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A Smart Walking Stick for Elderly People – Part 2 : Design Configuration, Technical Analysis and Prototyping

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Abstract: This paper is the second of two, which focuses on the use of walking sticks as the mobility aid tools that are used by the elderly or people with mobility limitations to maintain their balance and stability while they carry out their daily activities, enabling them to live a life of independence. With the advancement of technology, a modern walking sticks can be found aplenty on commercial platforms. However, choosing a suitable walking tool may not be easy. Ease of function, specific features and value for money are among important factors that influence potential users in choosing their walking aid. For this project, a Smart Walking Stick is developed. It is equipped with an auto fall alarm sensor and a Global Positioning System (GPS) is used to detect the location and later, send notifications to closely related people via mobile devices in the event of an emergency. This newly developed Smart Walking Stick aims to be a device that can improve mobility and accessibility. Notably, this device is also developed with the desire to contribute to Malaysia's IR4.0 and Sustainable Development Goals (SDG) ambitions, specifically in helping people with physical difficulties that may have barriers to mobility. Along with the development of digitalization, this innovation also links the user with the Internet of Things (IoT) to increase their safety. This paper covers detail on design configurations and technical analysis conducted on the prototype, while the first paper highlights the results and outputs from the market survey and concept generation.

Keywords: *Walking aid, Alarm sensor, Grid Positioning System (GPS), Internet of Things (IoT), National Fourth Industrial Revolution (4IR), Mobility issues*

1.0 Introduction

As Malaysia is fast becoming an aging society, demands for elderly products such as mobility scooter, walking stick, and grab bars are now a growing trend. However, even as the country is striving to pursue the Fourth Industrial Revolution (IR 4.0) agenda that will change the way we live, communicate and work, domestic market for the elderly products is still lagging and has not changed much from decades ago. As the traditional role of familial provision for aged care is expected to decline in the next few decades, the importance of elderly products to support users with mobility issues are becoming more significant.

A quick search on the internet on walking stick products will show that there is a mismatch in terms of market demand against the product's functionality and quality. Lack of innovation, insufficient research and development on products design and user experience, and poor user satisfaction are among the commonly encountered issues with elderly products on the market.

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Hence, to address these issues, a novel prototype of a smart walking stick with improved functionality and features are proposed. The first part of this research work highlighted the output from the market survey conducted, and several concept generations had been presented (Part 1). In this paper, which is the second of two, design configuration and technical analysis of a walking stick prototype are presented.

2.0 Embodiment Design

2.1 Overview

Abstract concept paths from the concept design phase are continued in this section to form a physically reproducible system. The design process is often called embodiment design, where consists of three activities which are:

1. Product architecture- arranging the physical elements of the design into a grouping known as modules.
2. Configuration design- creating special-purpose parts and selecting standard components.
3. Parametric design- determining the exact values, dimensions, or tolerances of the components.

This section also discusses important issues such as dimensioning the parts, designing to improve the aesthetic values of the design, and achieving a design that is both user and environmentally friendly.

2.2 Key Subsystems

Figure 2.1 shows the physical decomposition of smart walking sticks for older people with decomposition details on the components. Physical decomposition is the process of separating a product or subassembly into its subsidiary subassemblies and components and accurately describing how these parts are joined together to create the product's behaviour. Three main subsystems will define this smart walking stick system: power supply, Arduino, microcontroller, electronic, and substructure.

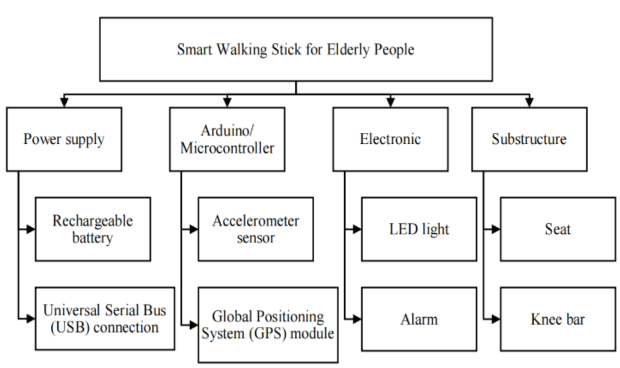

Figure 2.1 Physical decomposition of smart walking sticks for elderly people

2.2.1 Power Supply

A 10400 mAh rechargeable battery was used for the power supply. Therefore, a USB cable was provided to carry power and a signal to recharge the battery inside this walking stick. The charges could last at least 6 hours when used continuously.

2.2.2 Arduino/ Microcontroller

In terms of safety, Global Positioning System (GPS) and an accelerometer sensor were added to this walking stick. The accelerometer sensor was a low-power radio wave technology sensor that was used to detect and monitor the user's movements [1]. In contrast, GPS was employed for tracking the user's location no matter where they are.

2.2.3 Electronic Component

The electronic components that were used in this walking stick are an alarm and LED light. The sensor that operated in this walking stick was a GE buzzer. This alarm works by emitting sound waves at a frequency too high for humans to hear, which was 80 decibels (dB), and it could be triggered automatically when a user falls to attract attention. Next, the LED light on this walking stick could be adjusted and help users walk in dark areas, especially at night or early morning.

2.2.4 Substructure

This walking stick consists of a seat and a kneebar. The foam kneebar design had an anti-slip feature that provides balance while users stand and sit. Then, the half-round seat was designed to provide extra comfort to the user and prevent users from slipping when sitting.

2.3 Product Architecture

In engineering design, product architecture is related to the functional elements and physical components of products. It is used to define "the basic physical building blocks of the product in terms of what they do and their interfaces to the rest of the device. This definition joins design to framework level plan and the standards of framework designing [2]. Then, Figure 2.2 shows the schematic diagram of the smart walking stick system. The schematic diagram is transformed from the functional structure. Developing the product architecture includes clustering the physical elements and the functional elements into grouping or called chunks for performing the specific functions or sets of functions. Based on Figure 2.2, it can be concluded that there are a total of 5 modules used in the system.

i. Sensing module
ii. Alarm control module
iii. Light control module
iv. Microcontroller module
v. Notification module

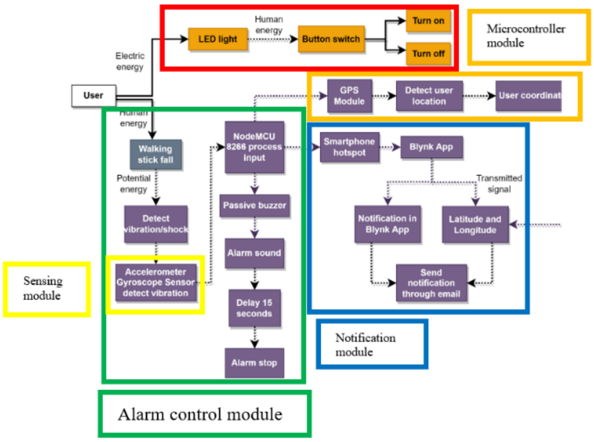

Figure 2.2 Schematic diagram of smart walking stick system

2.3.1 Schematic Diagram

Each module is self-explanatory, as stated in their respective names. For example, the sensing module consists of accelerometer sensors. These sensors have functions that will send signals to the microcontroller for further operations. First, the light control module converted from electrical energy will provide a light source, and the electrical energy will be stored in a rechargeable battery. Next, the alarm control module will be activated to detect vibration or shock when the stick falls. Thus, this system uses a sensor. Next, a microcontroller module will receive the database and transmit the signal of latitude and longitude from (GPS). Lastly, the notification module will obtain the database through the smartphone.

2.3.2 Geometric Layout

Making a geometric layout allows the designer to investigate whether there is likely to be geometrical, thermal, or electrical interference between elements and modules. A trial layout positions modules in a possible physical configuration [3]. The layout of the smart walking stick in Figure 2.3 indicates no physical contact between the notification module and any other module in the product. The light control module does not connect to other components of the smart walking stick. Next, three modules have contact interfaces: alarm control module, sensing module and microcontroller module. As a result, the interactions between these modules need to be analysed and planned. Electrical and vibration interference will have to be carefully considered to prevent any harmful effect on the sensing or positioning components. Tolerances and geometries will also have to be considered to ensure all parts fit together. Lastly, interactions with the other three modules will still have to be considered in terms of energy flows and material flows, but there should be no direct interference issues.

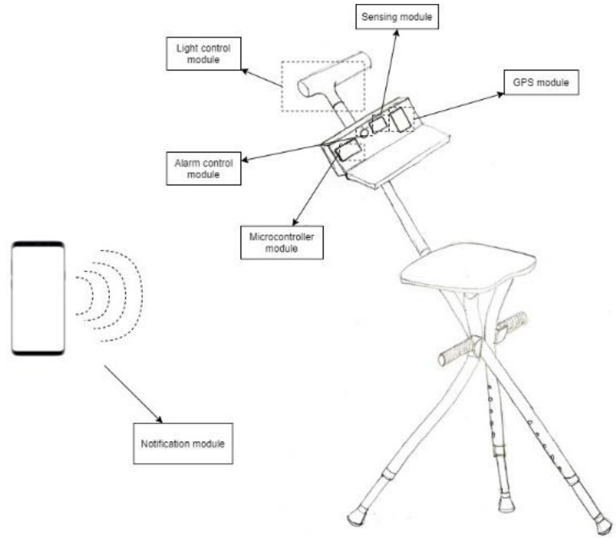

Figure 2.3 Geometric layout

2.4 Configuration Design

Configuration design synthesises a physical design from predefined elements and structures in certain ways. The configuration design phases include material selection, development, and item and electronic component layout.

