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Dear Dr. Robert Dony:

We are submitting our final report of our design project - "Automated COVID Screening Entrance Device" for your kind perusal. The ROBOTEX engineers thank you for your critical feedback and guidance throughout the process of this project. As COVID-19 is a widely and rapidly spreading disease, the design team has ensured that the solution developed is safe and achieves the functionality of the requirements set by the team. Currently, it is mandatory that the people wear a face covering, have a routine check of their temperature and any related symptoms at the entrance of stores, clinics and other public places. Due to these essential workers placed at the store's entrance/exit are in high risk of contracting the disease due to the exposure of incoming customers.

The team members sincerely appreciate your insight since it helped design a solution that can address and solve this current issue. The purpose of this report is to give a detailed account of the project with the supporting calculations and tools used during the design process. Altogether, ROBOTEX's goal is to play its role in stopping the spread of COVID-19 through a safe and efficient approach.

Sincerely,

Aarthi Christina Aruliah — Layal Alzaydi

Lina Shaabo — Nasiba Alchach

Whitney Trinh

ENGG*3100 – Engineering and Design III - W21

Final Design Report – Automated COVID Screening Entrance Device

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In signing this report, I certify that I have been an active member of the team and provided approximately equal contribution to the work. I take shared credit and responsibility for the content of this report. I understand that taking credit for work that is not my own is a form of academic misconduct and will be treated as such

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Date :____ **2021, April 12** ____

EXECUTIVE SUMMARY

The recent coronavirus pandemic has been an eye-opener to the world and has brought our everyday hygienic practices to attention as the mode of transmission of this disease is through infected respiratory droplets. Different world governments have enforced many restrictions and health measures to control the spread including wearing a mask at public places, maintaining social distance, sanitizing hands, and checking body temperature. At present, the screening test at store entrances have been assigned to essential frontline workers. Such an exposure poses a threat to both these workers and the customers as well.

The team of engineers at ROBOTEX have undertaken the task and have found a safe design solution that can be used in the place of a front-line worker based on certain constraints and criteria such as high accessibility, high accuracy and a cost-effective design being some of them. Initially, during the design process the team had come up with three alternatives, and by using the decision matrix and the sensitivity analysis, the design with an automated COVID screening station was chosen to be the optimal solution to the proposed problem. The final design consists of several components based on the three major functionalities: temperature measurement, mask detection and the number of people currently inside the building. These components include a camera, automated barriers, a thermal camera, and ultrasonic sensors. Based on careful calculations and research, the materials required are listed, and the related codes and circuitry of the subsystems are modelled. The final design fulfils the functionality of the required solution by having high accuracy and durability and removes the requirement of a worker being assigned at the entrances/exits by making the system completely automated. Moreover, the design is stress free, highly adaptable according to each store’s needs and has minimized negative impact on the environment along with the less waste produced.

ACKNOWLEDGEMENTS

The Engineering Design Team at ROBOTEX wants to express appreciation to Dr. Robert Dony, for his constructive feedback, suggestions, and his valuable advice during the entire design planning, testing and development process. The ROBOTEX Team would also like to extend a sincere thanks and obligation to the ROBOTEX team's Teaching Assistant, Amanda Nason, for the guidance, feedback, support, effort, and encouragement throughout the entire course of the project. A special thanks to the team selected and project managers at ROBOTEX for the constant compensation and administration in keeping the project on schedule. The ROBOTEX Team would like to further acknowledge the entire Engineering and Design III committee for the distribution of valuable information during lectures and labs which are associated in designing an impactful and impeccable product that aids in reducing the COVID spread. Finally, the ROBOTEX Team would like to thank the design engineers at ROBOTEX for their arduous work and commitment towards this project.

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1.0 INTRODUCTION/BACKGROUND

The ROBOTEX team have chosen a COVID related project, and the details of the problem are described in this section. This section also includes more information of projects that are related to the problem defined, the design requirements to comply certain standards and codes and the extent of project's scope. At the end of this section, the criteria and constraints that the design solution should meet are listed and explained.

1.1 PROBLEM DESCRIPTION

COVID-19 is a respiratory disease that is caused by the SARS-CoV2 virus (Huang et. al, 2019). It provides flu-like symptoms to those who have it, such as having a cough, sneeze, or fever (CDC, 2020a). The main form of transmission is through respiratory particles in the form of droplets that can be released from an infected person if they talk, sneeze, or coughs (CDC,2020b). While most tend to recover relatively well, there are still many things unknown about the virus. As the months pass, more information regarding the long-term effect of COVID are becoming known. Many people report being unable to fully recover to their pre-COVID health, and in a study, it was found that almost 20% of young adults who had COVID experienced prolonged symptoms such as chest pain and loss of senses like taste and smell (WHO, 2020b). In addition, as the cases rise, so do the hospitalization rates. Hospitals are often struggling to have available beds, and with a shortage of doctors and nurses, it can take days for those who have COVID or need medical care to be addressed (Abelson, 2020).

Within the last year, this disease has sent countries into a harsh lockdown, where everyone who could work from home are doing so (Financial Times, 2021). However, the exception of this was for essential workers, who remained working to maintain the key aspects society needed to function. These included those working in lower wage areas, such as grocery stores, fast food, and more (Government of Canada, 2021). With essential workers continuing to work and interact with customers daily, this places them at a higher risk of contracting the disease. In fact, even as the months went by and screening technology became implemented, those who worked with direct customer exposure were five times more likely to become infected (Lan et. al, 2020). This poses a risk not just to employees, but also to the large traffic of customers they interact with daily from a health and safety perspective.

