability rights and the positive experience of others may contribute to overcoming the barrier to hearing aid use and lead to destigmatization.

According to a recent study on how low vision impacted people's daily activities, it was found that the loss of vision greatly affected an individual’s mobility and in turn their independence. In this study, the Vision-Related Quality of Life (VR-QoL) was determined in a large sample of adults [36]. The study was designed as a cross-sectional survey with 37 questions, both open-ended and closed-ended questions. Then, the VR-QoL was assessed using the Questionnaire of Vision-Related Quality of Life Measure. The research showed that restrictions in mobility caused difficulties in their daily lives. Furthermore, there were far more cases of depressive symptoms and feelings of hopelessness reported among people in the blind community than there were in the sighted population. A large number of participants said that they were afraid of falling over when traveling outside of their homes by themselves and crossing the roads independently also proved to be a significant challenge for them. Also, the depths of pavements were reported as a major concern. There were also discussions of feeling anxious when they had to travel to new places.

Most participants felt that they were safe at home, or in a familiar environment due to these factors. However, among them, there have also been reports that indicate that this restriction in the movement has had a detrimental effect on their quality of life. They felt that this loss of independence has led to isolation from family and friends and that the inability to participate in hobbies and other social events due to anxiety related to traveling alone has affected their lives in a negative way. Also, there were instances of mistreatment and discrimination in public places when they asked for help. Many felt that their needs were not being accommodated, which made them feel excluded from other members of the society; an example given of this was one when a participant was excluded from a group holiday as others had assumed they would be unable to participate.

Although increased production of such aided technology will not directly improve the quality of life for the community, it can have a significant positive influence on its users. According to a study on the psychosocial benefits of travel aiding the visually impaired, users reported feeling safe from physical harm and having a greater sense of self-worth, and competency due to increased independence in movement [37]. The social benefits of travel aids were most noticeable in the study; being able to travel independently provided a level of social inclusion and connection that could not have been possible otherwise. Furthermore, being able to go outside freely, without assistance, and participate in work and leisure activities directly impacted the quality of life. It was also mentioned that the percentage of blind people who were willing to leave their homes increased drastically when they had access to better travel aids. This also increased their confidence and made them less nervous when traveling. Increased social engagement and self-reliance lead to increased self-esteem and reduced anxiety.

Expected growth in market size

It is crucial to investigate the supply-demand relationship of our product before releasing it in the market. Supply is the total amount of a particular good or service that is currently available at a given moment for the consumers to consume, at a given price. On the other hand, demand represents how willing the consumers are to purchase that specific good or service at that given price. Supply and demand are closely associated with the price of goods and quantities that are produced and consumed within a given economy. Therefore, studying consumer behavior is important in order to gather insights about the current demand as well as to predict the market size in the following years. One way to analyze this is by using graphs to determine the equilibrium price of certain goods and services. It is important to note that a number of different factors can come into play when analyzing the demand and supply of a certain product. In this section, we will be discussing a few of these factors related to our device.

According to a study on According to the WHO 2022 (World Health Organization) report, about 2.2 billion people are visually impaired or have low vision [38]. In another study on the causes of blindness and visual impairment in Bangladeshi adults, it was found that the main causes of low vision were cataracts, refractive error, and macular degeneration, with cataracts being the predominant cause. Other causes included glaucoma, diabetic retinopathy, trachoma, and unaddressed presbyopia [39]. An increase in the incidence of such eye-related disorders in recent years has spurred the demand for technological advancements and user-friendly assistive devices for the visually impaired.

As per the "World Report on Vision", population growth, an increase in the aging population, lifestyle changes, and urbanization will further increase the number of people suffering from vision impairment and low vision in the coming decades which will pose a great challenge to the current society and economy. [40]. Thus, even though there have been considerable advancements in medicine and healthcare, we can expect to see a significant increase in the population who will benefit from our product. Roughly, the increment rate is 2 million per decade. So, the need for assistive systems/devices for navigation will be a prominent issue in the near future. As per a recent study, the global assistive technology demand for the visually impaired market is slated to expand, with the market valuation surpassing US$ 7.17 Bn over the forecast period between 2020 and 2026 [41].

