July 11, 2021

Dr. Craig Scratchley
Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Re: ENSC 405W/440 Design Specification for the Smart Mask Box

Dear Dr. Scratchley and Dr. Rawicz,

In the following document attached below, you can find the outline of our design specifications for our Smart Mask Box. With the Smart Mask Box, public areas with little supervision will feel safe knowing that everyone has a mask to help prevent the spread of the flu and disease. The Smart Mask Box will be an easy, hands-free, and intuitive way for the public to safely acquire a mask and have peace of mind while spending the day shopping or traveling.

The Smart Mask Box will use a camera and identification software to determine if a person is wearing a mask or not. Using this feature, it will be seamless to integrate with existing security measures set up to send the saved picture of people who are not compliant with the safety measures put in place to keep everyone safe.

The design specification document has a specific section for each of our subsystems, and for the product as a whole. Design specifications are defined below in order to complete the requirements outlined in the requirements document.

Safetech is made up of a group of 6 senior engineering students: Gurshaan Brar (Systems Engineering), Marshall Li (Systems Engineering), Michael Celio (Systems Engineering), Mohit Sharma (Systems Engineering), Nathaniel Huang (Electronics Engineering), Roy Zhong (Electronics Engineering). Our team has a good balance of hardware and software background, which will help us integrate our product into a well-functioning machine.

We thank you for taking the time to review our requirements document, and if any questions may arise while going through our document, please feel free to email our Chief Communications Officer, Mohit Sharma. He can address any questions and can be reached at msa197@sfu.ca.

Sincerely,

Nathaniel Huang

Nathaniel Huang
Chief Executive Officer
Safetech

Requirements Specification:

Smart Mask Box

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Issue Date:
July 11th 2021

Abstract

The Covid-19 pandemic has shown the world just how important it is to maintain public health and safety precautions to combat the effects and mitigate the spread of this deadly virus. Safetech strives to encourage safe and clean hygiene habits in public areas and make these habits a societal norm regardless of there being a pandemic or not. The Smart Mask Box by Safetech will not only provide individuals with easy access to masks and hand sanitizer but also real-time analytics compiled by the machine learning facial and object recognition software to the business owners and managerial personnel that will own the Smart Mask Box product. The Smart Mask Box aims to be seen as a necessary public health device that will be easily found in commonly crowded and high-foot traffic locations.

Change Log

Date	Revision	Notes
2021-07-11	1.0.0	Initial Release

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Glossary

Term	Definition
MCU	Microcontroller Unit
GPIO	General Purpose Input/Output
PCB	Printed Circuit Board
OpenCV	Open-Source Computer Vision Library
API	Application Programming Interface
LCD	Liquid Crystal Display
AWS	Amazon Web Services

1. Introduction

1.1 Scope

This document is a breakdown of each subsystem within the Smart Mask Box and the required design specifications that correspond to them. Also provided is a test document for each subsystem and an overall system level functional test plan.

1.2 Intended Audience

The intended audience of this document is Safetech's design team, along with Dr. Craig Scratchley, Dr. Andrew Rawicz, Srishti Yadav, and Timothy Yu.

1.3 Design Classification

The design specifications in this document will follow the following format:

Des {section}.{Subsection}.{Requirement Number} - {Stage of Development}

This will allow us to easily reference and distinguish certain aspects of our project later on in development.

Stages of development can be broken up into three main categories:

Stage of Development	Shorthand
Proof of Concept	PC
Prototype	PT
Final Product	FP

Table 1: Development Stages

When referring to the stages of development, the proof of concept requirements are the ones that must be met by the end of ENSC 405W. The prototype requirements of our product are the ones that we must achieve by the end of ENSC 440. The final product stage requirements are for once our product goes into full scale production.

2. General Design

The Smart Mask Box is a complex device that provides further usage beyond the functionality housed in the Smart Mask Box itself. Not only does the Smart Mask Box offer the ability to purchase and receive masks and sanitize hands, it also comes with an associated mobile application that provides its own set of features, not intended for the Smart Mask Box user, but rather the Smart Mask Box owner. Features and functionalities associated with the mobile application include, access to comprehensive analytical information regarding statistics on number of users with or without masks and number of customers who choose to buy masks. Furthermore, the mobile application provides the owner with real-time information and surveillance on individuals passing or entering their respective business.

2.1 System Design Specifications:

As mentioned previously, the Smart Mask Box is not simply just a mask dispenser, rather it is a smart device that is composed of various sub-components to facilitate its wide range of functionality.

The Smart Mask Box system will house a microcontroller which will be responsible for most of the computation involved with our Smart Mask Box embedded system. Likewise, the microcontroller will be connected to a camera unit, external speaker system(s), LCD display, a power source and the mask dispensensing mechanism consisting of stepper motors.

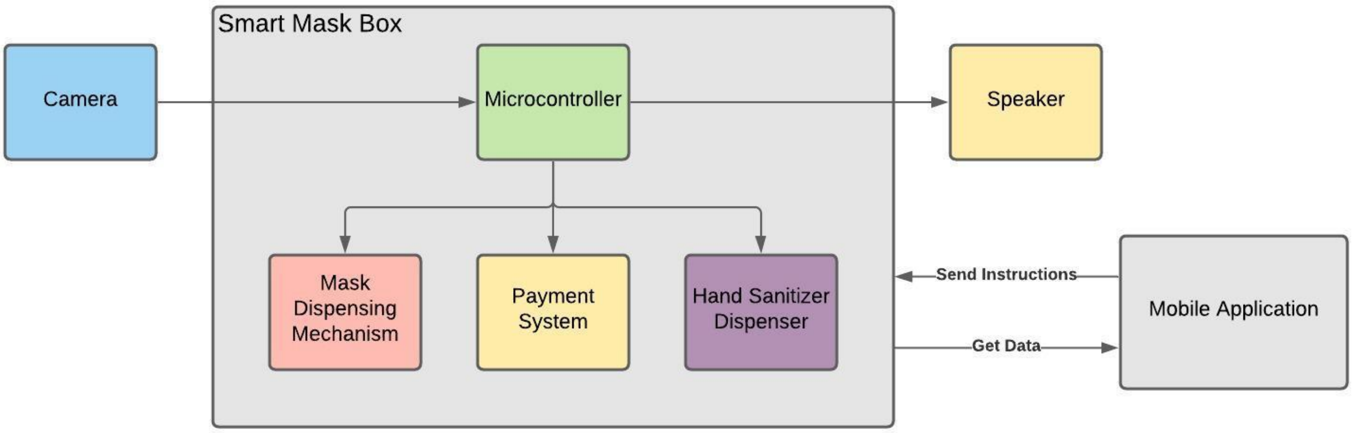

Figure 1: Block Diagram of the Smart Mask Box System

Figure 1 above, depicts the overall system and the subcomponents that our Smart Mask Box product is composed of. The microcontroller is associated with almost every subcomponent of the Smart Mask Box. The camera unit will be connected to the microcontroller and will be feeding it real-time data. The speaker unit(s) are an external component of the device. The implication of this is that the mask Box device will not come installed with an internal speaker, rather, it will have the ability to easily connect to pre-existing speakers on location and would be controlled via the microcontroller. The microcontroller will also be actively in charge of the mask dispensing mechanism, payment system, and the hand sanitizer dispenser. These three components will function independently of the camera and speaker unit.

The Smart Mask Box mobile application will be able to communicate with the box, more specifically the microcontroller. The application will be able to access and receive data from the camera unit and the mask dispensing mechanism while also being able to send certain functional instructions. These instructions will include setting the purchase amount for a single mask and configurability for the speaker unit output. Indeed, this Smart Mask Box system has been designed to be as touchless as possible to promote this product's underlying goal, which is public health and hygiene, through the limitation of transmission of Covid-19. A touchless payment system and motion detecting hand sanitizer dispenser will help facilitate this design. Design specifications needed for the Smart Mask Box system to fully function as its intended use are summarized and shown below in Table 1.

Specification ID	Specification Description	Requirement Reference ID
Des 2.1.1 - PC	System subcomponent will be a microcontroller responsible for most functions of the Smart Mask Box.	Req 2.1.1 - PC
Des 2.1.2 - PC	System subcomponent will be the camera unit for perceiving and collecting visual data.	Req 2.1.1 - PC Req 2.1.2 - PC
Des 2.1.3 - PC	A subcomponent of the system will be a speaker.	Req 2.1.1 - PC Req 2.1.2 - PC
Des 2.1.4 - PC	System subcomponent will be the mask dispenser mechanism.	Req 2.1.1 - PC Req 2.1.4 - PC
Des 2.1.5 - PT	The system will contain a payment system that is directly associated with the mask dispensing mechanism.	Req 2.1.3 - PT
Des 2.1.6 - PT	System subcomponent will be a touchless hand sanitizer dispenser.	Req 2.1.1 - PC Req 2.3.3 - PT
Des 2.1.7 - PT	System subcomponent will be the Smart Mask Box mobile application.	Req 2.1.6 - PT

Table 2: System Design Specifications

Indeed, the system design specifications shown in table 1 specify the overall functionality of the Smart Mask Box system.

2.2 Functional Design Specifications:

The primary functions of the Smart Mask Box are as follows:

1. Mask Detection and facial recognition capabilities.
2. Dispensing masks.
3. Ability to handle payment options (Interac, credit card, tap).
4. Hand sanitizer dispensing capabilities.
5. Mobile Application

The design specifications regarding the mask detection and facial recognition as well as the mobile application capabilities of our system will be discussed in the software section of this document.

One of the Smart Mask Box's primary functionalities is the ability to provide masks to users. Therefore, it is key to implement a mask dispensing mechanism that not only facilitates this function but does so flawlessly and quickly. Taking inspiration from printers and their paper dispensing mechanism, the Smart Mask Box will incorporate a mechanism with a similar design as it checks most boxes with respect to the intended functionality of the device.

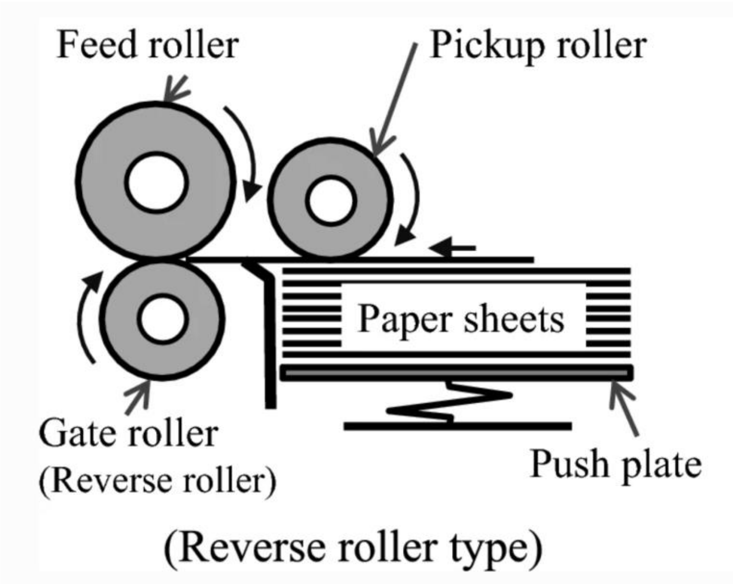

Figure 2: Pressure-Type Sheet Separation Mechanism

As seen in figure 2, the main principles used by a printer paper dispensing mechanism will be applied to the Smart Mask Box mask dispensing mechanism with a few variations. In the above reverse roller paper separation mechanism, the relationship between the various friction forces of this mechanism are the key factors in maintaining the correct functionality and facilitating the paper separation function of this mechanism [1]. The coefficient of friction between the paper sheets (μ_{paper}), the coefficient of friction between the feed roller and the paper sheets ($\mu_{Feed-Paper}$) and the coefficient of friction between the gate or reverse roller and the paper sheets ($\mu_{Reverse-Paper}$) have a unique and specific relationship that facilitates separation and production of the individual sheet of paper [1].