2.4.1 Materials Selection

Materials selection involves choosing the best material for an application. To reduce production costs while maintaining product quality. Only the best materials will be chosen. As manufacturing design changes to meet environmental standards, so does the materials selection process. Cost, ability to manufacture, mechanical properties, physical properties, and environmental impacts should be considered when choosing materials. Tables 2.1 to 2.8 list the strengths, weaknesses, costs, mechanical properties, descriptions, and specifications of grip handles, seats, walking sticks, GPS modules, and alarms. First, strength and resilience are used to determine the material's mechanical properties. The selection criteria should also include material prices.

Table 2.1 Type of Materials and Mechanical Properties for Handle Grip

Materials for Grip Handle	**Description**	
	Strength	**Weakness**
Foam	• Excellent for suppressing vibration • Durable and weather resistant handle • Easy to fit and replace for maintenance • Soft and comfortable handle	• Can rub off on hands and leaving black marks • Flakes away quite easily after scrapes across the ground • Have to replace grips more often

Rubber	• Cheap • Durable and long-lasting • The material does not degrade when exposed to UV light • Can absorb a good amount of shock • and vibration from the road or trail	• Rubber grips are not breathable • Do not allow the sweat to vent orabsorb • Can become too soft and too sticky when it is hot • Can become too hard when it is cold
Wood	• Expensive	• Carry a lot of weight
Plastic	• Does not rot or corrode in air or water • Cheap and affordable • Can be recycled	• Difficult to dispose • Some types of plastics catch on fireeasily • Released into the environment, plastics can be very harmful to wildlife, animals and plants

Table 2.2 Type of Materials and Mechanical Properties for Seat

Materials for seat	Mechanical Properties			
	Ultimate Tensile Strength	Endurance Limit (kg)	Maximum Yield Strength, (MPa)	Life Spent (Years)
Canvas • Durable, sturdy and heavy duty • By blending cotton with synthetic fibres, canvas can become water resistant or even waterproof	68	102-136	55	25
Polypropylene (PP) • Rugged and corrosion-resistant • It is used in a broad spectrum of applications such as packaging, labelling, textiles, stationary, plastic parts and many more	33	100	12-43	20
Wood • Solid but simple • Sometimes can be slightly uncomfortable, particularly hard and plain	210-68	115-136	41.1	10-15

Table 2.3 Type of Materials and Mechanical Properties for Walking Stick

Materials for Walking Stick	Mechanical Properties		
	Ultimate Tensile Strength	Shear Modulus, (MPa)	Maximum Yield Strength, (MPa)
Aluminum Alloy T6-6061 • High quality, stronger, lighter • Provides an extra degree of flexibilityand more convenience • Good corrosion resistance	290	26.2	241
Stainless Steel • Corrosion resistant • Such a "green material" par excellenceand is infinitely recyclable	515	82	205
Wood • Strong • Long-lasting • Can be sawn to exactly the right lengthfor the user	2.10	6.20	41.4

Table 2.4 Type of Materials and Electrical Properties for Walking Stick

Material for Walking Stick	Electrical Properties		
	Thermal Conductivity (W/m×K)	Thermal Conductivity (W/m×K)	Thermal Conductivity (W/m×K)
Aluminum Alloy T6-6061	167	3.5×10^{7}	2.82×10^{-8}
Stainless Steel	15	1.45×10^{6}	6.9×10^{-7}
Wood	0.12-0.04	1×10^{-4}	1×10^{3}

Table 2.5 Type of GPS module and Specification

Type of GPS module	Specification	Price per unit
 NEO-6M [4]	Size: 23mm × 30mm Update rate: 1Hz, max 5Hz Baud rate: Default 9600 max Navigation sensitivity: -161dBm Power requirements:3V-5V Number of channels: 22 tracking, 50 channels Time to first start: Warm start: 27s and Hot start:27s Antennas: External patch antenna Accuracy: 2.5m GPS horizontal position accuracy Product applications: -Battery operated mobile devices -GPS tracker -GPS navigator	RM32.99 (per pieces) SHIPPING DELIVERY: RM4.60 TOTAL: RM37.49
	Size: 40mm × 20mm × 13mm Update rate: 1Hz, max 10Hz Baud rate: 9600 - 115200	

 GROVE-GPS MODULE [4]	Navigation sensitivity: -160dBm Power requirements:3.3/5V Number of channels: 22 tracking, 60 channels Time to first start: Warm start: 13s and Hot start:1-2sAntennas: Antenna included Accuracy: 2.5m GPS horizontal position accuracy Product applications: -GPS tracker -GPS navigator -Distance measurement Other Features: -Low power consumption -Baud rates configurable -Grove compatible interface	RM98.74 (per pieces) SHIPPING DELIVERY: RM20.00 TOTAL: RM118.74
 GROVE-GPS (AIR530) [4]	Size: 40mm × 20mm × 13mm Update rate: - Baud rate: - Navigation sensitivity: - Power requirements:3.3/5V Number of channels: - Time to first start: Warm start: 30s and Hot start: 4s Antennas: Antenna included Accuracy: 2.5m GPS horizontal position accuracy Product applications: -GPS tracker -GPS navigator -Distance measurement Other features: -Highly integrated multi-mode satellite positioning and navigation -Grove compatible interface	RM54.41 (per pieces) SHIPPING DELIVERY: RM38.21 TOTAL: RM92.62

Table 2.6 Type of Alarm and Specification

Type of Alarm	**Specification**	**Price per unit**
 PS1420P02CT (70 dB) [5]	Category: Audio products, alarms, buzzers and sirens Driver circuitry: Transducer, externally driven Input type: Zero-peak signalVoltage-Rated: 5V Voltage Range: 30V(Max) Frequency: 2kHz Technology: Piezo Operating mode: Single toneDuration: - Sound pressure level (SPL): 70Db @ 5v,10cmPort location: Top Operating temperature: -10°C ~ 70°CMounting type: Through hole Termination: PC pins Size / Dimension: 0.551” diameter (14.00mm) Height- Seated (max): 0.500” (12.70mm)	RM2.98 (per pieces) SHIPPING DELIVERY: RM0.00 TOTAL: RM2.98
 EDWARDS SIGNALING (70 dB) [6]	Amperage rating: 0.05 Coil resistance: 725 Dimensions: 5-1/16 in H × 2-1/4 in W Frequency rating: 50/60 Material: Die cast aluminum Mounting type: Surface Sound level: 80/70 Type: Heavy duty Voltage rating: 120 Weight: 1.74 inch	RM627.17 (per pieces) SHIPPING DELIVERY: RM0.00 TOTAL: RM627.17
 KPEG232 (75 dB) [7]	Operating current max: 13mA Sound pressure level (SPL): 75dB Sound level distance: 30cm Resonant frequency: 3.2kHz	RM9.65 (per pieces) SHIPPING DELIVERY RM0.00 TOTAL: RM9.65
 GE buzzer (80 dB) [8]	Voltage: 40 ~ 120V Decibels: 80db Mounting: Surface Usage: Indoor Height: 3.1406 inch Width: 1.625 inch	RM187.23 (per pieces) SHIPPING DELIVERY: RM0.00 TOTAL: RM187.23

Rubber is an affordable, durable, and long-lasting grip handle material (Table 2.1). Table 2.2 shows that polypropylene is chosen for the seat because it is durable, corrosion-resistant, and widely available. From Tables 2.3 and 2.4, an aluminum alloy walking stick is selected. It's better than two other materials in quality, strength, weight, and mechanical properties. Table 2.5's NEO-6M GPS module can help our smart system work more efficiently and economically than other GPS modules. The GE buzzer has the highest decibel and is easy to install, according to Table 2.6.

2.4.2 Manufacturing Process

Our industries and infrastructure must be improved, and nature must be preserved. Recycling promotes sustainability. Recycling helps save raw materials and preserve natural environments. Our concept includes a rubber grip handle, an aluminum alloy stick, and a plastic seat. First, rubber can be recycled in a variety of ways, including reconditioned rubber products, broken down or ground up rubber, and rubber used in manufacturing for electricity or other uses. Aluminum alloy can be recycled for transportation, beverages, and other uses. Aluminum recycling has economic benefits. Polypropylene (PP) is a reprocess able plastic. Based on the Sustainable Development Goals (SDG), UN member states will frame their agendas and political policies over the next 15 years (2016– 2030). With 17 goals, 169 targets, and more than 200 indicators covering people, planet, prosperity, peace, and partnership, the SDGs will stimulate action over the next 15 years in critical areas for humanity and the planet.

This project supports SDG Goal no 9, which is industry, innovation, and infrastructure growth. Goal 9 ensures prosperity, sustains development gains and improves wellbeing. Build resilient infrastructure, promote sustainable industrialization, and foster innovation. Smart walking sticks for seniors combine three important aspects to achieve Goal 9. First, infrastructure includes basic social and economic facilities. Second, industrialization drives economic growth. Third, innovation helps people and industries solve problems and seize future opportunities [9]. Notably, SDG Goals number 8, 9, and 17 can be considered as the foundation of a healthy, inclusive, and functioning economy.

2.4.3 Part Layout

Rubber is an affordable, durable, and long-lasting grip handle material (Table 2.1). Table 2.2 shows that polypropylene is chosen for the seat because it is durable, corrosion-resistant, and widely available. From Tables 2.3 and 2.4, an aluminum alloy walking stick is selected. It's better than two other materials in quality, strength, weight, and mechanical properties. Table 2.5's NEO-6M GPS module can help our smart system work more efficiently and economically than other GPS modules. The GE buzzer has the highest decibel and is easy to install, according to Table 2.6. Tables 2.7 and 2.8 illustrates the items, parts, and their respective descriptions to support the operation of the smart system.