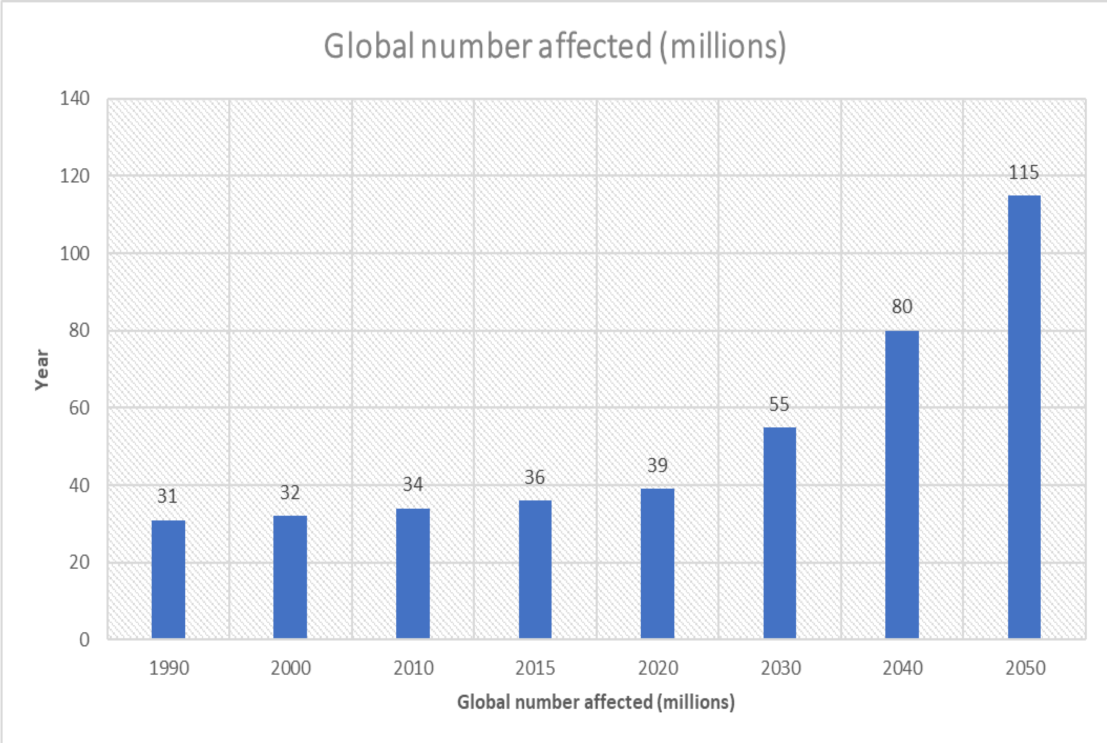

Figure 34: Estimates of people who are blind or have visual impairment [42]

Increased awareness about assistive technologies for the visually impaired, technological advancements and will also lead to rapid growth in market size. Already countless measures have been taken to accommodate the rising demand for assistive aids. For example, Access Bangladesh Foundation recently organized a roundtable discussion regarding this. Experts in the relevant field as well as ordinary people from different social statuses, and education participated in the discussion. The main goal of this meeting was to discuss how we could better involve and provide for persons with visual disabilities so that it was easier for them to become contributing members of society. Furthermore, suggestions and recommendations were discussed regarding policymaking for persons with disabilities in Bangladesh. One of such recommendations was imparting training to visually impaired persons, related NGOs, and educational institutes on the proper and meaningful use of white cane by the Department of Social Welfare; inspiring persons with visual impairment to use a white cane and making them aware of the proper use of it, and providing digital white cane for visually impaired persons at low cost [43].