The unique relationship of these coefficients of friction is shown in the relation below:

$$\mu_{Feed-Paper} > \mu_{Reverse-Paper} > \mu_{Paper} \quad \text{Eq. (1)}$$

Looking at the relation above it is shown that $\mu_{Feed-Paper}$must me larger than $\mu_{Reverse-Paper}$, and both coefficients must be larger than μ_{paper}. This is necessary since the feed roller must have a large enough force to overpower the friction between each sheet of paper. If this requirement is not met, then the friction between each paper will overpower the feed roller and the mechanism will not be able to separate the sheets and will result in a misfeed [1]. Likewise, the feed roller force must also be larger than the gate/reverse roller force of friction. This relation is necessary because, if not met, the gate roller will not allow the feed roller to pull and produce a single sheet of paper and instead the reverse roller will push back and keep the paper stack on the push plate. Instead, the force from the reverse roller must play a specific role of maintaining balance, meaning that the force generated by the reverse roller on the paper sheet must be less than that of the feed roller but greater than that of the force between each paper sheet [1]. As the feed roller and pickup roller pulls the top sheet of paper, the reverse roller is meant to "hold back" any extra piece of paper on the bottom coming through the feed as well.

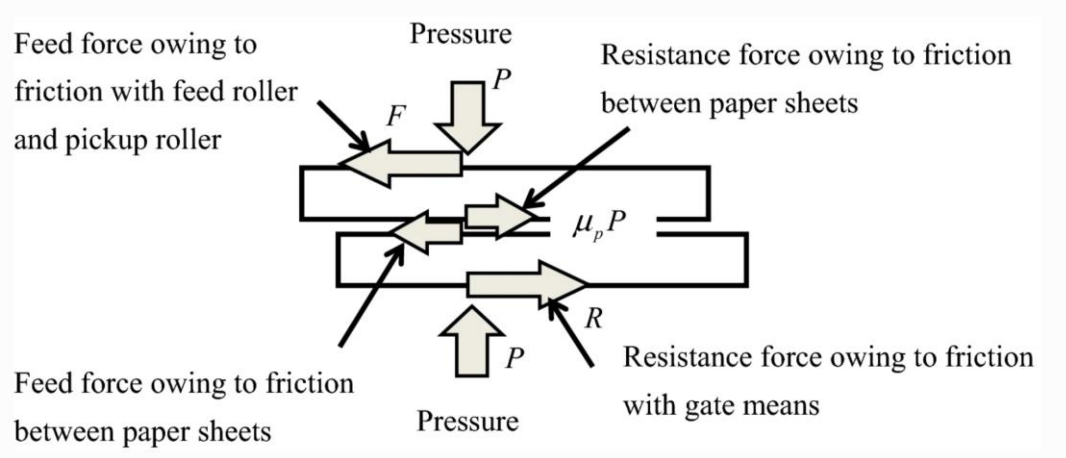

Figure 3: Forces Acting on Sheets of Paper in the Mechanism [1]

The overall representation of the applied forces on the sheets of paper in this mechanism is shown below in Figure 3.

Applying these same principles to a stack of masks rather than sheets of paper, this mechanism will perform the same function in separating and feeding masks.

Figure 4: Single-user Masks

Considering the single-use stack of masks shown above in Figure 4, these types of masks are a viable option of masks that will be handled by the Smart Mask Box, particularly its Mask dispensing mechanism. These masks are made primarily of paper and plastic, however, due to their uneven surface and rough surface, the paper mechanism above will need to be slightly changed to be able to handle this product.

Referring back to figure 2, the stack of paper sheets will be replaced with a stack of masks on the push plate. This change of product comes along with another change, namely, The force required to facilitate sliding one mask against another is much higher than the force required to slide one sheet of paper with another. This is a significant yet easily solvable hurdle. As long as the coefficient of friction relation of the paper-separating mechanism shown above is maintained as true, the mechanism will work on a stack of masks as well. In the case of the Smart Mask Box, the relation above (Eq (1)) will be changed slightly to the relation shown below:

$$\mu_{Feed-Mask} > \mu_{Reverse-Mask} > \mu_{Mask} \quad \text{Eq. (2)}$$

Alternatively, instead of using the masks shown above in figure 4, we also have an option of using individually sealed plastic wrapped masks as shown in figure 5 below.

Figure 5: Individually Plastic Wrapped Face Masks

There are more than a few benefits of using these masks shown above in figure 5 as opposed to the masks shown in figure 4. The masks shown in figure 5 are individually wrapped and therefore will be a much more sanitary option when compared to the other open and non-wrapped masks. Furthermore, the plastic wrapping on these masks will prove to be much less prone to friction compared to the previously mentioned masks. The implication of this material change is that the coefficients of friction may not need to be extremely high for the mechanism to function correctly using these plastic wrapped masks.

Roller Material

Looking further into the masks shown in Figure 5 that are wrapped with plastic, particularly polypropylene, details regarding the coefficient of friction of this material are shown below [24]:

Static coefficient of friction for polypropylene against polypropylene (dry): 0.76
Dynamic coefficient of friction for polypropylene against polypropylene (dry): 0.44

Static coefficient of friction for plastic against metal (dry) [23]: 0.25 - 0.4
Dynamic coefficient of friction for plastic against metal (dry) [23]: 0.1 - 0.3

Considering rubber as a material that is commonly known to have a larger coefficient of friction, the details regarding its coefficient of friction are shown below:

Static coefficient of friction for rubber against rubber (dry): 1.16
Dynamic coefficient of friction for rubber against rubber (dry): N/A

Static coefficient of friction for rubber against metal (dry) [23]: 1
Dynamic coefficient of friction for rubber against metal (dry) [23]: 0.5

Analyzing the properties of rubber and plastic shown above, particularly the coefficients of frictions, it is clear that rubber is a material that has a coefficient of friction much higher than that of plastic (polypropylene). Therefore, the material that will be used on the feed roller and pickup rollers of the Mask dispensing mechanism will most likely be rubber since these rollers will need to have the greatest coefficients of friction in the mechanism.

Regardless of the type of masks chosen to use in the Smart Mask Box, the same principles of the paper separating mechanism apply to these masks stacks albeit considering overall lower coefficients of friction regarding the plastic wrapped masks and much higher coefficients of friction regarding the non-wrapped masks, while maintaining the relationship shown above in Eq. 2.

Mask Capacity Within the Mechanism

To determine the optimal number of masks that the mechanism and hence the Smart Mask Box should hold will be determined through conducting an observational study. The overall process of this observational study will be to observe at least 3 different stores for the frequency of shoppers that they receive throughout a normal 8-hour workday. The next observation will be to determine approximately how many customers are wearing a mask already and how many are not, at the time of entering the particular business. This aspect of the study may be difficult to conduct by simply observing, hence, a consultation with the business' security or management may be required to determine how many customers have they come across that have needed to be prompted to wear a mask. These two observations may give us a general idea of how many masks the Smart Mask Box should be able to hold as to minimize restocking times.

As of now, without having done this observational study, we may consider a theoretical example. Considering a super centre such as Walmart may receive up to 11 000 shoppers per day and postulating that approximately a maximum of 10% of these customers are not wearing a mask at the time of entering a store, we can conduct simple calculations to narrow down how many masks may be needed in a single day. The calculations are as follows:

$$11000_{Shoppers/day} \times 0.1_{un-masked-shoppers} = 1100_{Shoppers/day}$$

The calculation above shows how many shoppers can potentially not be wearing a mask at a super center such as Walmart at any given day, which is 1100 shoppers. This implies that a single Smart Mask Box must be required to house at least 1100 masks, however this is unrealistic as that many masks will be extremely difficult to house in a single 30cm by 30 cm chassis. Instead, bearing in mind that Walmart is a “mega” store, it is reasonable to assume that they may have multiple entrances into the store, as well as, be able to own more than one Smart Mask Box to cover more ground. With this detail in mind, the number of 1100 un-masked shoppers can be divided by a factor of 3. This is done by assuming that a “mega” store such as Walmart may have at least two entrances with the main entrance having two Smart Mask Boxes and the secondary entrance having one. Calculations with this new implication are shown below:

$$1100_{Shoppers/day} \div 3_{Smart\ Mask\ Boxes} = 366_{(Shoppers/day)/(Smart\ Mask\ Boxes)}$$

The calculation above now implies that each Smart Mask Box should at most contain 350 masks to be able to cover at least 350 shoppers per day. This number of masks is both reasonable and realistic for the Smart Mask Box to be versatile and be able to handle multiple types of business both big and small.

Design specifications of the mask dispensing mechanism are shown below in Table 2.

Specification ID	Specification Description	Requirement Reference ID
Des 2.1.8 - FP	Mask dispenser mechanism will have a footprint of 18cm x 18cm x 10cm.	Req 2.3.1 - PC
Des 2.1.9 - FP	Dimensions of the push-plate will be 14 cm by 12cm to allow mask placement.	Req 2.1.7 - FP
Des 2.1.10 - PC	Feed-Roller will have a higher coefficient of friction than the coefficient of friction between masks.	Req 2.1.4 - PC
Des 2.1.11 - PC	Reverse-roller will have a coefficient of friction less than that of the feed-rollers but greater than between the masks.	Req 2.1.4 - PC
Des 2.1.12 - PT	Push plate will apply a constant force upwards using a spring attached underneath.	Req 2.1.7 - FP Req 2.1.4 - FP
Des 2.1.13 - PT	The Reverse Roller will apply a constant force upwards using a spring.	Req 2.1.7 - FP Req 2.1.4 - FP
Des 2.1.14 - PT	Feed roller and pickup roller will rotate in the opposite direction of the reverse roller.	Req 2.1.7 - FP Req 2.1.4 - FP
Des 2.1.15 - FP	The Mask dispenser mechanism will weigh a total of 1.8kg excluding the weight of masks.	Req 2.3.4 - FP

Table 3: Mask Dispensing Mechanism Design Specifications

The payment system required in the Smart Mask Box needs to meet certain requirements, specifically, it being a nearly touchless system and very compact as well. The product that will seamlessly integrate into the Smart Mask Box while also fulfilling the requirements set by our product is the Square Reader shown below in figure 6.

Figure 6: Square Reader Payment System

The Square Reader is a payment system offered by the company Square. This compact payment option provides a wide range of contactless payment solutions. These payment options include contactless credit card tapping, Apple and Google pay, as well as a card chip reader [2]. The Square Reader also has the benefit of extremely fast payment processing times, taking no more than a few seconds to process a single payment. It also provides wireless Bluetooth connectivity as well as a wide range of compatibility with various smartphone operating systems. Design specifications of the Square Reader payment system that will be integrated with the Smart Mask Box is shown in table 3 below.

Specification ID	Specification Description	Requirement Reference ID
Des 2.1.16 - PT	The Square Reader will be compatible with iOS 10.0 or greater and Android 5.0 or later.	Req 2.1.3 - PT
Des 2.1.17 - PT	The Square Reader will provide wireless connectivity through Bluetooth LE.	Req 2.2.3 - PT
Des 2.1.18 - PT	The Square Reader will accept payments from chipped cards, Apple pay, Google pay, Samsung pay, and contactless cards.	Req 2.1.3 - PT Req 2.1.8 - PT Req 2.3.3 - PT
Des 2.1.19 - PT	The Square Reader will be made of mostly moulded plastic.	N/A
Des 2.1.20 - PT	The Square reader will be 56 g in weight.	Req 2.3.4 - FP
Des 2.1.21 - PT	The Square Reader will have the dimensions 6.6cm x 6.6cm x 1cm.	N/A
Des 2.1.22 - PT	The Square reader will have come with a USB-A to Micro-USB cable.	N/A
Des 2.1.23 - PT	The Square reader will have a Micro-USB port.	N/A

Table 4: Square Reader Payment System Design Specifications

The design specifications of the hand sanitizer system, the final primary function of the Smart Mask Box, will be discussed in this section. The hand sanitizer dispenser is a key component to the Smart Mask Box and must meet a few requirements for it to be a viable feature in our product. These requirements include, contactless hand sanitizer dispensing, the option to connect the mechanism to a power source rather than use batteries, and it needs to have relatively compact dimensions to fit within the chassis of the Smart Mask Box.