Table 2.7: Part layout of smart walking stick

Item	Description	Price per unit
 Triple Cane Chair Tip Quad Base Walking Stick Crutches Aid Adjustable (25''/500LBS) [10]	• As a main product and we modified it • Adjustable legs and foldable • Height adjustments: 86-96cm • Material: Aluminum Alloy and ABS • Max weight capacity: 330LBS • Product weight: 0.8kg • Comes with LED light	RM57.00 (per pieces) SHIPPING DELIVERY: RM5.80 TOTAL: RM62.80
 APACS PU Overgrip (Thin Grip) Ap-016 [11]	• As a grip liner at the grip handle • To provide slip handle and good sweat absorbent • Materials: Polyurethane (PU) • Width: 25mm • Length: 1100mm • Thick: 0.65mm	RM1.90 (per pieces) SHIPPING DELIVERY: RM4.50 TOTAL: RM6.40
 FOOTREST [12]	• Material: Rubber • Work as a knee bar that can support user when sit down and sit up	RM8.74 rxz-local rear (per pieces) SHIPPING DELIVERY: RM4.60 TOTAL: RM13.34

Table 2.8: Part layout of smart walking stick (Electronic)

Item	Description	Price per unit
 ESP8266 V3 NodeMCU LUA CP2102 WIFI ESP12E-10 [13]	• To connect objects and let data transfer using the Wi-Fi protocol • Size: 49mm × 26mm • Operating voltage: 3.3V • Input voltage: 4.5V-10V • Product weight: 7g	RM15.50 (per pieces) SHIPPING DELIVERY: RM4.60 TOTAL: RM20.10
 MPU6050 3-Axis Acceleration Gyroscope Module [14]	• Work as motion tracking devices designed • For low power, low cost and high performance • Voltage range: 3.3V-5V • Dimension: 21mm × 16mm × 3mm	RM4.50 (per pieces) SHIPPING DELIVERY: RM4.50 TOTAL: RM10.70
 9V Rechargeable Battery [15]	• To store battery and rechargeable • Fast charging time 1.5 hours • High capacity 650mAh • 1200 times charging	RM22.00 (per pieces) SHIPPING DELIVERY: RM4.60 TOTAL: RM26.50
	• Used to bear mechanical loads or electricity	RM2.80 male-male (per pieces)

 Jumper Wires [16]	telecommunications signals • To connect components to each other on the breadboard without soldering • Length: 10cm	SHIPPING DELIVERY: RM4.50 TOTAL: RM7.31
 Prototype Breadboard Kit [17]	• To builds the first prototype from breadboard and uses to test circuits	RM8.16 (per pieces) SHIPPING DELIVERY: RM4.50 TOTAL: RM12.66

2.5 Parametric Design

Parametric design can be defined as a process based on algorithmic thinking that enable the expression of parameter and rules, that together define, encode, and clarify the relationship between design intent and design response. Parametric design is examining set values for the design variables that will produce the best possible design considering both performance and cost. There will be a few designs parametric to be consider and specified.

2.5.1 Calculation of Material Toughness

A walking stick must be designed for different type of material for different components in the product that will be produce. Some of the components using steel, aluminum, rubber and plastic. The good and economical material have to be used to ensure the product can stand the heavy load of user and high impact of the fall purpose.

Flaws in materials are not always easy to detect, and more often than not, they are unavoidable as they may emerge during processing, manufacturing or servicing a certain material. Since it is difficult to make sure that the material is free of flaws, engineers suppose that a certain flaw exists and approach the problem using methods such as the Linear Elastic Fracture Mechanics (LEFM) method. Developed by A. A. Griffith in the 1920s, LEFM provides a means of solution for engineering problems, including the estimation of safety and life expectancy of structures with cracks [18].

The LEFM revolves around a parameter called the stress-intensity factor (K), which is a function of the loading stress, the size of existing or assumed crack, and the structural geometry. This factor is a suitable way to understand the stress distribution around a crack. In mathematical terms, the stress intensity factor can be reached as follows: Energy required to cause fracture (*Gc*) is a function of the stress σ, crack length α, and the elastic modulus E:

$$G_C = \frac{\sigma^2 \pi a}{E}$$

Rearranging the equation gives:

$$\sqrt{EG_c} = \sigma\sqrt{\pi a}$$

Stress intensity factor K of unit [MPa.m$^{0.5}$] can be defined as:

$$K = \sigma\sqrt{\pi a}$$

Fracture takes place when the stress intensity factor reaches a critical value K_c, i.e:

$$K_c = \sqrt{EG_c}$$

K_c is what is known as the fracture toughness of the material:

$$K_c = \sigma\sqrt{\pi a}$$

This can be described also in relation to material thickness. As the thickness of a material changes, the states of stress around the crack change. When the material thickness reaches a critical value, the value of the stress intensity factor K relatively plateaus at a critical value known as the fracture toughness K_c. In thin samples, the stress state is called plane stress, while that in thicker samples is referred to as plain strain. Plain strain characterizes more acute stress states and lower K values.

2.5.2 Calculation of Rubber Friction

The contact area contribution is written as contact area times a frictional shear force. The normal force is the nominal contact area times the normal stress. Thus, the friction coefficient is the viscoelastic friction coefficient plus the true contact times the frictional shear stress divided by the nominal contact times the normal stress. Our theory approach calculates the viscoelastic contribution when the power spectrum and the material properties are known. Note that in this approach are no fitting or open parameters which could be used to manipulate the result. The nominal contact area is known as well as the normal stress. The contact area at the particular magnification where shearing the interface becomes important is calculated by the Persson contact mechanics theory and the shear stress acting is assumed based on earlier experimental studies of this quantity [19]. The total rubber friction is the sum of the hysteretic, or viscoelastic, contribution and the contact area contribution as follows:

Sum of the hysteretic:

$$F_f = F_{visc} + F_{cont}$$

Sum of the viscoelastic:

$$F_{con} = A\tau_f$$

Sum of the contribution:

$$F_N = A_0\sigma_N$$

The contact area contribution:

$$\mu = \frac{F_f}{F_N} = \frac{F_{visc}}{F_N} + \frac{F_{cont}}{F_N} = \mu_{visc} + \frac{A\tau_f}{A_0\sigma_N}$$

Where,
μ = Friction coefficient
μ_{visc} = Viscoelastic friction coefficient
F_f = Total rubber friction
F_{visc} = Viscoelastic contribution
F_{cont} = Contact area contribution
F_N = Normal force
A = True contact area
A_0 = Nominal contact area
τ_f = Frictional shear stress
σ_N = Normal stress

2.5.3 Calculation of Power Input and Output

For the electronic circuit to complete the connection, the input and output power supply must be suitable for the circuit to be able to function to the sensor. The input power supply also must not exceed the limit to prevent the circuit from burning or explode that can endanger the user and to prevent the cost for testing getting higher. Georg Ohm found that, at a constant temperature, the electrical current flowing through a fixed linear resistance is directly proportional to the voltage applied across it, and inversely proportional to the resistance. This relationship between the Voltage, Current and Resistance forms the basis of Ohms Law and is shown below [20].

Ohms Law Relationship,

$$Current, (I) = \frac{Voltage, (V)}{Resistance, (R)}\, in\ Amperes, (A)$$

Electrical Power, (P) in a circuit is the rate at which energy is absorbed or produced within a circuit. A source of energy such as a voltage will produce or deliver power while the connected load absorbs it. Light bulbs and heaters for example, absorb electrical power and convert it into either heat, or light, or both. The higher their value or rating in watts the more electrical power they are likely to consume.

The quantity symbol for power is P and is the product of voltage multiplied by the current with the unit of measurement being the Watt (W). Prefixes are used to denote the various multiples or sub-multiples of a watt, such as: milliwatts (mW = 10^{-3}W) or kilowatts (kW = 10^{3}W). Then by using Ohm's law and substituting for the values of V, I and R the formula for electrical power can be found as:

$$P = VI$$

$$P = \frac{V^2}{R}$$

$$P = I^2R$$

Where,
P = Power (W)
I = Current (A)
V = Voltage (V)
R = Resistances (Ω)

2.5.4 Calculation of Decibel of Buzzer

GE Buzzer have been used to produce emergency sound when the sensor has detected fall from user and seek attention from surround people for help. The sound that wants to be produce must be loud and not break the human ear because the limit decibel human can accept is 120 dB only. The decibel, dB utilizes a logarithmic scale based to compare two quantities. It is a convenient way of comparing two physical quantities like electrical power, intensity, or even current, or voltage. The decibel uses the base ten logarithms, i.e., those commonly used within mathematics. By using a logarithmic scale, the decibel is able to compare quantities that may have vast ratios between them [21].

Decibel formula for power comparisons:

$$N_{dB} = 10\log_{10}\left(\frac{P_{output}}{P_{input}}\right)$$

Decibel formula for voltage & current:

$$N_{dB} = 20\log_{10}\left(\frac{V_{output}}{V_{input}}\right)$$

$$N_{dB} = 20\log_{10}\left(\frac{I_{output}}{I_{input}}\right)$$

Voltage & current decibel formulas for different impedances:

$$N_{dB} = 20\log_{10}\left(\frac{V_{output}}{V_{input}}\right) + N_{dB} = 20\log_{10}\left(\frac{Z_{input}}{Z_{output}}\right)$$

Where,
N_{dB} = Ratio of two power expressed in decibels, dB
P_{output} = Output power level
P_{input} = Input power level
V_{output} = Output voltage level
V_{input} = Input voltage level
I_{output} = Output current level
I_{input} = Input current level
Z_{input} = Input impedance
Z_{output} = Output impedance

2.5.5 Design for Robustness

Robustness is the phase in which technology, product or process efficiency are minimally sensitive to factors that result in variability in the engineering or environmental performance and aging at the lowest units of cost of production. A smart walking stick for elderly people has fall detection system that can detect if the user has fall and been in emergency situation. Besides of that, this system also can detect the location of the user by collecting the coordinate using Global System for Mobile Communications (GSM) module to easier the relatives of the user to track the user. By sending the alert notification and the location to the relative of the user, the elderly people can be safe in a short time and prevent them from the worst scenario.