Even though companies such as “Phoenix" and “a2i” are currently operating in the Bangladeshi market, the products that are being supplied are not sufficient to meet the rising demand of the community and they do not provide the same facilities either. Furthermore, with more advanced technology and increased funding, it is possible to optimize the available products. Recently, the Bangladeshi government has started meticulously working on strategies that will improve the mobility of the visually impaired [44]. A lot more work is needed to improve the situation and more policies like these will help spread awareness about visually impaired people. One such policy includes introducing digital braille books up to the secondary level to increase the literacy rate among the blind.There has been a special emphasis on developing mechanisms that can give visually impaired people their right to travel safely and independently. This shows how committed Bangladesh is to ensuring mobility and using innovation and technology.

Initiatives like these will further increase the need for more innovative assistive devices like the smart cane. Already, in other countries, government and private companies or manufacturers have teamed up to provide for the visually impaired. For example, in India, the Central Government has helped the visually challenged through its program which provides them with a smart cane at a subsidized rate or at no cost at all. Furthermore, the Indian Association for Blind had also arranged a workshop where volunteers were given instructions on how to use the cane and their feedback was taken so that it could be improved further. Events like these would be beneficial for both marketing and creating social awareness.

8.3 Cost-benefit analysis

Budget for one prototype:

SL	Component	Quantity	Price (tk)
	Detection System		
1	Arduino Nano V3.0 (CH340)	2	1300
2	HC-SR04 Ultrasonic sonar sensor	4	392
3	SEN-00235 Water Sensor	1	50
	Power Source		
4	Lipo Battery 3300mAh 11.1V	1	2292
5	B3 pro charger		443
	Notification System & SOS system		
6	Digital Buzzer Module	1	192
7	Grove - Vibration Motor	2	180
8	GPS Module GY-NEO-6M V2	1	845
9	SIM800L Mini GPRS GSM Module	1	450
10	speaker	1	55
	Other materials		
11	Button	1	7
12	Cane	1	800
13	Wheel	1	389
14	xt60 male female connector		62
15	BC547 NPN Transistor	1	2
16	wires		500
17	dc dc buck converter LM2596	1	250
18	others		2500
	Total (component price)		**10709**

Figure 35: Estimated cost of one prototype

Payback analysis

Usually, a cane is used for 5-7 years, the components we have used in this project are expected to last for at least 5 years within which the user might need to change certain lightweight components such as the speaker or sensor, which can cost them an up to 600 Tk.

If no alterations are required in the first 5 years:

The cost is 10709 / 6 years = 1,785 Tk per year for the first 6 years, after which the breakeven point is reached.

If the product needs altering twice in the first 5 years:

The cost is 10709 + (2*600) / 6 years = 1,985 Tk per year for the first 6 years, after which the breakeven point is reached.

8.4 Evaluate economic and financial aspects

Lastly, the costs and benefits of this project are compared to determine whether the benefits outweigh the costs. As we have already mentioned, the benefits, both monetary and intangible, are far greater than the costs. This project will have an immensely positive impact on the economy and society. It will not only help visually impaired people be more self-reliant but will also drastically improve their quality of life. On top of that, we have tried to reduce the costs as much as possible and we hope that further advancements in technology will lead to more accessible assistive devices.

8.5 Conclusion

In this section, we have analyzed the effect of implementing the project on the economy. For this, an economic analysis was done where we looked at different costs associated with the product such as direct cost, contingency cost, etc. Depreciation and life cycle were also discussed here. In addition to this, we looked at the various benefits that this project might have included affordable access to assistive devices and an increase in the workforce due to increased participation from the visually impaired community. We also studied various papers and reports and obtained a rough estimate of how important these factors are to the economy in terms of monetary value. We also discussed intangible benefits such as increased awareness and acceptability. Next, a cost-benefit analysis was done and a breakeven point was determined. It was found to be 6 years after considering replacements and modifications that could be needed. In the end, we concluded that the benefits far outweigh the cost both in terms of social benefits as well as monetary value.