The hand sanitizer dispenser that was narrowed down and will be used in the Smart Mask box is the Automatic Hand Sanitizer Dispenser from the company Vancouver Hand Sanitizer.

Figure 7: The Automatic Hand Sanitizer Dispenser from Vancouver Hand Sanitizer

The dispenser shown above in figure 7 is the ideal type of dispenser that the Smart Mask Box requires. This dispenser includes a motion sensor that is used to recognize a hand and will dispense hand sanitizer into the palm in the form of a spray or drip [3]. This feature maintains the original Smart Mask Box requirement of being a touchless product that prevents the spread of germs.

Likewise, this dispenser meets the most restrictive of requirements which is that the size and dimensions must be small enough to fit within the dedicated compartment in the Smart Mask Box. Indeed, the dimensions of the Automatic Hand Sanitizer Dispenser are 26 cm in length, 12.5 cm in width, and 11 cm in height, being the perfect size to fit within our product [3].

The dispenser also provides flexibility in its power by supporting up to 6 Volts and being powered via a DC power source or four C batteries [3].

Finally, another beneficial feature of this dispenser is that its sanitizer reservoir is large and has a maximum capacity of 1500ml which is also easily refillable by removing the reservoir from the back of the dispenser [3]. Furthermore, the dispenser offers many options of mountain such as, an adhesive tape backing that can stick to a flat surface or small mounting holes that can be used to hang the dispenser similar to a picture frame [3].

The design specifications of this Automatic Hand Sanitizer Dispenser are shown in table 4 below.

Specification ID	Specification Description	Requirement Reference ID
Des 2.1.23 - PT	The dispenser will have an automatic sensor to detect a hand.	Req 2.3.3 - PT
Des 2.1.24 - PT	The dispenser sanitizer reservoir will have a capacity of 1500ml.	N/A
Des 2.1.25 - PT	The dispenser reservoir will be removable for refilling.	N/A
Des 2.1.26 - PT	The dispenser will support 6 volts, 1 A and a DC power supply.	N/A
Des 2.1.27 - PT	The dispenser chassis will be made of ABS plastic.	N/A

Table 5: Hand Sanitizer Design Specifications

2.3 Physical Design Specifications:

The physical design with regards to looks and durability is an integral component to the Smart Mask Box. The Smart Mask Box must maintain an appealing aesthetic as this device will be placed in malls and outside businesses. Business owners will be much less inclined to adopt such a device if the product does not seamlessly integrate into their business environment and desired ambience. Likewise, mall goers must also feel a certain curiosity and attraction to the product as opposed to avoiding it due to being intimidated by a hulking, ugly, or confusing design.

Maintaining an attractive design is important, however, just as important, if not slightly more, is to also ensure durability and sustainability of the device to establish a sense of reliability in both the user and owner of the Smart Mask Box.

Indeed, the Smart Mask Box strives to portray an attractive design while also being made of sturdy materials. Various views of the Solidworks model of the Smart Mask Box are shown below.

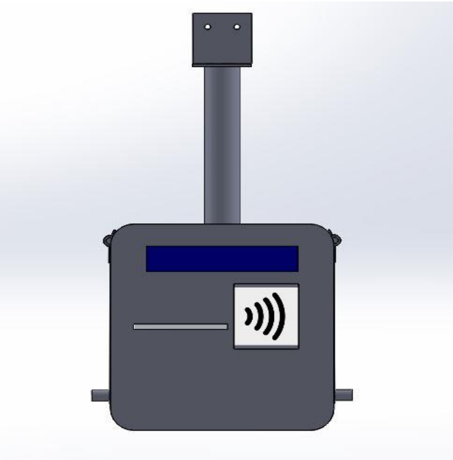

Figure 8: Front View of the Smart Mask Box SolidWorks Model

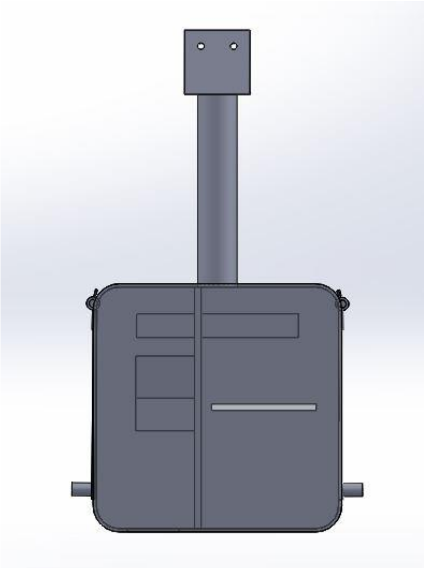

Figure 9: Translucent Rear-View

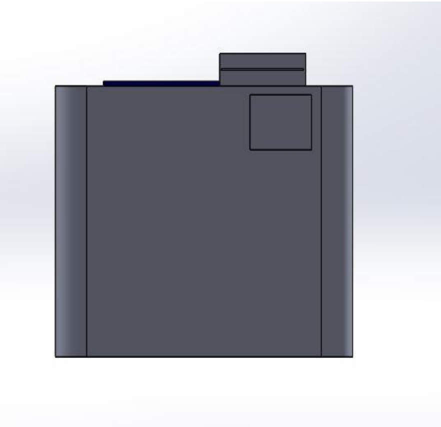

Figure 10: Bottom View

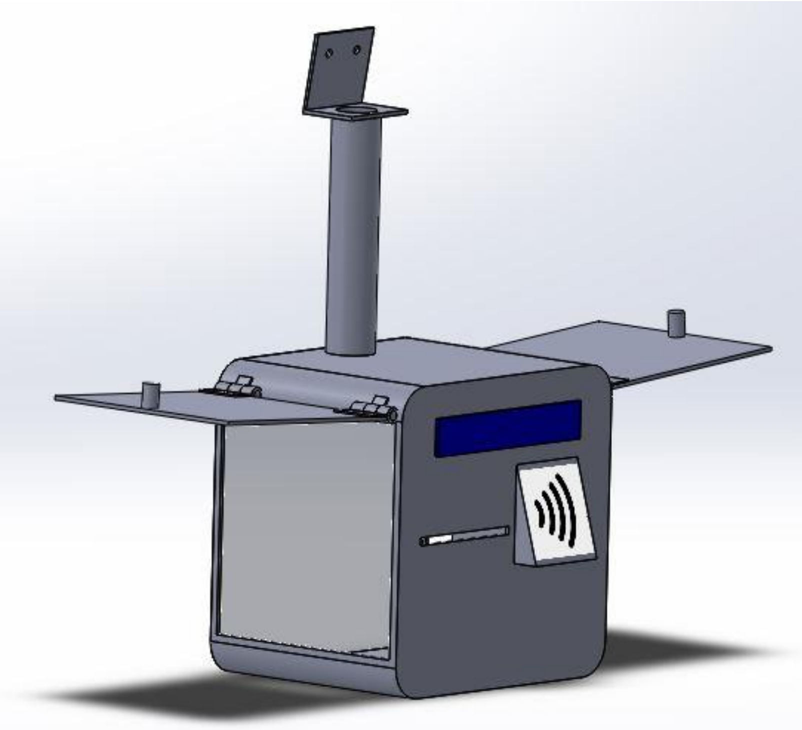

Figure 11: Isometric View With Open Side Doors of the Solidworks Model

The box portion of the Smart Mask Box is a 30 cm by 30 cm cube. This size was chosen to allow for easy storage of all internal components of the box, namely, the mask dispenser mechanism, the hand sanitizer dispenser, mask storage area, and the microcontroller. This size is large enough to account for internal components but also small enough to be portable and not a lumbering distraction such as a vending machine may be. The main box also has rounded edges along the sides which is primarily for aesthetic purposes but also to minimize sharp edges that have the potential to cause harm to aloof individuals.

As seen in figure 11 above, the main chassis of the Smart Mask Box has side doors that were necessary to allow Smart Mask Box owners easy access into the two main compartments of the box, specifically, the Mask dispenser mechanism to allow the restocking of the masks and the sanitizer dispenser section to allow the refilling of the sanitizer reservoir. The door range of motion is 180 degrees to allow a clear open view into the internals of the Smart Mask Box.

Analyzing the chassis further, particularly the front view shown in in Figure 8, it is clear that the Smart Mask Box design is meant to be minimalist with barely any user input areas and only one LCD screen that will be used to prompt the user to pay for their mask as well as display the price of each mask. Figure 8 and figure 11 also show a wedge-shaped protrusion from the chassis with the credit card tap symbol on it. This protrusion is the location where the previously mentioned Square Reader will be mounted that will facilitate the payment process of our box. Lastly, located to the left of the Square Reader is a thin slit that is 16cm in length and 1 cm in width. This slit on the face of the Smart Mask Box is the mouth of the mask dispenser mechanism and is where the user will be collecting the dispensed mask.

Figure 10 above shows the bottom view of the Smart Mask Box. There is a small cut out on the top right of the chassis here and its purpose is to allow an opening for the hand sanitizer dispenser to dispense sanitizer appropriately.

Figure 9 above shows the rear-view of the Smart Mask Box. The backplate of this model was purposefully made translucent to show the internal area of the chassis, however, the physical product would instead have an opaque backplate. Looking within the chassis, a visible vertical divider is present, sectioning off two portions of the chassis. This divider is primarily present for internal structural support and internal mounting points for the mask dispenser mechanism and the hand sanitizer dispenser.

Moving away from the main chassis of the Smart Mask Box, one can notice a pole extension from the main chassis leading to a mounting point at its end. This pole and mounting point extension is a key and necessary component that attempts to overcome and solve certain issues regarding the camera module and the facial and mask recognition system. Initially, the Smart Mask Box was designed to be a fully contained, simple box unit, that included an internally housed camera module. As discussed previously, this camera module is responsible for collecting visual data for the facial recognition and mask detection software that this product uses. A significant issue with housing the camera internally in the box is that while a customer is using the box, the camera is highly prone to obstruction. While obstructed, the camera will not be able to collect visual data of its surroundings as it is meant to be doing so constantly. A redesign of the Smart Mask Box was required and the pole extension with a camera mount at its end was added. This pole solves the issue of obstruction by extending the camera 30 cm above the main chassis box. Since the chassis box is meant to be mounted at average height eye level, the pole extension will extend well above most individuals and be able to scan the area constantly and unobstructed. Furthermore, the pole is not just a solid rod but instead it is hollow through both its ends. The hollow pole allows the camera to connect to the microcontroller, which is housed within the main chassis, by running wiring through it.

The material used for the chassis of the Smart Mask Box will be aluminium. Taking inspiration from mailboxes, it is seen that aluminium is one of the more popular materials used in their construction [4]. Aluminium has many benefits such as its strong and durable nature while also being a lightweight material [4]. Furthermore, aluminium is much less prone to rusting compared to steel and other metals [4]. These key qualities of aluminium make it an ideal material for the Smart Mask Box. Apart from aluminium’s physical durability, it is also a very malleable metal that is able to bend at room temperature with enough force. Likewise, it is often used as sheet metal in many aspects of construction and is easily “welded by conventional methods” [5]. Aluminium is also a very commonly available and relatively affordable material which will help decrease manufacturing and production costs.