In addition, there is a long-life battery for the fall detection system to operate in the time being of the user use the smart walking stick. It is suitable as the elderly people use the walking stick in most of the time to walk from one place to another place even in indoor or outdoor. So, the long-life battery is the suitable to be use in the smart walking stick. Other than that, the LED light have been used in the prototype to easier the elderly people to use especially in the dark surrounding. Even it is a small improvement, it easier for the user to operate without bring extra equipment just for the lighting purpose.

2.5.6 Design for Reliability

Reliability alludes to interruptions in use during administration. It is a more specialized display characteristic than durability and is estimated by the likelihood that an item will neither breakdown nor fail within a specified time period. Design for reliability is a systematic, smoothed out, simultaneous designing system where dependability designing has meshed into the complete improvement cycle. It depends on a variety of unwavering quality designing apparatuses alongside an appropriate comprehension of when and how to utilize these devices all through the planning cycle. This cycle incorporates an assortment of instruments and practices and portrays the generally of sending that an association needs to continue to plan unwavering quality into its items.

Hence, to apply the design of reliability to the smart walking stick for elderly people, SOLIDWORS software is used to visualize the design of the project before the manufacturing process. SOLIDWORS software is used to illustrate the durability of the walking stick of the project to ensure that material can maintain in certain conditions like example heavy load & falling situation. Meanwhile, the fitting and design parameter for the purpose of the manufacturing process can be done on SOLIDWORS software. Besides that, some calculations are performed to analyze the perfect capacity of the project that can be produced while the user uses it and to give higher reliability for the user.

2.5.7 Design for Safety

Product safety is the ability of a product to be safe for intended use, as determined when evaluated against a set of established rule. In addition, product safety is a product which does now no longer incur product legal responsibility prices wherein capability chance wishes to be detected, for you to produce a chance-unfastened product. Safety may be utilized in diverse bureaucracy via way of means of growing an environmentally secure version that protects customers.

One of the product functions taken is the walking stick handle cover. We use the comfort and thick material that become squishy and smooth to give the good grip to the user's hand. Good and suitable quality of handle cover should be used to ensure it could stand towards huge pressure. This type of handle cover gives the user maximum handgrip and easier for the user to walk, sit and standing up.

Next, the material use for the smart walking stick is mostly in steel and aluminum that can withstand the heavy load and pressure of the user especially in extreme conditions. This type of material makes the prototype light in weight and also less in costing if we make comparison with the other materials. In addition, the rubber underneath the smart walking stick can prevent the user from slipping while they are walking, sitting and standing up from seat. The good rubber can be use either in dry surface or wet surface. The type of rubber can be long-life material and easy to purchase in the market.

2.5.8 Design for Ergonomic

Ergonomics is a study of how people connect with man-made objects. The intention of ergonomics is to create an atmosphere that is well matched to the physical needs of the customers [22]. Ergonomics is applicable in a variety of field that used to build a comfortable environment for the user. In ergonomic scope design, optimizing human well-being and the overall system performance, our design gives preference to the weight, scale and dimension of the complete prototype that make it user-friendly.

For the prototyping, the actual size is not too big and not too small because of the size fits for and walking and keeping purpose. The purpose is to solve the problems of some people that having limited space in their house. As the design of the seat on the smart walking stick can be fold, we can fit the walking stick between the small gap of the furniture. The prototype also has the knee-bar special just to make easier for user to standing up from the seat. With the comfort and grip knee-bar, it makes easier for user to standing up without hurting their knee. Therefore, it is the right decision for the walking stick users to use this smart walking stick in their daily-life.

2.5.9 Consideration for Aesthetic in Design

Aesthetics is a central design philosophy that determines the pleasing qualities of a design. Visually, aesthetic requires aspects such as colour, balance, pattern, movement, form, size and visual weight [23]. The purpose of aesthetics usually to compliment the usability of the products, thereby improving performance with appealing layouts to attract the user. However, the performance and the functionality are the most important things in the design system.

For the prototyping, the design of the walking stick handle is the first aesthetic part of the product. The product purposely uses for walking, the design for the grip handle must be comfortable and good grip at the same time. Moreover, the design of the plastic seat also gives aesthetic value to the user. The seat using polypropylene material as it can withstand high load, easier to fabricate and less in cost. As the material has been used in most of the product, polypropylene easy to be found in the market.

3.0 Prototyping

3.1 Detailed Design Overview

In this chapter, all the details about finalized decisions and electronic connection were put together in detailed design. Detailed design is an overall mechanism that involves conceptual design, embodiment design and professionally presents a successful design approach. This section displays the complete schematic drawing of the electrical circuits, analysis of prototypes and the technical drawing of the full 3D model of the actual appearance of the prototypes. In this stage, the design was refined and planned, specifications and estimates were drawn up.

3.1.1 Sensor Circuit

In our prototype, a vibration sensor and passive buzzer were placed to alert the people near the user's when the Smart Walking Stick for Elderly People fell to the ground. It is important to ensure the functionality is maintained in a long-term period. When the vibration sensor detects a sudden impact, the vibration sensor sends the data to the microcontroller to process the data. Next, from the microcontroller, it will send the data to the GPS module to detect the location of the walking stick and send back the coordinate to the microcontroller. Simultaneously, the microcontroller will send the data to the Blynk App through Wi-Fi connection for the notification email and the coordinate of the Smart Walking Stick.

Blynk application is a new platform that allows you to quickly build interfaces for controlling and monitoring your hardware projects from your iOS and Android device (Figure 3.1). After downloading the Blynk app, you can create a project dashboard and arrange buttons, sliders, graphs, and other widgets onto the screen. Using the widgets, you can turn pins on and off or display data from sensors. This application still needs some improvement to the interfaces, but a lot of projects use the old version of Blynk because of more reference from sources. With Blynk, though, the software side is even easier than the hardware. So, we chose a Blynk application to complete our system for fall detection systems that can be monitored from a long distance.

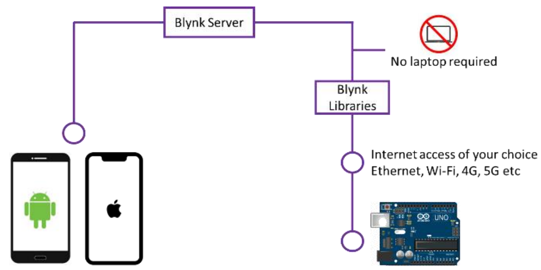

Figure 3.1 Process of data transfer from Blynk application to microcontroller

3.1.2 Schematic Diagram

The simple circuit of the smart management planting system is shown in Figures 3.2 and 3.3. All electrical parts were used to control the whole device and to provide the necessary operations. For the electronics part of the product, there are few common schematic symbols such as resistor and transistor and the vital part is microcontroller. Besides that, there are two main sensors used in this smart system which are the vibration sensor (Accelerometer Gyroscope MPU6050 module) and the GPS Module (GPS Neo-6M module). The feedback devices respective to the above sensors include the passive buzzer for alarm and notification by transferring the data through Wi-Fi connection. Each component system has its corresponding functions to establish the entire system and maximize performance.

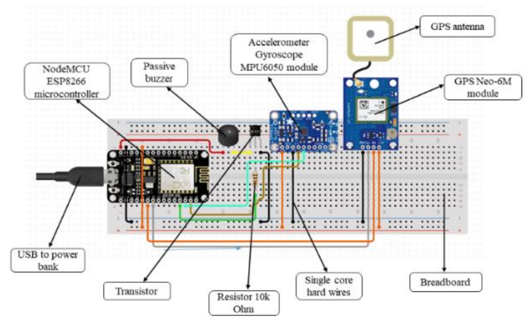

Figure 3.2 Circuit diagram of Smart Walking Stick for Elderly People

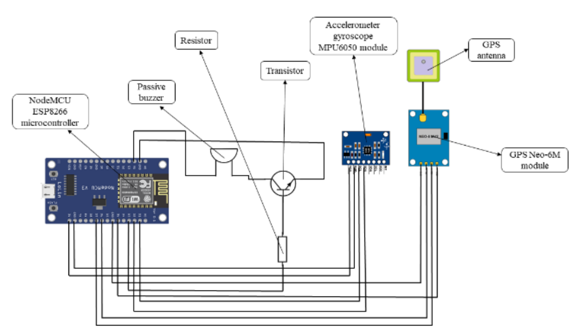

Figure 3.3 Schematic diagram

3.1.3 Technical Drawing

In this segment, all technical drawings with appropriate dimensions are provided. The measurements presented are in millimetre (mm). Figure 3.4 shows the isometric view of the 3D model, while Figure 3.5 and Figure 3.6 show the exploded view of systems and components. Furthermore, Figures 3.6 - 3.11 show the individual parts of the assembly with respective dimensions.