Chapter 9

Ethics and Professional Responsibilities

9.1 Introduction

Professional ethics and responsibilities are a series of principles for making decisions in any professional work environment. Individuals should aim to comply with these principles to maintain work ethics. Integrity, responsibility, compassion, and kindness are part of these principles.

9.2 Identify ethical issues and professional responsibility

In a professional environment, there can be various professional responsibilities. But in the case of our project, the responsibilities can be narrowed down to the following: Using references with proper credit or citation, refraining from plagiarism, and maintaining applicable standards and codes. While maintaining professional ethics, we need to take ethical considerations into account, so according to the paper [45], we must:

1. Promote the inclusion and participation of visually impaired people (or people with low vision) in our project and project dissemination.
2. Ensure that our project data is accessible to the people taking the test.
3. Avoid harm to project participants.
4. Ensure voluntary and informed consent before participation in product testing.
5. Understand and fulfill relevant legal responsibilities before any testing.

9.3 Apply ethical issues and professional responsibility

We did not resort to any unfair means while preparing this project report and we did not use references without proper credit or citation. The design that we made is unique and was not a replication of other projects or publications. Ethical issues like anonymity, confidentiality, and informed consent will be addressed. We have tried to address these ethical issues through a consent form. So, before taking part in the project, the participants will have to go through a consent form and agree to its terms. Blind or vision-impaired people need to be introduced to this consent form with the help of their relatives or friends. We will take the consent of our participants with this consent form (a sample is given):

Smart Cane Usability Test Consent form

Please read and sign this form.

In this usability test:

- You will be asked to put our smart cane to the test.
- You will be given a small training to use our smart cane properly.
- You will provide the necessary feedback & information to improve the smart cane.

Participation in this usability test is entirely optional. All information will be kept private. The descriptions and results could be used to improve the smart cane. However, we will never utilize your name or any other identifying information. You have the right to withdraw your permission to participate in the test study at any time.

Please email Ahmad Ibrahim Fyaaz at ahmad.ibrahim.fyaaz@g.bracu.ac.bd if you have any questions.

I have read and fully understand the information on this form and have had all of my questions answered.

____________________ ____________________

Subject’s Signature Date

9.4 Conclusion

By maintaining the professional ethics and responsibilities related to engineering practice, we will exhibit the highest standards of honesty and integrity and will hold paramount the safety, health, and welfare of the public.

Chapter 10

Conclusion and Future Work

10.1 Project summary/Conclusion

The proposed device aims to make navigation easier for the blind community. During the designing process, emphasis was given to the users' requirements. The optimal design and solution were then chosen based on comparative analysis. The final design consists of ultrasonic and IR sensors attached to different positions of the walking cane. These detect elevated and lower-level ground, as well as any obstacle near the user. A water surface detector subsystem has also been included. Notifications will be given via vibration, buzzer, and voice commands to the user. Lastly, a communication module has been included so that the users' closed ones can be notified if the user is ever in danger or needs help. Most importantly, there is a power supply module to ensure that the device can be used for extended periods of time and does not require constant charging. Impact analysis and economic analysis were also reported in this document along with ethical considerations and the applicable codes associated with our project. A logbook has been attached which shows our progress over the entire project.

10.2 Future work

This work proposes a cost-efficient and accessible smart cane that will help people with low vision navigate their surroundings easily. Mass production of such devices would further reduce the cost and thus help ensure access to those who need it. However, there is still work that needs to be done to provide better services to the blind community. Further improvements can be made with the current design such as using camera modules to identify objects and conveying the information to the user via voice commands through an earpiece. Wireless connectivity between different subsystems is also a possibility. Google maps integration can be used to direct the user along a specific path. Enhancement using artificial intelligence, deep learning, and image processing will greatly improve the product. Technologies like these would detect obstacles much more accurately. There are only a limited number of assistive technology solutions available currently in Bangladesh. Thus, more research needs to be done to identify the issues faced by the community so that better assistive devices can be developed.

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