Aluminium is a durable material and can withstand physical pressure of the environment, however, it still does not solve issues related to water damage. To protect against water damage, the Smart Mask Box will be lined with a neoprene rubber foam seal strip as shown in figure 12 below.

Figure 12: Neoprene Rubber Foam Seal Strip

This neoprene rubber foam strip has an adhesive backing that will allow it to be applied to any joint or opening. In the case of the Smart Mask Box, this strip will be applied to the edge of the side doors as well as the joints of these doors specifically since those are the main areas that are prone to water damage. The neoprene strip will protect the Smart Mask Box against weather by being resistant to extreme fluctuations in weather temperatures, dust, water, and other debris that can be found outside [6].

The specific physical design specifications of the Smart Mask Box are compiled in table 6 below.

Specification ID	Specification Description	Requirement Reference ID
Des 2.1.28 - FP	The Smart Mask Box main Chassis will be a 30 cm by 30 cm box.	Req 2.3.1 - FP
Des 2.1.29 - PT	The Smart Mask Box will have side doors on each side of the box to allow access to the main mechanism of the box.	N/A
Des 2.1.30 - PT	The Smart Mask Box will have a 30 cm pole extension leading to a camera mount.	N/A
Des 2.1.31 - PT	The Smart Mask Box will have cut outs to facilitate the dispensing of the masks and sanitizer.	N/A
Des 2.1.32 - PT	The Smart Mask Box will be constructed of Aluminium sheet metal (~0.6mm thickness).	Req 2.3.2 - FP Req 2.3.4 - FP
Des 2.1.33 - FP	Major openings of the Smart Mask Box will be lined with neoprene rubber foam seal strips.	Req 2.3.6 - FP Req 2.3.7 - FP Req 2.3.8 - FP

Table 6: Smart Mask Box Design Specifications

3. Hardware Design Specification

Hardware design is one of the most important parts in our project, it integrates with the software design to perform all the functions of the Smart Mask Box.

3.1 Camera

For the mask detection system, a camera that can clearly show the face of the person passing by and distinguish if the person is wearing a mask or not are the first step for the system. The camera that we chose has to be able to operate in high and low light, as the sun will be brighter during some hours of the day. In order to compensate for this, the camera has to have dynamic range to capture the image correctly.

Another necessity that our camera needs is a wide angle lens, to ensure the entire entryway is visible and available to scan by our software. Without a wide angle lens, parts of the corridor would be missed, allowing people with no masks to enter from the sides. As this is a matter of public safety, our goal is to scan the entire entrance and identify people who may cause an issue while being in a public place.

Figure 13: KEYESTUDIO Fisheye wide-angle camera

The company KEYESTUDIO provides this fisheye wide-angle camera shown in figure 13. This camera is designed for the Raspberry Pi 3A/3B/4/4B board which is suitable for our system [7]. It required at least 120 degree angle of view to monitor all the people passing through the Smart Mask Box, and the Fisheye wide angle camera has 130 degree of view which perfectly satisfied our needs. With the photosensitivity of 5 Megapixels, the faces of people passing by are clearly being captured by our system.

Specification ID	Specification Description	Requirement Reference ID
Des 3.1.1 - PC	The camera will be 5 Megapixels.	Req 3.1.1 - PC
Des 3.1.2 - PT	The camera will have a 130 degree view.	Req 3.1.2 - PT
Des 3.1.3 - PC	The camera will have active focusing.	Req 3.1.3 - PC
Des 3.1.4 - PC	The Camera Parameters: CCD Size: 1/4 inch Aperture (F): 2.35 Focal Length: Adjustable	N/A
Des 3.1.5 - PT	The camera will have 4 Screw holes for mounting.	Req 3.1.5 - PT
Des 3.1.6 - PT	The camera will be powered with a 3.3V external power supply.	Req 3.1.6 - PT
Des 3.1.7 - PC	The camera size will be 25mm × 24mm.	N/A
Des 3.1.8 - PT	The camera will use a Photosensitive Chip OV5647.	N/A

Table 7: Camera Design Specifications

The camera supports 3.3V external power supply and the size is only 25mm x 24mm which helps us to lower down the final size of the Smart Mask Box.

Brand	KEYESTUDIO
Manufacturer	keyes
Part Number	SMP0079
Standing screen display size	4 Inches
Video capture resolution	1080p
Batteries included	No
batteries required	No
Wireless Standard	Infrared
Has auto-focus	No
Has Programmable Buttons	No
Manufacturer	keyes
Manufacturer reference	SMP0079
Product Dimensions	14.2 x 7.11 x 4.6 cm; 31.75 Grams
ASIN	B076MPL9P1

Table 8: Camera Technical Details

3.2 Microcontroller

The microcontroller is the core of the whole Face Mask system, it builds up all of the subsystems and connects the hardware components to the software systems. This includes our camera, speaker, LCD screen, and stepper motor.

The microcontroller we have chosen to use for our project is the Raspberry Pi 3B, because of the large memory space, high number of GPIOs, and wireless capabilities. The Raspberry Pi is also ideal for us because it supports HATs (Hardware Attached on Top), which we will be using for the motor driver. Below in figure 14, the layout of the MCU is shown.

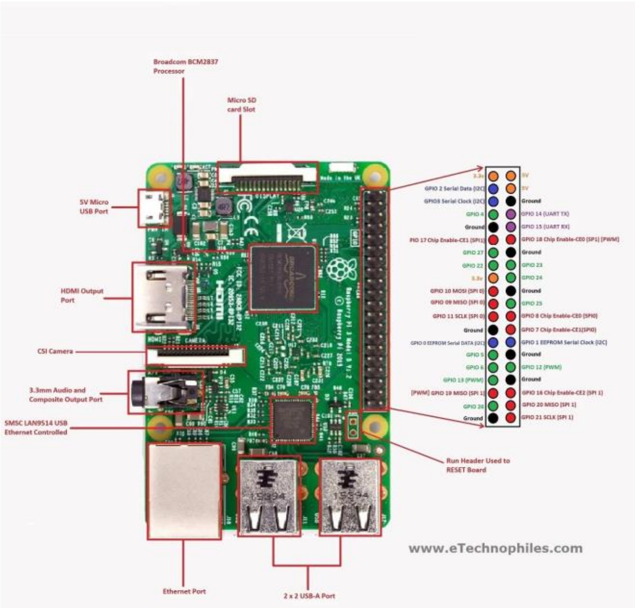

Figure 14: Raspberry Pi 3B board

The components such as camera and external power supply need a CSI camera port and USB port to be connected. Raspberry Pi 3B has all of these ports that allow our project to accept these plug-ins and perform more functionalities [8]. Raspberry Pi allows the addition of the motor driver board, so that the roller mechanism that transports the mask becomes feasible.

Specification ID	Specification Description	Requirement Reference ID
Des 3.2.1 - PC	The microcontroller will have the ability to add a motor driver board.	Req 3.2.1 - PC
Des 3.2.2 - PC	The microcontroller is able to be powered with the available DC power.	Req 3.2.2 - PC
Des 3.2.3 - PC	The microcontroller is programmable using python.	Req 3.2.3 - PC

Des 3.2.4 - PC	The microcontroller will be fitted with an ADC.	Req 3.2.4 - PC
Des 3.2.5 - PC	The microcontroller will have four USB connections.	Req 3.2.5 - PC

Table 9: Microcontroller Design Specifications

Specification Type	Values
Dimensions	11cm x 7cm x 3cm (L x W x H)
Weight	60g
Processor	Quad Core 1.2GHz Broadcom BCM2837 64bit CPU
Memory	1 GB RAM
Access	40-pin extended GPIO
Connectivity	BCM43438 wireless LAN and Bluetooth Low Energy (BLE)
Ports	4 USB 2 ports
Audio/Video	4 Pole stereo output and composite video port Full size HDMI CSI camera port for connecting a Raspberry Pi camera
Input Power	Upgraded switched Micro USB power source up to 2.5A

Table 10: Microcontroller Technical Details

3.3 Speakers

The purpose of the speaker system is to remind customers who passed the smart box whether they have a mask on or not. And guide the people who want to buy a mask to use our smart mask box. The speakers are an important way to interact with our customers, so that the experience of the speaker system is critical.

The noise level of a mall is around 60dB, so we need the speakers at least 80dB's speaker system to give a clear and loud enough guide to customers. And since the speaker's system will be mounted on top of a smart mask box, we need to use a speaker's with long enough wire to connect with microcontroller.

Figure 15:Mask Box Speaker [37]

Specification ID	Specification Description	Requirement Reference ID
Des 3.3.1 - PC	The speaker will have a maximum volume of 100dB.	Req 3.3.1 - FP
Des 3.3.2 - PT	The speaker's power output will be 3 Watt and impedance is 8 Ohms.	Req 3.3.2 - PT
Des 3.3.3 - PT	The speaker's wire length will be 420mm.	Req 3.3.3 - PT

Table 11: Speakers Design Specifications

Specification Type	Values
Dimensions	7 cm x 3.1 cm x 1.6 cm (L x W x H)
Weight	68 g
Power	3 W
Resistance	8 ohm

Table 12: Speaker Technical Details

3.4 LCD Screen

The LCD screen is the only screen and the only display aspect we have on our smart mask box. It's aim is to show messages and necessary information to our customers. The LCD screen will show the name of our product and welcome page when our product is in detection mode, and it will show price of each mask and buying guides when it is in buying mode.

To show the guides detailed, we need at least 2 rows with 12 characters per row. And need backlight in case the smart mask box is sitting in a bright environment, and the customers cannot see the words on the LCD screen clearly.

Figure 16: LCD Backlit Display Screen [38]

Specification ID	Specification Description	Requirement Reference ID
Des 3.4.1 - PT	The LCD is in a 16x2 matrix.	Req 3.4.1 - PT
Des 3.4.2 - PT	The LCD will display font in 5x8 dots.	Req 3.4.2 - PT Req 3.4.3 - PT
Des 3.4.3 - PT	The LCD will have blue LED backlight.	Req 3.4.4 - PT
Des 3.4.4 - PT	The LCD will use 5V ±0.5V%.	Req 3.4.5 - PT
Des 3.4.5 - PT	The LCD will support STN display mode.	N/A
Des 3.4.6 - PT	The LCD viewing direction is 6 O'Clock.	N/A
Des 3.4.7 - PT	The LCD input data has 4-Bits or 8-Bits interface available.	N/A
Des 3.4.8 - PT	The driving scheme for the LCD will be 1/16 Duty,1/5 Bias	N/A

Table 13: LCD Screen Design Specifications

Specification Type	Values
Dimensions	11.2 cm x 7.1 cm x 3.6 cm (L x W x H)
Weight	45.5 g
Voltage	5 V
Display	LCD Backlight 16 x 2 Display

Table 14: LCD Screen Technical Details

3.5 Power Supply

The power supply that we have chosen is the following one, because it is capable of powering all of our electronics with ease. The max current that will be supplied is 3A from this power supply. Using a power supply will remove the need for charging batteries, as that would be a disruptive task throughout the day.