Figure 3.4 Isometric view

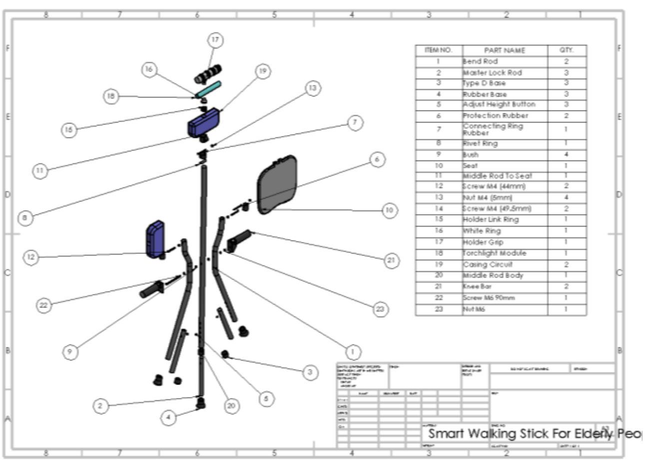

Figure 3.5 Exploded view of Smart Walking Stick for Elderly People

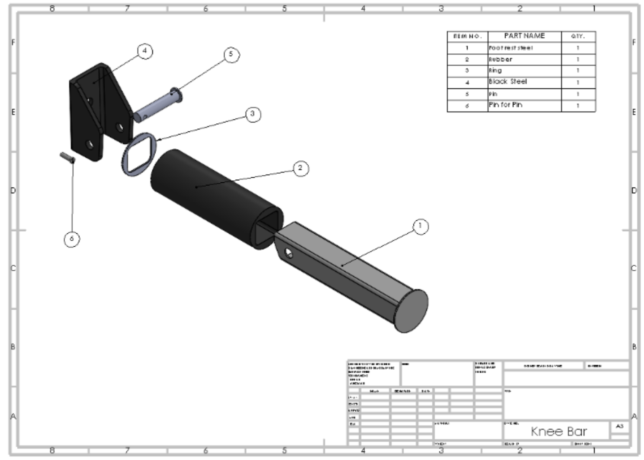

Figure 3.6 Exploded view of knee bar

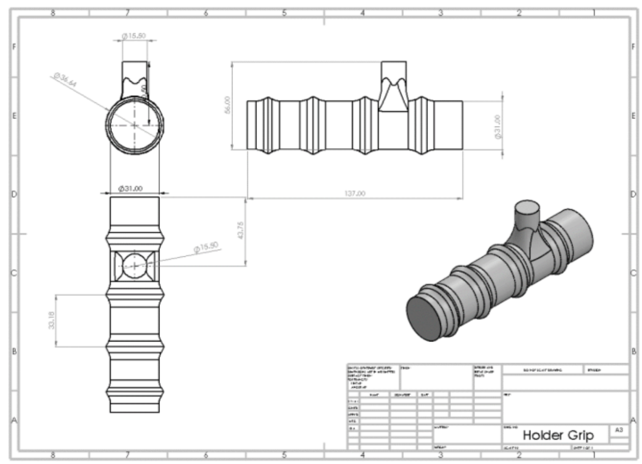

Figure 3.7 Detailed drawing of holder grip

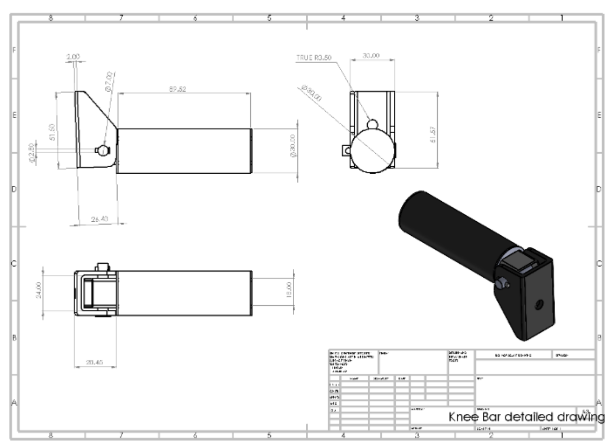

Figure 3.8 Detailed drawing of knee bar

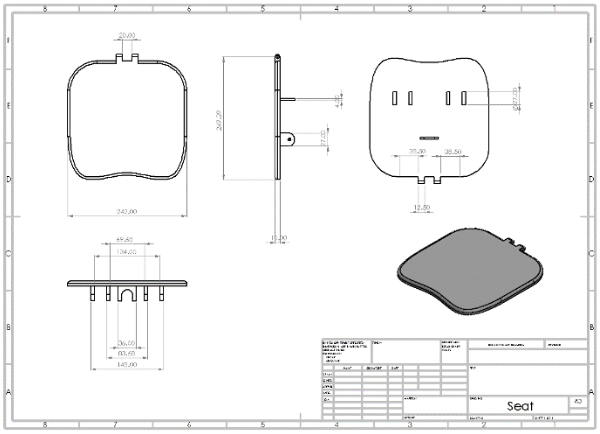

Figure 3.9 Detailed drawing of seat

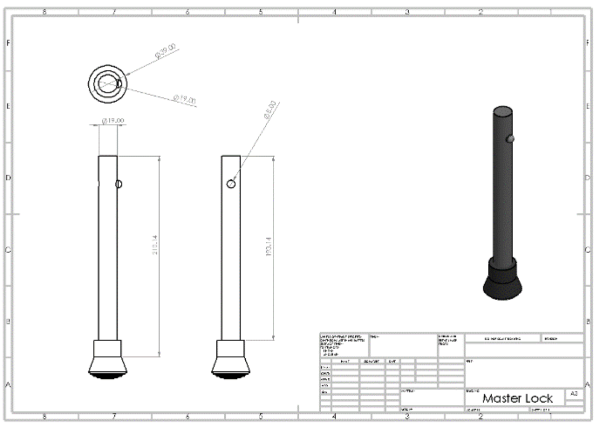

Figure 3.10 Detailed drawing of master lock

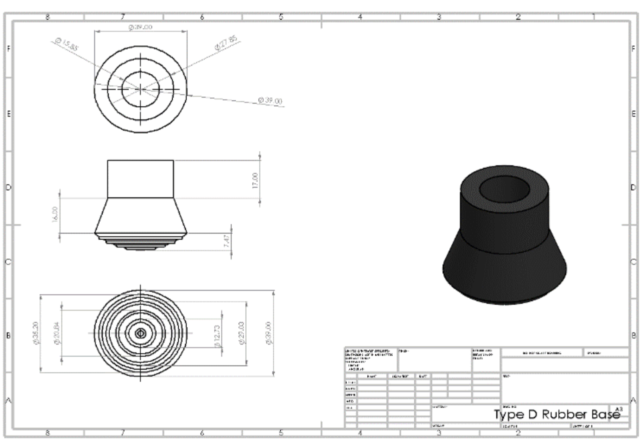

Figure 3.11 Detailed drawing of type D rubber base

3.2 Engineering Analysis of Prototype

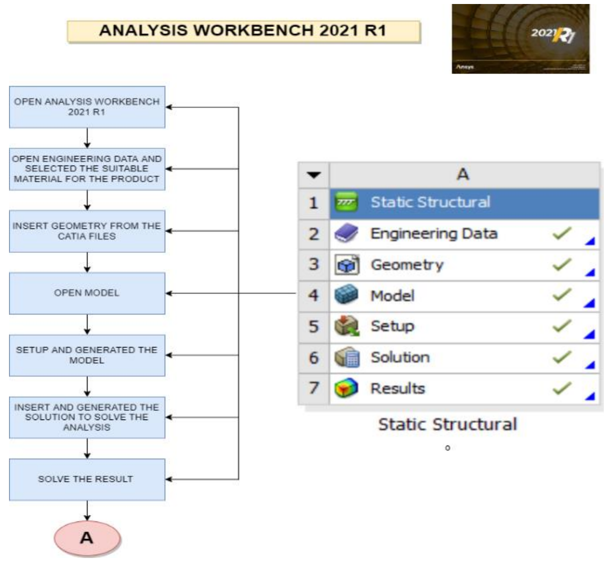

Figure 3.12 Analysis workbench 2021 R1

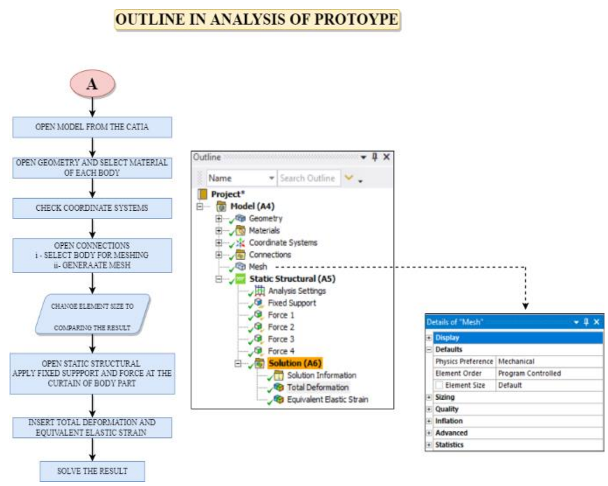

Figure 3.13 Analysis workbench 2021 R1

ANSYS Workbench is a new modern interface with more up to date functions and a common platform for solving engineering problems. ANSYS Workbench can be importing models from CATIA for design simulations and performing analysis simulations. In this project, analysis workbench can determination of the effects of loads on physical structures and their components. Next, the structural analysis is performed into three different part of components which is handle, seat and body part. Then, this analysis is performed to test out the deformation and strain of the components. Figures 3.12 and 3.13 highlight the steps in conducting analysis in ANSYS workbench.

3.2.1 Seat

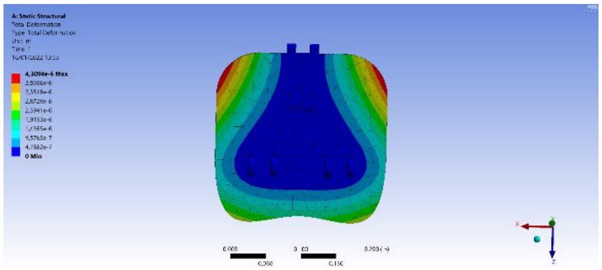

Figure 3.14 Total deformation for seat

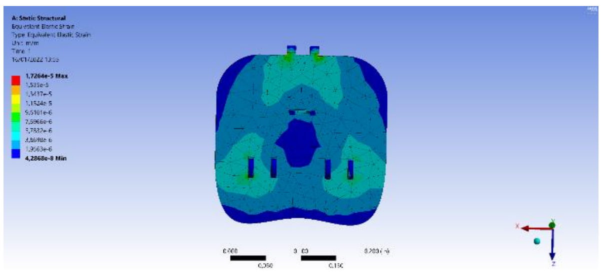

Figure 3.15 Equivalent elastic strain for seat

Seat is the very important part of the walking stick and directly responsible for the comfortable when using it. In this context, the maximum capacity of bodyweight 3300lbs or 150kg. Assumptions that the gravitational acceleration is of 9.81 m/s^2 throughout the project, the force for respective mass is 1471.5N. Next, fixed support can be applied at the static structural and set 0 m for element mesh.