Figure 17: Power Supply [39]

$$P_{total}(Supply) = V * I = 24V * 1A = 24W$$
$$P_{avg}(Raspberry\ Pi) = V * I = 5V * 0.260A = 1.3W$$
$$P_{avg}(Amplifier) = V * I = 5V * 0.7A = 3.5W$$
$$P_{avg}(LCD) = V * I = 5V * 21mA = 105mW$$
$$P_{avg}(Stepper\ Motor\ Driver) = V * I = 5V * \ 0.7A = 3.5W$$
$$P_{avg}(Dispenser) = V * I = 6V * 0.5A = 3W$$
$$P_{total}(Load) = 11.5W$$
$$P_{total}(Load) < P_{total}(Supply)$$

Specification ID	Specification Description	Requirement Reference ID
Des 3.5.1 - PC	The Power Supply will supply up to 24V.	Req 5.1.1-PC
Des 3.5.2 - PC	The Power Supply will supply up to 1A.	Req 5.1.1-PC
Des 3.5.2 - PC	The Power Supply input voltage will be 100-240VAC 50/60Hz.	Req 5.1.1 - PC
Des 3.5.3 - FP	The Power Supply will be 1.5m in length.	Req 5.1.2 - FP

Table 15: Power Supply Design Specifications

3.6 Stepper Motor Driver

The stepper motor driver is used to control the roller motors. It allows them to roll with controlled motions to complete the desired action we need to dispense a mask. With this we are able to control the roller spinning motion in either direction and the stops by controlling the logic input voltage. The stepper motor drive can also control the motor speed and the motor torque. These necessary functions will be implemented to successfully dispense the masks inside the box to the end user.

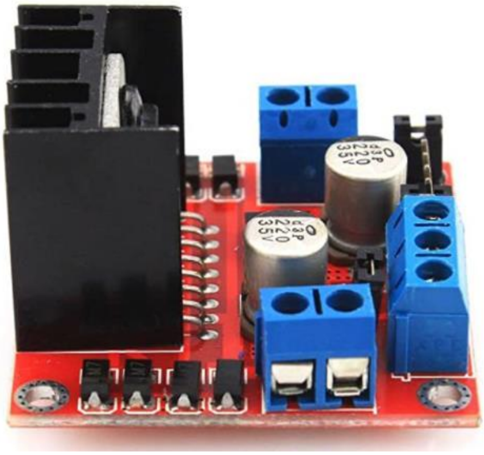

Figure 18: Stepper Motor Driver [40]

With the use of the stepper motor driver and control from the microprocessor will need to begin testing on the correct inputs needed to obtain the correct dispensation of our masks. The driver will control the motors for specified times to dispense a single mask. This process will need to be tested and thoroughly gone through.

Specification ID	Specification Description	Requirement Reference ID
Des 3.6.1 - PT	The stepper motor drive will use 5v/0mA-36mA as Logic input	N/A
Des 3.6.2 - PT	The stepper motor drive will use 5V-35V/ 2A(MAX single bridge) as drive input	N/A
Des 3.6.3 - PT	The stepper motor drive will have maximum power of 25W	N/A

Table 16: Stepper Motor Design Specifications

Technical Details	Values
Dimensions	4.3 cm x 4.3 cm x 2.7 cm
Weight	40 g
Logic Voltage	5 V
Logic Current	0 mA - 36 mA
Drive Voltage	5 V - 35 V
Drive Current	2 A
Max Power	25 W

Table 17: Stepper Motor Drive Technical Details

3.7 Stepper Motor

The stepper motors used are an important component of the separation mechanism system. The stepper motor will connect with the rollers and drive them. They will be controlled through the stepper motor driver. These motors will need to overcome the frictions used between the masks to pull them out of the stack and out to the consumer. This is an easily accomplished task. Each of the motors will be coordinated through the stepper motor driver and will work in unison to achieve the goal.

Figure 19: Stepper Motor Unit [41]

Specification ID	Specification Description	Requirement Reference ID
Des 3.7.1 - PC	The stepper motor with gear reduction, the reduction rate is 1/64.	N/A
Des 3.7.2 - PC	The stepper motor has 4-Phase 5-Wire.	N/A
Des3.7.3 - PC	The motor can support 5V DC as power source	N/A

Table 18: Stepper Motor Design Specifications

Technical Details	Values
Dimensions	4.3 cm x 3 cm x 3cm (L x W x H)
Weight	34 g
Voltage	5 V
Step Angle	1/64 or 5.625 degrees

Table 19: Stepper Motor Drive Technical Details

3.8 Audio Amplifier Board

This audio amplifier will be used to power the speakers our Smart Mask Box will be using. The reason we chose this box is because it uses a class D amplifier, which has an efficiency of 85%. This will allow us to choose a smaller power supply to power this board, and not compromise the output we get from the speakers.

Figure 20: Audio Amplifier Board [42]

Specification ID	Specification Description	Requirement Reference ID
Des 3.8.1 - PT	The audio amplifier will have an output of 3W per channel.	Req 3.3.2 - PT
Des 3.8.2 - PT	The audio amplifier will have an operating Voltage of 2.5-5VDC.	Req 3.3.2 - PT
Des 3.8.3 - PT	The audio amplifier will have an efficiency of 85%.	Req 3.3.2 - PT
Des 3.8.4 - PT	The audio amplifier will be able to drive an 8 Ohm speaker.	Req 3.3.2 - PT

Table 20: Audio Amplifier Design Specifications

4. Software Design Specifications

4.1 Facial Recognition

The Smart Mask Box will use the camera module mentioned above in combination with an open-source python machine learning software system built using the framework of OpenCV, Caffe-based face detector, Keras, TensorFlow, and MobileNetV2 [15]. This program is compatible with microcontrollers such as the Raspberry Pi 3B mentioned above that we will be using as our microcontroller of choice. This open-source software also provides an exhaustive data set which includes 2165 images of mask wearing individuals and 1930 images of non-mask wearing individuals [15].

This program is capable of mask detection in still images however it is also capable of mask detection in a real-time video feed, which is the function that the Smart Mask Box will be using this software for. An example of this particular software at work is shown below in figure 21.

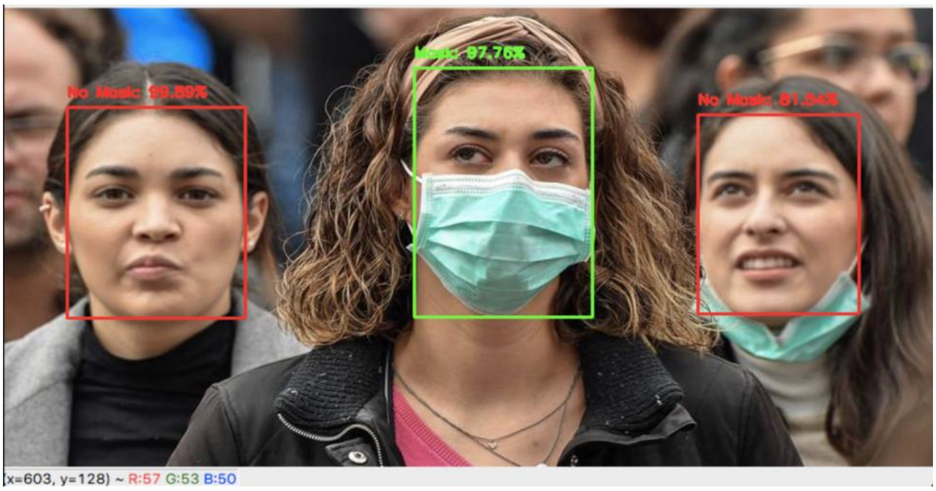

Figure 21: Face Mask Detection Software Applied to a Still Image

As previously mentioned this program makes use of Open Source Computer Vision Library (OpenCV). OpenCV is an open source computer vision and machine learning software library [16]. OpenCV has countless algorithms that are capable of detecting and recognizing faces and objects [16].

Likewise, the Caffe-based face detector used in the framework of this program is a deep learning framework that heavily considers speed and modularity as its key qualities [17].

Keras is an easy to use and easy to understand Application Programming Interface (API) designed for humans [18]. It is one of the more popularly used deep learning frameworks and is built on top of TensorFlow 2.0 [18]. Likewise, TensorFlow is an "end-to-end open source platform for machine learning" [19].

The design specifications of the facial recognition software is summarized in the table below.

Specification ID	Specification Description	Requirement Reference ID
Des 4.1.1 - PC	The face mask detection software will use OpenCV, Caffe, keras/TensorFlow and MobileNetV2 to facilitate Face Mask detection.	Req 2.2.2 - PC Req 4.2.1 - PT Req 4.2.2 - PC Req 4.2.3 -PT
Des 4.1.2 - PC	The face mask detection software will be able to detect multiple faces in a real-time.	Req 4.2.5 - PT

Des 4.1.3 - PC	The face mask detection software will be able to show the result of what the software detects and with what percentage of accuracy atop of the image.	Req 4.2.4 - PT
Des 4.1.4 - PC	The software will be able to run on embedded systems such as Raspberry Pi 3B	Req 4.1.2 - PC

Table 21: Facial Recognition Design Specifications

4.2 Front End: User Application

For the front end, we decided to use Google Flutter to design the mobile application. Flutter is an open-source platform that allows us to create both Android and IOS applications by the same code. Flutter is a comprehensive SDK for developing mobile applications, not simply a framework. It comes with many things we will need to build a user interface.

Specification ID	Specification Description	Requirement Reference ID
Des 4.2.1 - PT	The mobile application will be able to run on iOS 11.0 or above and Android 10.0 or above.	Req 4.3.7 - PT Req 4.4.2 - PT
Des 4.2.2 - PT	The mobile application can send API request to the server	Req 4.3.1 - PC Req 4.3.2 - PT
Des 4.2.3 - PT	The mobile application will be able to check the number of remaining masks.	Req 4.3.3 - PT
Des 4.2.4 - PT	The mobile application will be able to set the price of the Mask.	Req 4.3.2 - PT

Table 22: User Application Design Specifications

4.3 Back End Server

For the backend, we decided to use Node.js. A node web server will be hosted on a PC or AWS.

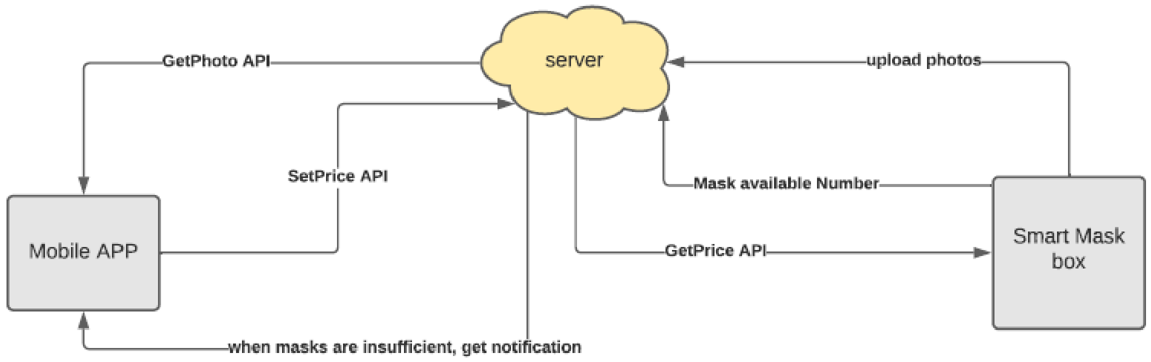

Figure 22: Block diagram of the interaction of subcomponents of the Smart Mask Box with the server.

Specification ID	Specification Description	Requirement Reference ID
Des 4.3.1 - PT	The system will use a web server to communicate with the mobile application using API requests.	Req 4.1.1 - PC Req 4.3.1 - PC Req 4.3.2 - PT Req 4.3.6 - FP
Des 4.3.2 - PT	The web server will be hosted on a pc or AWS.	Req 4.1.1 - PC Req 4.3.1 - PC Req 4.3.2 - PT Req 4.3.6 - FP
Des 4.3.3 - PT	The web server will connect to the database to store and fetch data.	Req 4.1.1 - PC Req 4.3.1 - PC Req 4.3.2 - PT Req 4.3.6 - FP

Table 23: Back End Server Design Specifications

5. Conclusion

Safetech is paving the way in keeping the community safe with the on-going pandemic of Covid-19. For our product, the Smart Mask Box, we have a number of different systems which are all coordinated to work together to make the product work the way it is supposed to. The first is the hardware side, where we have the camera and speaker, whose main function is for identification of people who may be potential threats for public safety. The rollers make up the system which dispenses the masks, where the rollers must dispense exactly one mask. To control all of our hardware, Safetech has chosen to use a Raspberry Pi because of the excess number of GPIOs that are available on the PCB to connect to our hardware. The next system we have is the software subsystem, which is used to integrate the unit and the mobile phone application together, so the administration can have full control of the unit. Finally, the electrical subsystem controls all the power being delivered to the unit and all its peripherals.

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Appendix A: Test Plan

A.1 Introduction

Test Purpose

The purpose of the test plan is for proof of concept to demonstrate that all design specifications and requirements are met.

Test Coverage

The test plan is a full comprehensive test that will cover all the functionality of the Smart Mask Box. Each section of the product will be tested independently from each other, starting with software, then hardware, finally followed by mechanical. After all of that, a system functionality test will be conducted to verify the product works the way it is supposed to.

Test Methods

The test methods will rely on mostly visual inspection. Verifying the Smart Mask Box meets the design requirement.

Test Responsibilities

All testing must be done by a verified Safetech member and calibrated equipment must be used.

A.2 Software Testing

Facial Recognition Test	Date:
Test Description: The software must be able to recognize multiple faces with and without masks.	
Expected Outcome: The app will state the device is connected.	
Actual Outcome/Comments:	
☐Pass	☐Fail

App Communication Test	Date:
Test Description: The Smart Mask Box will connect to the mobile app.	
Expected Outcome: The app will state the device is connected.	
Actual Outcome/Comments:	
☐Pass	☐Fail

Server Communication Test	Date:
Test Description: The Smart Mask Box will upload pictures to the cloud.	
Expected Outcome: Pictures will be available on the server within a couple minutes.	
Actual Outcome:	
☐Pass	☐Fail

Speaker Identification Test	Date:
Test Description: The Smart Mask Box will identify people with the camera, then alert them to come buy a mask through the speakers.	
Expected Outcome: The Smart Mask box will be able to recognize people and colors, and call out for people by the color of their clothing they are wearing.	
Actual Outcome:	
☐Pass	☐Fail

Subsystem Test Results (Pass/Fail)	Initials

A.3 Electronics Testing

LCD Test	Date:
Test Description: Visual inspect if the correct text is displayed on the LCD.	
Expected Outcome: Instructions will be on the LCD screen and price of a mask.	
Actual Outcome:	
☐Pass	☐Fail

Speaker Test	Date:
Test Description: Speakers will play audio from the audio amplifier.	
Expected Outcome: Speakers will say, “Please come buy a mask.”	
Actual Outcome:	
☐Pass	☐Fail

Subsystem Test Results (Pass/Fail)	Initials

A.4 Mechanical Testing

Mask Distribution Test	Date:
Test Description: The Smart Mask Box will dispense a single mask.	
Expected Outcome: The product will dispense exactly one mask after payment.	
Actual Outcome:	
☐Pass	☐Fail

Hand Sanitizer Dispenser Test	Date:
Test Description: Place a hand below the hand sanitizer sensor in order to test the dispensing mechanism.	
Expected Outcome: The unit will dispense 30mL of hand sanitizer to the user.	
Actual Outcome:	
☐Pass	☐Fail

Subsystem Test Results (Pass/Fail)	Initials

A.5 Electrical

Voltage Test	Date:
Test Description: Check to see if the correct voltage is seen at the input of the Raspberry Pi with a digital multimeter.	
Expected Outcome: 5V ± 0.5V	
Actual Outcome:	
☐Pass	☐Fail

Voltage Test	Date:
Test Description: Check to see if the correct voltage is seen at the input of the audio amplifier with a digital multimeter.	
Expected Outcome: 2.5-5V	
Actual Outcome:	
☐Pass	☐Fail

Subsystem Test Results (Pass/Fail)	Initials

Appendix B: User Interface and Appearance Design

B.1 Introduction

B.1.1 Purpose

The purpose of this appendix is to go through the user interface design of the Smart Mask Box and explain It. It provides a straightforward experience to the customers.

B.1.2 Scope

This document will cover 6 major topics in our user interface design process:

User Analysis:
User analysis explains the knowledge users need before using the device and who is the audience for this device.

Technical Analysis:
The technical analysis discusses our design process according to the seven points: discoverability, feedback, conceptual models, affordances, signifiers, mappings and constraints are the major criteria from Don Norman's The Design of Everyday Things.

Engineering Standards:
The Engineering Standards shows the standards that applied to our user interface

Analytical Usability Testing:
Analytical Usability Testing discusses the analytical testing of our system and lists out the interactive design that supports the running of the system for our product.

Empirical Usability Testing:
Empirical Usability Testing discusses the testing methods that will be performed on our target users in future. Including both app users and the Smart Mask Box users

Graphical Presentation:
The graphical presentation presents the concept and design of our product using graphics.

B.2 User Analysis

The main target users of this product are some shopping malls and small and medium-sized businesses that want to monitor whether customers wear masks and sell the mask to customers, during the pandemic. There are two parts of the project, the mask box and the admin mobile App.

The Smart Mask Box is a pc size box that is easy to install on any table surface. The Smart Mask Box's main chassis features side doors that were required to enable Smart Mask Box owners easy access to the box's two major sections, namely the Mask dispenser mechanism for replenishing masks and the Sanitizer dispenser section for refilling the sanitizer reservoir. The door opens 180 degrees, allowing a clear view into the Smart Mask Box's inside

The Smart Mask Box, especially the microcontroller, will be able to connect with the Smart Mask Box mobile application. The application will be able to send and receive data from the camera and mask dispensing mechanism, as well as send and receive specific functional commands. Setting the purchase amount for a single mask will be part of these instructions.

B.3 Technical Analysis

A good product must be designed from the user's perspective. For our product, we will discuss from Don Norman's The Design of Everyday Things: discoverability, feedback, conceptual models, affordances, signifiers, mappings and constraints[26].

B.3.1 Discoverability

Discoverability means that the interface is easy to understand and the operation is easy to use. We want to keep everything like switches, buttons and menus as simple as possible. For the mobile app user interface, it should be designed in the same way.

Hardware:
- There will be just two states for the turn on/off switch.
- The switch should be set on the back of the Smart Mask Box.
- No button for the mask customer, only need to tap the credit card.

Software:
- All mobile app software buttons are easy to understand.
- Mobile app interfaces behave in the same pattern.

B.3.2 Feedback

The feedback of the user interface should be noticeable and clear. Users get feedback whether or not a product is responding.

Hardware:
- The LCD clearly shows the instructions for the mask customer.
- When a customer taps the credit card a sound will play.

Software:
- When the admin mobile app connects to a new Smart Mask Box successfully, a toast notification will show.

B.3.3 Conceptual model

A conceptual model is a straightforward and practical description of how something functions.

Hardware:

- Credit card tap areas imply people can tap their credit card at the designated area.
- A switch lights off when the switch state is off.

Software:

- Time format will follow the ISO 8601:YYYY-MM-DD [27].
- Switch button for connection or disconnection of the Smart Mask Box.

B.3.4 Affordances

The perceived activity and real qualities of an object that help us identify its functioning are referred to as affordance.

Hardware:

- I/O shows the switch states.

Software:

- Buttons are shown with different shapes and fonts compared with regular text.
- The help button can show instructions documents to the user.

B.3.5 Signifiers

The location of the activity is communicated to us through a signifier. It is similar to affordances and feedback.

Hardware:

- I/O shows the switch states.
- The switch light shows the states of the switch.
- The contactless payment symbol shows the tapping areas.

Software:

- Turn on/off button shows the user the Smart Mask Box is connected or disconnected.
- Information pages show the mask price.
- The progress bar shows the number of remaining masks.

B.3.6 Mappings

Mapping is the link between controls and their impact on the world. In other words, it is the layout of the user-interface and how intuitive it may be to understand and interact with.

Software:

- Set the price of the Masks by +/- sign.
- Progress bar shows the number of remaining masks.

B.3.7 Constraints

Constraints can limit the kind of interactions that can take place, reducing the quantity of data we must analyse.

Hardware:

- There is no button for the mask customer.
- There is no touch requirement to get the hand sanitizer.

Software:

- Only administrators can monitor the device by administrator mobile application.

B.4 Engineering Standards

This section will list and outline the various engineering standards that our product must follow and uphold. These standards are regarding environmental management, safety with respect to electronics, wireless communication constraints, and more.

Standard Number	Standard Description
ISO 8601:2019	Date and time format.[27]
ISO/IEC PRF TR 29119 - FP	A series of five international standards for software testing.[28]
ISO/IEC/IEEE 21840:2019 - FP	Guidelines for the utilization of ISO/IEC/IEEE 15288 in the context of system of systems.[29]
IEC 60491:1974 - FP	Safety requirements for electronic flash apparatus for photographic purposes.[30]
IEC 61508-2:2010 - FP	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems.[31]
C22.2 No.0.8-M1986 (R2008) - FP	Safety Functions Incorporating Electronic Technology [32].
CAN/CSA-ISO 14040:06 (R2011) - FP	Environmental Management - Life Cycle Assessment - Principles and Framework.[33]

Table 24: Engineering Standards Description

B.5 Analytical Usability Testing

To ensure that the design of the user interface makes customers feel comfortable, a list of interactions that should be performed while using the Smart Mask Box is needed. There are two main sections which are the mobile app and the Smart Mask Box. The interactive designs are listed below:

Device switch page for mobile app

1. As default, the switch background colour should be gray and the bar is on the left side, indicating that the device is off.
2. After the user presses the switch button, the switch background colour should become blue and the bar will be on the right side. Indicating that the device is on.
3. Right top of the page should be the sun when it is sunny day, and become a cloud when it is rainy day

Smart Mask Box

1. The Smart Mask Box should be placed on the eye level
2. There should be a hand sanitizer located at the right bottom of the box that will automatically drop the hand sanitizer when it interacts with user’s hand
3. The mask will come out from the Smart Mask Box when user tap their credit/debit card on the box

B.6 Empirical Usability Testing

In this part, we will list some questions that we will be asking our future customers. In order to get feedback that does not contain any personal sympathy, the users that we choose will be not any of the family members from our company. The users will be the customers from Metrotown Mall or Lougheed Mall to ensure that we get the authentic feedback. The questions are split into two parts, which are questions for app users and the Smart Mask Box users:

Feedback questions for App Users:

1. Do you like the colour of the pages?
2. Do you like the weather icon on the top right and is it helpful?
3. Are you able to see the add device option easily on the home page?
4. Are you able to identify the device is on or off through the icons?
5. Do you have further suggestions for our app?

Feedback questions for Smart Mask Box Users:

1. Do you think the height of the box is easy to reach?
2. Do you think the size of the texts shown on the LED screen are big enough to be seen?
3. Are you able to notice that there is the free hand sanitizer located at the bottom of the box?
4. Are you able to find out the payment method through the sign on the box?

5. Are you feeling more comfortable wearing the mask from our product when you see that each mask is packed individually?
6. Do you have further suggestions to help us improve our product?

B.7 Graphical Presentation

The dispenser and the mobile application are the two primary components of the Smart Musk Box system with which the user interacts the most. For the structure of the dispenser, please refer to the physical Design specifications in the design specification.

B.7.1 Hardware

The interactive elements of the hardware parts are very simple as Figure B.1. It is clear that the Smart Mask Box design is meant to be minimalist with barely any user input areas and only one LCD screen that will be used to prompt the user to pay for their mask as well as display the price of each mask. Mask customers are able to buy masks by simple tapping.

Figure 23: Interactive Elements of The Hardware Parts

B.7.2 Software

The mobile application will be used for the majority of the user interface.
The mobile application's home page is shown in Figure B.2. People can monitor the number of connected machines on the home page and control the connection and disconnection between the admin mobile app and mask vending machine.