From Figures 3.14 and 3.15, the maximum deformation for this seat occurs at 4.3094 x 10^{-6} m with there is no min deformation. The maximum elastic strain occurs at 1.7264 x 10^{-5} m/m while the minimum elastic strain occurs at 4.2868 x 10^{-8} m/m. In this context, the value of mesh element is changed to compare the result of the analysis. Throughout the project, the fixed support and the force for respective mass is same where is 1471.5N. Then, 8 meter mesh element was generated to compare the result.

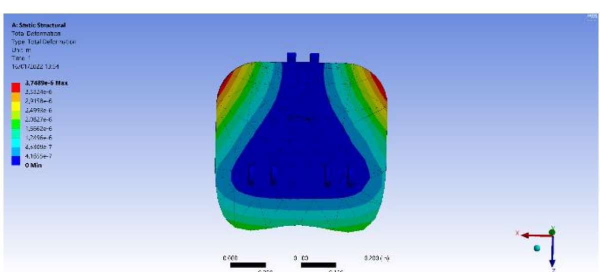

Figure 3.16 Total deformation for seat

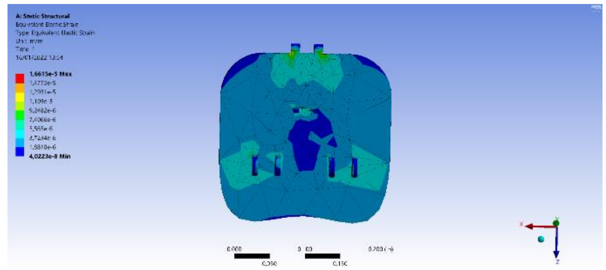

Figure 3.17 Equivalent elastic strain for seat

As the result, the maximum deformation for this seat occurs at 3.7489 x 10^{-6} m and there is no min deformation (Figure 3.16). The maximum elastic strain occurs at 1.6615 x 10^{-5} m/m while the minimum elastic strain occurs at 4.0223 x 10^{-8} m/m (Figure 3.17).

3.2.2 Handle

The handle is one of the parts that can be analysed because it is used at the top of the product. The result of this part is a solution to verify that this design is appropriate. Assume a force of 20kg is applied at the top of handle. In addition, the gravitational acceleration is 9.81 m/s^2 throughout the entire project, the force for respective mass is 196.2N.

From Figures 3.18 and 3.19, the maximum deformation for this seat occurs at 2.1706 x 10^{-5} m with there is no min deformation. The maximum elastic strain occurs at 7.7333 x 10^{-5} m/m while the minimum elastic strain occurs at 1.7111 x 10^{-8} m/m. In this context, the value of mesh element is changed to compare the result of the analysis. Throughout the project, the fixed support and the force for respective mass is same where is 196.2N. Then, a 3m mesh element was generated to compare the result.

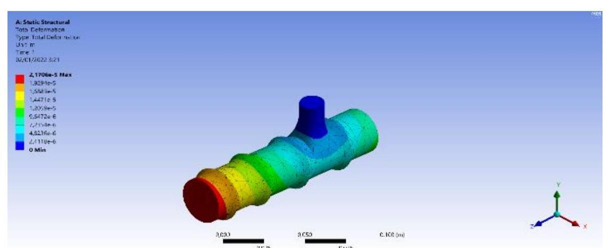

Figure 3.18 Total deformation for handle

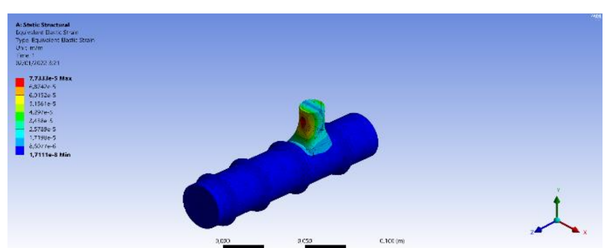

Figure 3.19 Equivalent elastic strain for handle

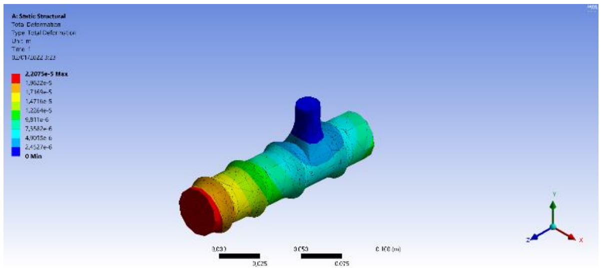
Figure 3.20 Total deformation for handle

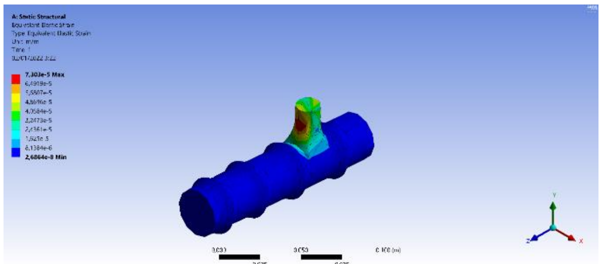
Figure 3.21 Equivalent elastic strain for handle

From Figures 3.20 and 3.21, the maximum deformation for this seat occurs at 2.2075 x 10^{-5} m and there is no min deformation. The maximum elastic strain occurs at 7.303 x 10^{-5} m/m while the minimum elastic strain occurs at 2.6864 x 10^{-8} m/m.

3.2.3 Body Part

In this context, body parts are a major component of the product and require static analysis to determine the physical structure and the impact of loads on that component. Next, the material that will be used is aluminum alloy. The maximum capacity of the bodyweight is 150kg. It is assumed that the total force of all parts is also 150kg. As the gravitational acceleration is 9.81 m/s^2 throughout the entire project, the force for respective mass is 1471.5N. In addition, 196.2N of force are apply at the curtain body part. Lastly, fixed support also required to solve the deformation and elastic strain.

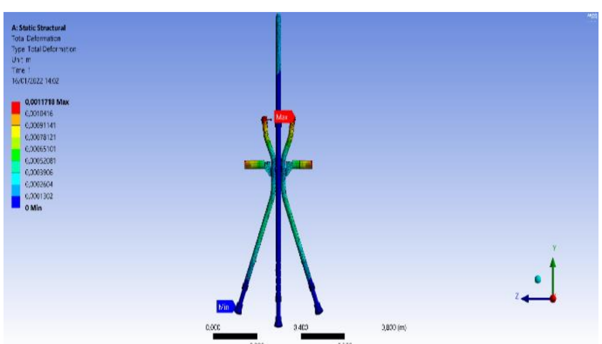
Figure 3.22 Total deformation for body part

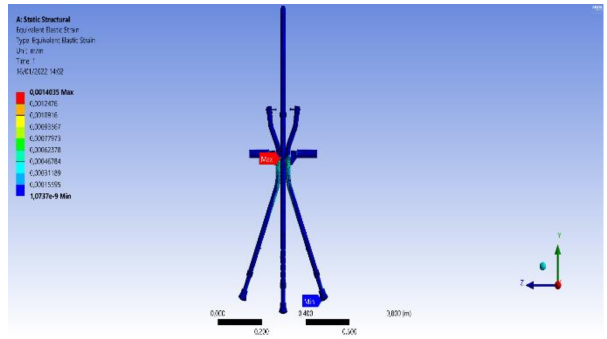
Figure 3.23 Equivalent elastic strain for body part

As the result, the maximum deformation for this seat occurs at 0.0011718 m and there is no min deformation. The maximum elastic strain occurs at 0.0014035 m/m while the minimum elastic strain occurs at 10737 x 10^{-9} m/m (Figures 3.22 and 3.23).

3.3 Proof of Concept Prototype

A prototype is a draft version of a product that allows designers to explore the ideas and show the intention behind a feature or the overall design concept to users before investing time and money into development.

3.3.1 Design for Manufacture

Design for manufacture (DFM) are statements of good design practice that have been empirically derived that help narrow the range of possibilities so that the mass of detail that is considered. DFM guidelines were necessary as the time for thoughtful consideration of all steps of production. A good designer must possess a good understanding of design for manufacture. This is because it is able to cut down the manufacturing cost effectively. With the knowledge of design for manufacture, designers will always avoid unwanted or excessive design which will increase the cost of manufacture.
In this Smart Walking Stick for Elderly People, there are 3 components that need to be installed to the prototype which are knee bar, circuit box and power bank holder. The fabrication process of the design of these 3 components are reduced to the lowest to reduce the manufacturing cost. Besides these 3 components, other parts are able to be found in the market.


Figure 3.24 Knee bar

Figure 3.25 Size of the power bank holder relative to the shaft

Manufacturing the part that is already in the market and installing the external component reduces a lot of costs and time. As the technology grows faster, we focus on the implementation of IR 4.0 which is user-friendly to the elderly people and community. To achieve a smart system of the product, standardize the size and function of electronics components which are suitable for small scale electronics projects. All these components are already available in the market for purchasing, which is NodeMCU ESP8266, Accelerometer gyroscope MPU6050 module, GPS Neo-6M module and others. The life and reliability of standard components have their fixed function, which helps us as designers to choose the right component to be included in the system. The cost reduction comes through quantity discounts, elimination of design effort, avoidance of equipment and tooling costs as well as better inventory control.

3.3.2 Design for Assembly

Design for assembly (DFA) is the technique for a plan of the item for simplicity of assembly. This assembly process comprises two actions, treatment, which includes grasping, orienting, and situating followed by inclusion and affixing. There are three sorts of getting together which are manual assembly, automatic assembly, and mechanical assembly are grouped by the level of automation.

In the smart walking stick for elderly people, the assembly method is only manual technique. This is because the expenses for any automation and robotic assembly is high. By using manual assembly, all processes can be accomplished by manpower. Besides, the machine and tools have been used from the design lab for grinding and drilling processes and some of the tools for small assembly can be obtained from the store nearby.

Figure 3.26 Portable grinding machine at design lab

Figure 3.27 Drilling machine at design lab

To have a mistake proofing of the design and assembly, tolerances on every dimension on the assembly part are calculated before inserting or fastening the part. For example, every drill hole needs to be offset for 0.5mm as a consideration for the bolt to get through the alloy tube without eliminating the grip for the knee bar.

3.3.3 Design for Environment

Design for an environment (DFE) is a way to deal with decreased ecological impacts toward the item and safety of humans. Plan for the environment should be a necessary piece of stage plan rules as it tends to shield the environment's wellbeing from risks and harm of mining. However, the undertaking has limited the sorts of material utilized. In Smart Walking Stick for Elderly People, all the material utilised and fabrication procedures that involves from the start till finished will lessen influence on the environment. To put it another way, design for the environment took into account how we, as designers, could remanufactured or recycle wasted materials in our work.

For example, the tube for the walking stick uses good material for the walking stick to withstand the weight of the user and the customer does not have to change to the new one and can be used for a longer time. In addition, by choosing the good material, the maintenance cost for the Smart Walking Stick for Elderly People can be reduced. Other than that, electronic components can be harmed by environmental conditions, so an effective maintenance program needs to be developed to keep the components clean to withstand those conditions. Among the environmental conditions that can negatively affect electronic components are moisture from humidity and dust particles. Our electronics components were environmentally friendly considering the energy used in supplying the power energy to generate the power to the system using a power bank which reduces the amount of batteries produced each year. On statistic, in 2021, about 82 000 metric ton of lithium batteries were produced.

DFE is concerned with the power drawn by the electrical product during the operation of the components, the time necessary to be active, and the recycling of the raw materials used to construct it at the end of its lifecycle. It is easy for us as a designer to complete the requirements of a circuit without much thought to power efficiency unless the application involves a big scale of power source such as function.

Figure 3.28 Circuit box

Figure 3.29 Power bank holder

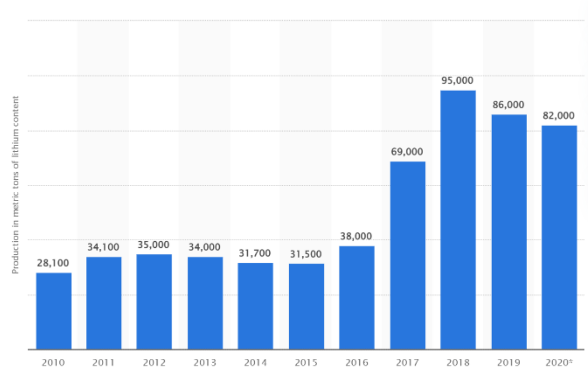

Figure 3.30 Lithium mine production worldwide from 2010 to 2020

3.4 Fabrication Process

3.4.1 Hardware

Figure 3.31 Removing the nut on the footrest using a combination plier

Figure 3.32 Make a hole on the iron plate of the footrest using a pillar drill machine

Figure 3.33 Decrease the thickness of the iron plate on the footrest side using portable grinding

Figure 3.34 Reassemble all the footrest components using a combination plier

The footrest and walking stick used to make this smart walking stick prototype was purchased online at the Shopee website. Figure 3.31 shows the footrest disassembly work for the modification process according to the measurements and design created. This footrest will be modified and used as a smart walking kneebar. Once disassembled, drill the iron plate on the footrest side to make a hole by size 7mm using a pillar drill machine, as shown in Figure 3.32.

Then, as shown in Figure 3.33, the next step is decreasing the thickness of the iron plate on the footrest side by 5mm using portable grinding. This step prevents the footrest from shifting with the body walking stick when pulled up at 90 degrees. Lastly, reassemble all the footrest components using a combination plier, as shown in Figure 3.34.

3.4.2 Electronics

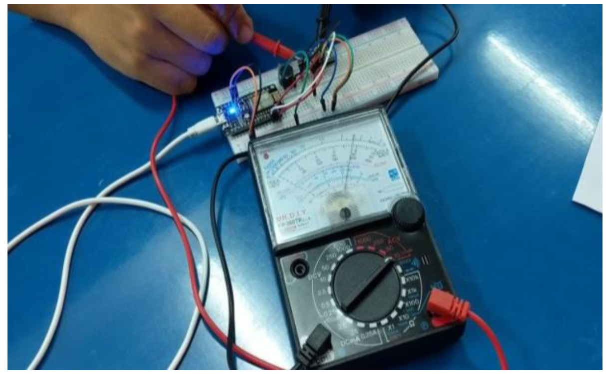

Figure 3.35 Test the voltage of each electronic components using a voltmeter

Figure 3.36 Soldering process on circuit board

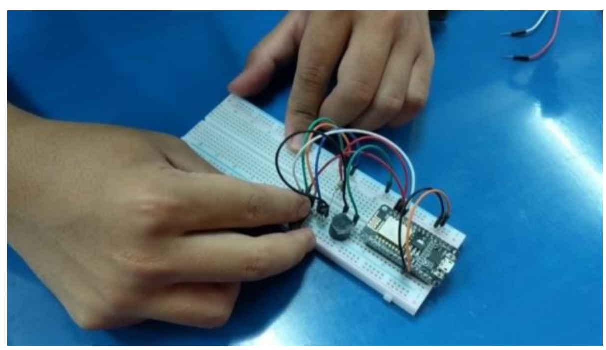

Figure 3.37 Attach all electronic components to the breadboard

First, as a safety step, test and check each electronic component's voltage first before starting wiring or installing all electronic components on the breadboard. Voltage measurements are essential for problem-solving, so this step is critical. This step is helpful to ensure that the circuit receives too much or too little voltage, and then, based on the voltage drop, it can identify which individual components are the cause. As shown in Figure 3.35, the instrument used is a voltmeter since the voltage of each electronic component must be measured using the unit of volts, V. This voltmeter must connect in parallel with the electronic component. Then, joining electronic components on the circuit board forms an electrical bond. Soldering and a low melting point metal alloy (solder) are used in this step, as shown in Figure 3.36. Lastly, attach all the electronic components on the breadboard in the correct order to ensure the circuit can work correctly, as shown in Figure 3.37.

3.4.3 Assembly

Figure 3.38 Final prototype

Figure 3.39 Tighten the nut on the footrest

Figure 3.40 A circuit box is fastened to the rod body using a reusable, adjustable cable fastener

Figure 3.41 A power bank is attached under the chair

Figure 3.38 shows the final prototype shape for the smart walking stick, and as shown in Figure 3.39, the two footrests are screwed with the walking stick together. Then, the nut on this footrest is tightened using a spanner. Next, based on Figure 3.40, the circuit box is fastened to the rod body using a reusable, adjustable cable fastener. Meanwhile, the power bank is attached under the chair using adhesive glue. After testing the capabilities of this prototype, then can be concluded that all the functions of this smart stick can be fully functional and easily stored due to its ability to be folded in half, as shown in Figure 3.41.

3.5 Bills of Materials

Bill of materials (BOM) is a list of all raw materials, assemblies, subassemblies, parts, and components needed to make a product, as well as the quantities of each. BOM also helps with budgeting for the entire order to complete the finished product by providing a much clearer image of the structure of the item being created. The material and cost of each component in our smart walking stick for the elderly are shown in Table 3.1. The total cost is computed based on the quantity used by listing all the required components and materials.

Table 3.1 Bill of materials

No	Parts Name	Quantity	Price (RM)
1.	Triple cane chair tip quad base walking stick	1	62.80
2.	Footrest	1 set	13.34
3.	Pencil box	1	2.10
4.	GPS module	1	37.49
5.	Gyroscope module	1	10.70
6.	Breadboard	1	12.66
7.	Single core hard wire	1 meter	0.40
8.	Node MCU 8266	1	20.10
9.	Passive buzzer	1	0.90
10.	Powerbank (10000 mAh)	1	39.00
11.	Transistor (BC548)	1	0.40
12.	Resistor (10k Ohm)	1	0.99
13.	Wallpaper sticker	1	2.10
14.	Steel ring	4	0.10
15.	Foam wallpaper sticker	1	2.10
16.	Tightening rope	1 packet	1.00
17.	Wrapping	1	1.00
18.	Super glue	1	1.00
19.	Bolt M6 90mm and Nut M6	1 set	0.70
		Total	209.18

3.6 Economic Analysis on Project

Economic analysis is a first step in the project planning process. Because, unlike financial analysis, which should assess the impact of a project on the income of its owners, economic analysis is a more generalised cost-benefit analysis tool. Economic analysis has two primary goals in project planning. First, to provide information for making decisions on project acceptability from the customer's perspective, and second, to provide valuable information for project design and planning, macroeconomic planning, and economic research. Economic analysis is also used to assess the societal costs and benefits of a project.

According to Table 3.1:

Costs of Goods	=	RM 209.18
Net Sales	=	RM 450.00
Gross Profit	=	RM 240.82

Gross Profit Margin $= \frac{\text{RM } 240.82}{\text{RM } 450.00} \text{x} 100$

$= 53.51\%$

3.6.1 Income Statement per 1000 products

Estimated profit for the sale of 1000 units. The gross profit is calculated by dividing the difference between net sales and the cost of goods by 1000 products. Except for income tax, operating expenses are the last cost to be considered after all other expenses have been deducted. The costs included selling, general, and administrative expenses. Administrative costs include employee salaries, payroll taxes, leasing, office supplies, and insurance. Remove all taxes and expenses from the gross profit and total income to arrive at the net profit. The economic analysis data is shown in Table 3.2, and the income and expenses are shown in Table 3.3, along with a calculation for computing the product's net profit in 1000 products.