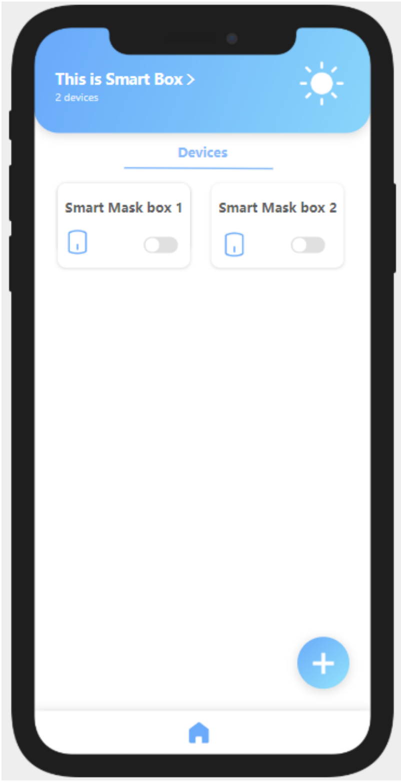


Figure 24: Admin Mobile Application Homepage

Administrator users can add devices that need to be connected via the “+” button at the bottom right corner, just simply enter the device ID.

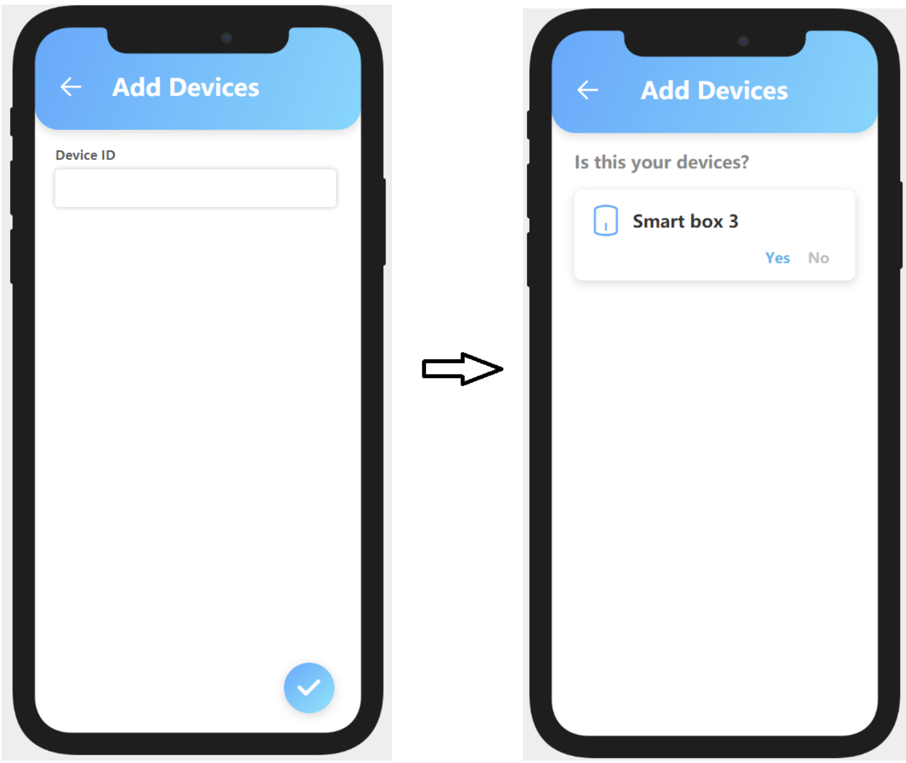


Figure 25: Adding Devices Process

In the device details page, the administrator can set the price of masks, view the remaining amount of masks, and view photos of those who do not wear masks.

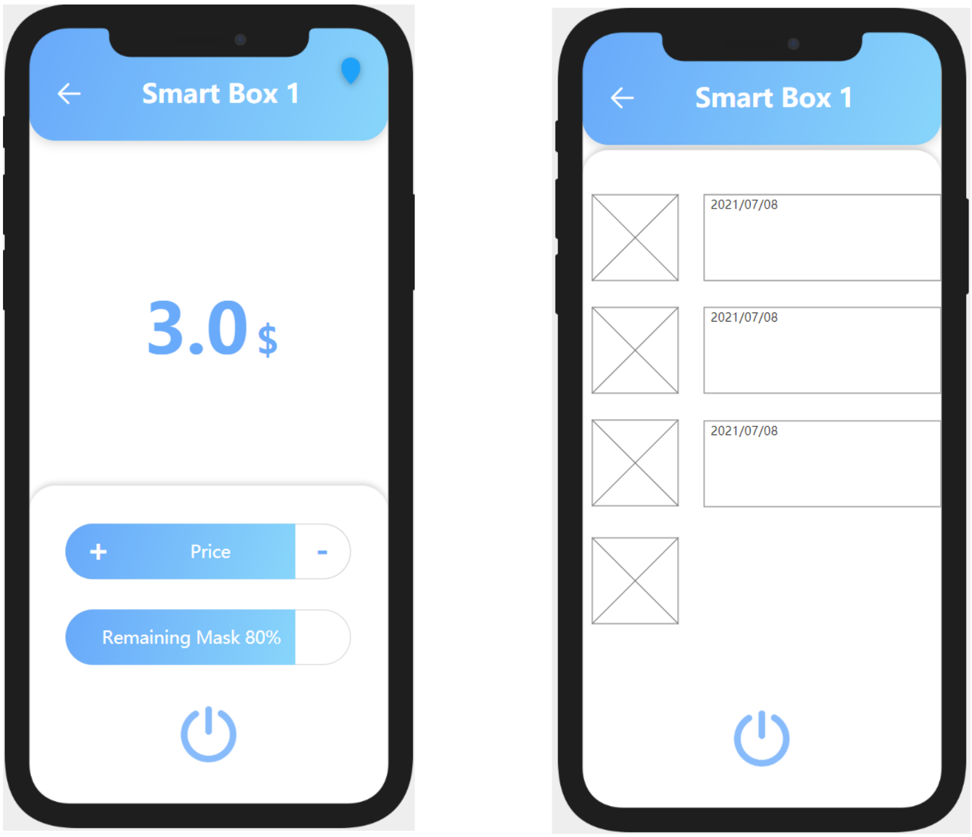


Figure 26: Device Details

B.8 Conclusion

The criteria for User Interface Design are essential to getting our products approved by people. As a result, it is critical to create an interface that caters to the user. Safetech team will conduct usability testing with users to get feedback on usability. For our proof-of-concept and prototypes, our team will carry out hardware and software iterations and determine to provide better systems.

Appendix C: Supporting Design Options

C.1 Physical Design

Chassis Material

A major aspect of the physical design of the Smart Mask Box is the material from which it will be constructed. Primary material options were found to be types of sheet metal commonly found at hardware stores such as Home Depot. Options of sheet metal include Copper sheet metal, galvanized steel sheet metal, and aluminium sheet metal. All sheet metal options are viable however, aluminium sheet metal is our primary choice as of now since it is lightweight and much easier to manipulate at room temperature to fit our construction requirements [9]. A summary of the price, size, and availability of each sheet is shown in the table below.

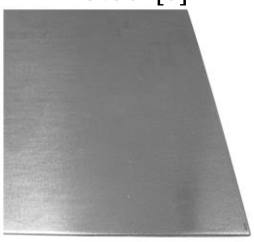
Sheet Metal Material	Specifications
Copper [9] 	**Size:** 12 x 24-inch **Thickness:** 26 gauge **Weight:** 0.57 kg **Price:** $ 39.11/each CAD **Local Availability:** Yes
Steel [9] 	**Size:** 24 x 48-inch **Thickness:** 22 gauge **Weight:** 0.73 kg **Price:** $ 33.64/each CAD **Local Availability:** Yes
Aluminum [9] 	**Size:** 24 x 48-inch **Thickness:** 21 gauge **Weight:** 0.73 kg **Price:** $ 40.86/each CAD **Local Availability:** Yes

Table 25: Chassis Material Options of Sheet Metals

Hand Sanitizer Dispensers

Finding a capable hand sanitizer dispenser that will integrate with our product while meeting certain requirements is key for the Smart Mask Box as well. There are many options of hand sanitizer dispensers that can be easily found on online retailers. The dispenser required for the Smart Mask Box must be a contactless motion detecting dispenser. The dispenser must also have a sufficiently large sanitizer reservoir that is also removable for easy refilling. Shown in the table below are a few hand sanitizer dispenser options that have been considered to be used in the Smart Mask Box.

Hand Sanitizer Dispenser	Specifications
Automatic Hand Sanitizer Dispenser by Vancouver Hand Sanitizer [3] 	**Size:** 26 x 13.4 x 11.4 cm (L x W x H) **Capacity:** 1500 ml **Weight:** 0.85 kg **Power:** Wired or Battery (DC) 6V and 1 A **Material:** ABS Plastic **Mounting Options:** Adhesive back/holes **Contactless:** Yes **Extra Features: N/A** **Price:** $54.89 **Local Availability:** Yes
Hand Sanitizer Dispenser by Ready First Aid [10] 	**Size:** 27.2 x 11.5 x 12.7 cm (L x W x H) **Capacity:** 1000 ml **Weight:** 0.83 kg **Power:** Battery powered only **Material:** ABS Plastic **Mounting Options:** Adhesive/holes **Contactless:** Yes **Extra Features:** UV-Light disinfection **Price:** $29.99 **Local Availability:** Yes
Steryll Automatic Dispenser [11] 	**Size:** 27.5 x 12.5 x 11 cm (L x W x H) **Capacity:** 1500 ml **Weight:** 4.99 kg **Power:** Rechargeable Battery powered **Material:** ABS Plastic **Mounting Options:** Adhesive/holes **Contactless:** Yes **Extra Features:** N/A **Price:** $79.99 **Local Availability:** Yes

Table 26: Hand Sanitizer Dispenser Options

The primary option of consideration are the Automatic Hand Sanitizer Dispenser by Vancouver Hand Sanitizer and the Hand Sanitizer Dispenser by Ready First Aid. These two options are lightweight, touchless, and much more affordable compared to the third option.

C.2 Electronics

Microcontroller

Table C.2.1 lists two options we had for microcontrollers and the specifications correspond to these two microcontrollers.

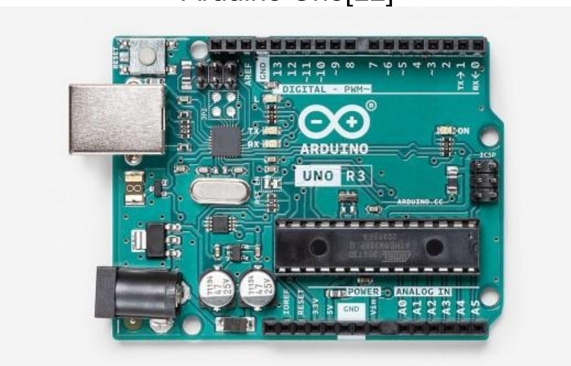
Part Name	Specifications
Arduino Uno[12] 	**Microcontroller**: ATmega328P **Operating Voltage**: 5V **Digital I/0 Pins**: 14 **USB Ports**: 0 **SRAM**: 2KB **Clock Speed**: 16MHz **Programming language**: C++ **Weight**: 25g **Price**: $23
Raspberry Pi 3B[13] 	**Microcontroller**:BCM2837B0 **Operating Voltage**: 5V **Digital I/O Pins**: 40 **USB Ports**: 4 **SRAM**: 1GB **Wireless LAN Speed**:2.4GHz **Bluetooth Speed**: 5GHz **Programming language**: Python **Weight**: 42g **Price**: $48.95

Table 27: Options for Microcontroller

The Raspberry Pi 3B is being chosen for our project because it has larger SRAM, which provides faster access to data.