Table 3.2: Economic analysis data

Item	Calculation	Price (RM)
Net Sales	RM 450.00 x 1000 products	450,000
Costs of Goods	RM 209.18 x 1000 products	209,180
Gross Profit	**Net sales – Costs of goods**	**240,820**

Table 3.3: Income and Expenses

Operating expenses	Price (RM)
Selling expenses General expenses Administrative expenses	RM 7000.00 RM 5000.00 RM 1000.00
Total operating expenses = Selling expenses + General expenses + Administrative expenses	RM 13000.00
Incomes	**Price (RM)**
Operating income	RM 5000.00
Other income	RM 3000.00
Interest income	RM 1000.00
Total income = Operating income + Other income	RM 8000.00

Net profit = Gross profit + Total income – Total operating expenses = 235,820

Gross profit margin = (Net profit/sales) x 100

$$= \frac{\text{RM } 235820}{\text{RM } 450000} x100$$

= 52.40%

The gross profit margin ratio shows the percentage of sales revenue a company keeps after it covers all direct costs associated with running the business. This makes it an important ratio for helping business owners and financing professionals assess a company's financial health. The gross profit margin ratio is typically used to track a company's performance over time

$$\text{Profit margin ratio} = \frac{Net\ Profit}{Sales\ Amount} \times 100\%$$

$$= \frac{RM\ 235820}{RM\ 450000} \times 100\%$$

= 52.40%

Based on the profit margin of 52.40%, it indicates that the proportion of sales revenue that turns into net profit. For this case, the net profit margin of 52.40% means that for every RM 1200 sale contributes towards the net profits of the business. Net Profit Margin ratio is one of the two elements that determine the return on assets, the other element being the sales turnover ratio. Measuring the trend of profit margin over several periods in comparison to industry benchmarks is crucial for identifying gaps that could be overcome to improve the profitability of a business in the future.

4.0 Discussion

4.1 Concept on Prototype

Basically, the idea of prototype is a preliminary version of a product that allows developers to explore the designs and show developers the purpose behind a function or the overall design concept before spending time and money in production. This project used working prototype to validate the concept and step in developing an idea into a real product. Before prototyping is performed, several ideas are developed by using the working prototype. Decision tools such as Pugh Chart and Weighted Decision Matrix are used to choose the best concept, based on the concept developed. The decision tool is based on the evaluation of the selection criteria where the Concept 4 is selected.

4.2 Discussion on Solution Justification

The rationale for the solution is to validate the choice made in the production of this project. In this part, the material, the manufacturing process as well as the price are decided on the basis of the concept selected.

4.2.1 Concept of Prototyping

Generally, the concept is to create a smart walking stick with safety features for elderly people. It leads our project to focus on the fall detection system as a main aspect. The smart walking stick is to encourage the efficient way for the relatives of the user to take action if any bad things happen to their family. The microcontroller for the fall detection system is NodeMCU ESP8266, it is chosen due to the low commercial cost and capability in carrying out the fundamental system function compared to the other microcontroller. Including other electronics components, the low-cost requirement is achieved with the costing of not more than RM100,00 for the system.

In order to ease the set up or fabrication process of the fall detection system, the programming phase was created based on the coding from online sources and edited according to the fall detection system. With the use of well-built open-source coding from Arduino IDE, the user only requires connecting the electronics and set up the microcontroller. In the aspect of fall detection, the system will make an alarm sound to notify people around the user and simultaneously send the alert notification with coordinates to the relatives of the user. This maximizes the safety features of the current smart walking stick in the market.

The sustainability aspect is designed by using a power bank as the power supply. Electricity will be stored in the power bank and supplied to the microcontroller and sensor module during the activation of the system. Because of the basic system and the focus on coding for the fall detection system, the amount of electricity used has decreased. This significantly reduces the uptime of the system and prolongs the lifetime of the sensor module.

The system only requires to procedural set up at the early phase and then it will be fully automated by fall detection system depending on the usage style of the user. This design is to achieve the requirement of ease in operation, where the involvement of human energy to alert the surrounding and relatives is minimized. Lastly, the sensor module has to be replaced when it has been using in a long time due to obtain accurate vibration and coordinate detection. The sensor module is easily available and cheap to be replaced. This coincide with the target on achieving ease in maintenance where the replacement procedure can be easily done by swapping new sensor according to the original connection.

4.2.2 Material

It is necessary to strengthen the life cycle of the material to choosing the appropriate material to be used. Materials need to be carefully chosen to match the design. One of the material considerations made on the tube rod, seat and the circuit box of this product. Aluminum alloy is chosen as the material of the tube rod as it has appropriate mechanical efficiency, lightweight and can withstand heavy load from the user of the walking stick. As for the seat, polypropylene used for its good chemical resistance, good fatigue resistances, good heat resistance and tough. Moreover, the circuit box was made from aluminum material, which is light in weight, stainless from rusty, can withstand huge impact from the falling and is comparatively inexpensive compared to the other material.

4.2.3 Manufacturing Process

In the prototyping process, we go first to the footrest for the knee bar. We disassemble all the parts. We used a grinder to reduce the thickness to 5mm and it took about 20 minutes for two footrests to save time. We then increased the size of the screw holes on the footrest from 4mm diameter to 6mm diameter holes. This approach gives the knee bars greater strength, can withstand greater user loads, and is less prone to breakage.

Also, we change the diameter of the hole at the tube body of the smart walking stick. The original diameter of the bolt is 4mm. We increased the diameter to 6mm with a drill and round file tool with a tolerance of 0.5mm. In addition, changes were made to fasteners such as bolts and nuts made of steel, taking into account the design and practicality of the prototype. The original diameter of the bolt and nut was 4mm, so we changed it to a 6mm diameter because of the add-on for the cane. The 4mm diameter bolts are 50mm long, which is fairly short and not long enough to assemble the knee bar. The 6mm diameter bolts are 90mm long and secure the knee bar to the tube body. These changes have been for the knee bar to withstand load efficiently.

4.2.4 Cost

Based on market survey carried out, the relevant costs collected from respondent should be above RM 200.00. The most of components are using are NodeMCU ESP8266, passive buzzer, accelerometer gyroscope MPU6050, GPS Neo-6M module and single core hard wire and others are common parts that are conveniently supplied either from a local shop and online store, which will also reduce the price of manufacturing the product successfully. The connections of all electronics components are often soldered, and the assembly of all mechanical components requires fasteners such as bolt and nut and a hot melt gun, which is least expensive. It also including the wage cost for the assembly of the product.

4.3 Impact to Society

The product that developed has brought several positive impacts on the society. Firstly, the product is safe and does not produce any harmful effects due to the environmentally friendly material and operating method. Thus, this product is eco-friendly where the power supply is utilized to supply electricity to operate the system. Moreover, the product itself give a great amount of flexibility in modification and improvising. The cheap pricing on the selected electronics components is to promote more individual to be involved in the application of IoT. Where the main goal is to upgrade the traditional walking stick to modern method through expansion of IoT in their working environment.

4.4 Ethical Issues

As an engineer, we need to ensure the safety of our product. Design ethics concerns moral behaviour and responsible choices in the practice of design. It guides how designers work with clients, colleagues, and the end users of products, how they conduct the design process, how they determine the features of products, and how they assess the ethical significance or moral worth of the products that result from the activity of designing.

4.4.1 Professional Code

i. ***Respect for others***
Treat people as you want to be treated. It is mandatory to respect everyone you interact with. Be kind, polite and understanding. It is a must to respect others' personal space, opinion and privacy. It is not allowed to harass or victimize others. This project respects the elderly people in terms of ergonomic design and employing technology. Where affordable methods and components are adapted to build a smart walking stick for elderly people.

ii. ***Integrity and honesty***
Tell the truth and avoid any wrongdoing to the best of ability. First, always keep in mind of the organization's mission. The behaviour of engineer should contribute to our goals, whether financial or organizational. Engineers need to be honest about the design selection and specification in order to gain the user's trust and avoid having any issues when running the system.

iii. ***Teamwork***
Collaborate and ask for help. Working well with others is a virtue, rather than an obligation. Engineers certainly get to work autonomously and be focused on designated projects and responsibilities. Be generous with expertise and knowledge. Be open minded to learn and evolve. This project is completed in a group based on what was given and prioritize the needs in their field based on the questionnaire that was distributed.

4.4.2 Standard or Act

Due the conceptual design of ram pump, it requires to transport water in a distance. To operate this concept, it is bounded to the Laws of Malaysia act 514 Occupational Safety and Health act 1994. This section will discuss the related rules and regulations that are written under the Act.

4.4.3 Rules and Regulations

Firstly, using the design ideas and research methods of user experience to probe into design art in the field of the elderly products, thus presenting an innovative smart walking stick with a better user experience. Next, based on the questionnaire surveys, observation and other methods were employed to research the lifestyle and travel behaviour of the elderly people, gain the users' characteristics, recognition mentality, perception features and other valuable information, identify the present home caring conditions and travel features of the elderly group.

As a conclusion, on the basis of cluster analysis on the characteristics of the typical user group and the survey results, the persona of users was created was made in the form of story board to define the needs of the target personas and output the design prototype. After that, the design scheme was completed to offer a reference for design of relevant products.

5.0 Conclusion and Recommendation

As the aging population in Malaysia is fast growing, improved marketplace, products and services that cater to this group are needed. With IR 4.0 is expected to influence the way we live, work and communicate, it is also fair to envisage that elderly people could benefit from the innovation that comes with it. From this project, a novel prototype of walking stick product was designed, developed and fabricated based on market requirements such as product ability to detect location, user friendly durable, safe and portable. Notably, this project is aligned with the Sustainable Design Goal 9, which is to apply the knowledge in studies to the community, while also incorporating IR 4.0 element.

As for recommendation, more research and experiment may be done better improve the design of the product to make it more ergonomic. Additionally, new system can also be integrated to enhance the accuracy of the detection system. Lastly, to ensure lasting power supply, kinetic energy recovery system may also be implemented on the product.

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