Camera

The camera that we will be using is an integral part of our unit, as we cannot operate without it. The criteria for our camera was that it had to be compatible with the Raspberry Pi, have a wide angle lens that would be able to view an entire entry way, and have dynamic contrast to combat the bright light which would be let in when the doors to entry ways would be open.

Part Name	Specifications
KEYESTUDIO Fisheye wide angle camera 	**Photosensitive Chip**: OV5647 **Operating Voltage**: 3.3V **Number of Pixels**: 5M **Size**: 14.2 x 7.11 x 4.6 cm **Display Screen Display Size**: 4 inches **Video Capture Resolution**: 1080p **Diagonal Angle**: 130 degrees **Weight**: 31.75g **Price**: $21
Arducam IMX219 Wide Angle Camera Module [43] 	**Optical Format:** 1/4 inch **Frame Rate:** 30fps at 8MP, 60fps at 1080p, 180fps at 720p **Data Format:** RAW8 / RAW10 **EFL:** 2.5 mm **F.NO:** 2.8 **Focus Type:** Fixed Focus **Interface:** MIPI CSI-2 2-lane / 4-lane **IR Sensitivity:** Integral IR Filter, visible light only **Price:** $25.63

Table 28: Options for Camera

LCD Screen

Our goal with the display was to keep it simple, and just have instructions on how to buy a mask. Following our company mission, we were trying to avoid larger displays and touch screens in order to keep the product sanitary. Our choice for displays boiled down to two main types of displays, LCD and OLED, from which we could choose our desired size.

Part Name	Specifications
KEYESTUDIO LCD 16x2 Display 	• **Interface:** I2C • **Price**: $12.98 • Allows for 16 characters per line, and comes with 2 lines • Backlight allows for easier readability • Easy to use open-source library
Monochrome 128x32 SPI OLED graphic display[14] 	• **Number of Pixels**：128 × 32 • **Interface**：4-wire SPI • **Price:** $17.50 • Allows for more intricate design, such as displaying our Safetech logo • Comes in monochrome (white)
2.8" Nextion HMI LCD Touch Display 	• **Display Size:** 2.8” • **Display Resolution:** 320 * 240 • **Display Interface:** Serial • **Price:** $29.75 • SD Card Socket • Touch Screen

Table 29: Options for Display

Speakers

For the speaker, our demand is to make sure that people walking around the Smart Mask Box are able to hear the sound coming out from the box in a crowded mall. At the same time, the sound from the speakers should not be so loud that it would scare the person who is standing in front of the box trying to buy a mask. Using two 3W speakers should allow us to achieve a max volume of 100dB, which should be a good range for us to operate within.

Part Name	Specifications
InduSKY 2pcs Speaker 3 Watt 8 Ohm with JST-PH2.0 	**Size**: 15.24 x 10.67 x 1.52 cm **Weight**: 68g **Power**: 3 Watts **Impedance**: 8 Ohms **Wire Length**: 420mm **Material**: Plastic **Price**: $14.99
Stereo Enclosed Speaker Set - 3W 4 Ohm 	● **Weight:** 25g per speaker ● **Dimensions:** 30mm x 70mm x 17mm / 1.2" x 2.8" x .7" ● **Length:** 30" long total, 15" from each speaker to SPK plug ● 3.1mm diameter mounting holes ● 24mm x 64mm mounting rectangle ● **Price:** $7.50

Table 30: Options for Speakers

Power Supply

Power supplies for the Raspberry Pi 3 are fairly standard across the board. The main requirement we had for the power supply was that there should be enough power to supply the other peripherals as well. A breakdown of characteristics of a couple different power supplies can be shown below.

Part Name	Specifications
Raspberry Pi Power Supply 5V 3A (Micro USB) 	**Input Voltage Type**: AC **Input Voltage**: 100-240 V **Output Type**: DC **Output Voltage**: 5V **Output current**: 3A **Size**: 75 x 40 x 30 mm **Price**: $7.68
5V 2.4A SWITCHING POWER SUPPLY W/ 20AWG 6' Micro USB Cable 	**Input Voltage Type**: AC **Input Voltage**: 110-240 V **Output Type**: DC **Output Voltage**: 5.25V **Output current**: 2.4A **Price**: $10.99
Lithium-ion Batteries	If we wanted no cables/wires running from our unit to the wall, this would be the way to go. Rechargeable lithium-ion batteries would be able to power the Raspberry Pi and everything plugged into it with ease. The downside of batteries is that they will need to be charged up periodically or swapped with fully charged batteries.

Table 31: Options for Power Supply

Motor Driver

The rollers which will dispense the masks are going to be controlled by two stepper motors that the Raspberry Pi will control. Since the microcontroller does not have enough power to drive the motors, a motor driver board will be required. Below are some options that our company has decided are good fits for our design. Since our motors do not require a lot of power, we do not have to worry about large currents being drawn.

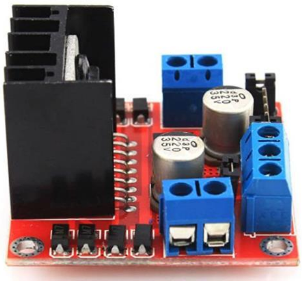
Part Name	Specifications
L298N Dual H Bridge Stepper Motor Driver Controller Board 	**Chip**: L298N **Motor Capability**: one 2-phase stepper motor and one 4-phase stepper motor **Operating Voltage**: 5V **Power Source**: Hand-Powered **Size**: 10.8 x 8 x 6 cm **Weight**: 40g **Price**: $16.99
DC & Stepper Motor Driver HAT Kit for Raspberry Pi [44] 	**Current Draw:** 1.2A per channel and 3A peak current capability **Driver Type:** Fully-dedicated PWM driver chip for excellent performance **Operating Voltage:** Can efficiently run on motors ranging from 4.5VDC to 13.5VDC **Price: $19.07** **Mount:** Sits right on top of the Raspberry Pi

Table 32: Options for Stepper Motor Driver

Stepper Motor

As mentioned previously, the mask dispensing mechanism will require primarily two DC stepper motors. Constraints regarding the stepper motors are regarding the voltage, current, dimension and weight requirements of the motor. Shown below are the two options of stepper motors that have been considered to be a part of the mask dispensing mechanism. It is seen that both options have very small voltage and current demands and are relatively compact and lightweight in size.

Part Name	Specifications
DC 5V 4Phase 5Wire Stepper Motor Micro Reduction Gear Stepping Motor  	**Chip**: uln2003 **Reduction Rate**: 1/64 **Phase type**: 4-Phase, can be used as 2-Phase as well **Size**: 4 x 4 x 3 cm **Weight**: 30g **Spout Height**: 1 cm **Price**: $15.09
SY42STH38-0806A Unipolar Stepper Motor by SOYO [45] 	**Resolution**: 1.8 degrees/step **Voltage:** 6V DC **Size**: 3.9 x 42.3 x 42.3 cm **Torque:** 36 oz/in **Current Draw:** 0.8 A **Precision:** +/- 5% **Price**: $19.22

Table 33: Options for Stepper Motor

Audio Amplifier

While designing the speakers, we needed an audio amplifier in order to ensure that people are able to hear the speakers in a loud entryway. The design specification states that our final product speakers should have a volume of 100dB. Using one of the following 3W amplifiers, we should be able to achieve that target. In addition to reaching that volume requirement, our company is also aware that a loud sound might startle customers who are buying a mask, and have compensated for that by placing speakers on mounts, in order to not blast sound directly at the customer.

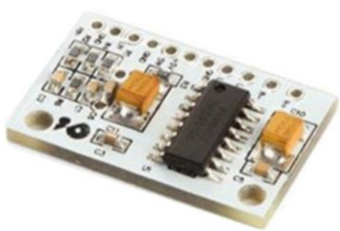
Part Name	Specifications
ADAFRUIT 3W Stereo Speaker Bonnet [46] 	**Sound processor**: PAM8403 **Power**: 3 Watts **Operating Voltage**: 2.5 to 5 V **Speaker Driven type**: 4 O/8 O **Size**: 65.0mm x 30.0mm x 7.2mm **Price**: USD$16.99
3W Audio Amplifier Board 	**Sound processor**: PAM8403 **Power**: 3 Watts **Operating Voltage**: 2.5 to 5 V **Speaker Driven type**: 4 O/8 O **Size**: 23 x 16 x 2 mm **Price**: USD$7.46

Table 34: Options for Audio Amplifier

C.3 Software

Facial Recognition

Facial recognition and object detection is a broad and comprehensive field. There are more than a few methods that can be utilized to facilitate facial and object recognition. Shown below are some facial detection methods and approaches that can be relevant to the functionality of the Smart Mask Box mask detection feature.

Facial Detection Method	Description
Holistic Matching Method	This particular approach receives the entire face region as an input into the system. A popular example of the Holistic Matching method is Eigenfaces. These eigenfaces are created by extracting specific features from the inputted facial region via the mathematical tool, Principal component Analysis [34].
Feature Based (Structural) Method	This approach focuses on local features of the face, such as the nose, eyes, and mouth. These extracted features are then inputted into a structural classifier which is later used in matching and recognizes facial features [34].
Hybrid Method	This Approach implements a mixture of both the Holistic matching approach and the feature based approach. This method makes use of 3D images of a face which gives this approach more detail and information regarding a face such as eye-socket depth and cheek bone height. This method proceeds with 5 main processes to facilitate facial recognition: detection, position, measurement and matching [34].

Table 35: Options for Facial Recognition

Front End

The front end software for our product has to be something that is easy to use for any company who will be setting up a Smart Mask Box for their store or area.

Design Option	Description
Mobile Application	A mobile application will have all the controls at the palm of your hand. Since most public places nowadays have free public wifi, it will not be a difficult task to integrate the unit and the mobile app. This option will be the easiest to alert the user if the Smart Mask Box is running low on masks, as the mobile application can send push notifications.
Website	A website would be another good way to communicate with the owner of the Smart Mask Box, as it would also have all the necessary data allowing the owner to make changes as required. The one downside is that it is not portable and requires the user to be on a PC.
Internal Display	An internal display would not be ideal for our situation, because it would require the user to check periodically if the masks were running low, and would not be able to show the user in real time how many people were coming in without masks.

Table 36: Options for Front End Development

From these options, our company has decided the mobile application is the best match for our needs, as it is portable, informative, and able to display information in real time to the user anywhere.

Back End

The back end of our software is an important staple of the entire project, because it integrates everything together and establishes communication between the two parts, the unit and the mobile application. Ideally, the user should be able to see the real time data of the unit at any time and place, as long as they are connected to the internet.

Communication Design Options

Design Option	Description
Bluetooth	Bluetooth would require the user to be within a certain proximity in order to connect the unit to the mobile application. If the user was always close to the unit while at work, this form of communication could be a potential solution.
Wifi	Since Wifi is available in most public places nowadays, this form of communication between the unit and mobile application would be fairly easy to set up. This would also allow the user to check the real time data of the unit anywhere they were connected to wifi.
Wired LAN Connection	A wired LAN connection would offer the same capabilities as the Wifi connection would, but there is a hazard of tripping over wires which has us concerned. Wired LAN connection would be the optimal solution, because it offers the strongest connection compared to the other two.

Table 37: Options for Communication Design

Database Design Options

Design Option	Description
AWS	Amazon Web Services (AWS) is a popular cloud computing platform. AWS has a far-reaching global infrastructure and offers low latency and high throughput networking. Additionally, AWS is an extremely secure platform that is widely used by military services, government organizations and global banks [35].
Local Database	A local database server will be created using MicrosoftSQL Server program. This local server and database provides more security of having a single locally stored database yet has significant limitations in data transfer versatility. Indeed, this option is more cost-friendly [36].

Table 38: Options for Database Design