Considering that in the US, 50% of these workers are unable to receive paid sick leave, along with the fact that unemployment rates have doubled since quarantine had started, there are many who would still feel pressured to show up to their job even if they feel ill or anxious about the pandemic (BLS, 2018; Statistics Canada, 2020; Bhattarai, 2020). Certain protocols were recommended by the government to increase health safety, such as wearing a mask when leaving the house, as it has proven to be an effective control measure (Greenhalgh et al., 2020). While in Asian countries, such methods have been in place for years, and thus were easy to implement, other countries such as Canada and America faced difficulty adjusting to those new norms (Wong, 2020). Even then, there still poses a need to be able to develop a system that would allow customers and employees to enjoy a more safer shopping space and reduce the spread of COVID-19.

For large retail stores like Walmart, there are rules in place saying that face masks are required for entry- however, there have been contradictions to that as well. Employees have reported that though stores say this, there is no way to enforce it. Out of concern for their staff safety, stores have told employees that they should not refuse entry, or even confront a customer who comes in mask-less as some become violent and hostile upon confrontation (Corkery, 2020; Meyersohn 2020; Azpiri, 2021). With around 4% of customers refusing to wear a mask, or wearing them ineffectively, concerns are raised about the efficiency of their policies, since it still exposes those inside to a higher level of risk (Haischer et al., 2020). In addition, for stores like Walmart, there is no system set up that would account for those who do have COVID from coming into the store, should they be wearing a face mask or not (Walmart, 2020). Some of the social impacts that play into the problem are that employees are experiencing an increase of anxiety and depression due to the high exposure that they are forced to endure for their job (De Boni, 2020). It can also be linked to the high amounts of aggression and violence since the pandemic came, especially if they are a minority (Statistics Canada, 2020). There has been a surge in xenophobic attacks towards Asians, with almost 30% of people in a survey exclaiming that they have experienced discrimination of some form since COVID came to America, with some being extremely violent (Washington State University, 2020; Yancey-Bragg, 2021). Anxieties extend to the customer as well, around 60% of people in the US have said that since the virus hit, they have felt anxious going into a grocery store (C+R, 2020).

The economic impacts of COVID can be huge, especially considering pre-existing losses that were experienced since March 2020. From Statistics Canada, the following month saw a staggering amount of 110 thousand businesses closing and almost 2 million people becoming unemployed (Statistic Canada, 2021). On a global scale the number of jobs lost exceeded the 2008 financial crisis- nearly 255 million people lost their jobs and $3.7 trillion US dollars of income was lost (International Labour Organization, 2021). Restaurants and stores are struggling to find ways to adapt to the fluctuating government regulations and earn some revenue to pay off the debt that has incurred throughout the past few months. Even with government funding money, this amount is not enough to cover for all those debts (Lourenco, 2020). Adding on, should a potential employee test positive, the Public Health Agency of Canada advises a thorough disinfection process of the store to ensure that potential transmission is minimalized (Region of Peel, n.d.). Doing so can mean closing the store for a day- which loses a day's worth of revenue. This only causes further damage for smaller, local stores who already are struggling, or for low wage employees who were already more impacted from the economic crash that COVID caused than other employees (Statistics Canada, 2020).

While there are little to no environmental impacts on this issue of regulating COVID precautions for stores, there have been growing concerns regarding the usage of masks as a result of COVID. Due to the nature of the problem, it is unsafe to reuse single use masks. Thus, many are disposed of after use, and this has created a growing concern in terms of waste. Masks are often equipped with 3 layers for optimal efficiency (Bahl et. al, 2020), however the materials used are harmful to the environment. Categorized as infectious waste, the non-biodegradable material has started to pollute oceans along with other COVID equipment such as gloves and hand sanitizer bottles (Kassam, 2020). Considering Asia alone goes through almost 17 thousand tons of medical waste per day, these masks can pose huge problems in coming future years (Sangkham, 2020).

1.2 BACKGROUND INFORMATION AND LITERATURE REVIEW

The COVID-19 outbreak placed the world into a global pandemic following the discovery of a zoonotic pneumonia virus in an elderly man in Wuhan, China. Further testing of COVID-19 (otherwise known as SARS-CoV-2) revealed it to be a highly contagious beta-coronavirus that is like SARS (SARS-CoV). There are 4 types of coronaviruses: alpha, beta, gamma and delta. Beta-coronaviruses are transmitted primarily through mammals, with COVID-19 originating from bats, and are more dangerous in terms of severity and fatality (Mousavizadeh & Ghasemi, 2020). To understand the virality of this virus, it is important to understand the structure of coronaviruses. Coronaviruses are single-stranded RNA viruses and contain the largest genomes in comparison to other RNA viruses. It is enclosed by nucleocapsid proteins, spike proteins, a membrane, and an envelope. The spike protein in particular plays an important role in interacting with cells and the neutralization of antibodies. Once the spike protein attaches to the ACE2 protein receptor of a host, it can unload its viral RNA into the cell (Cevik et al., 2020). Current research is working to block the spike protein's attachment to ACE2.

Elderly, immunocompromised individuals and smokers are shown to be most affected by the virus and experience the highest mortality, whereas many individuals can experience fewer symptoms, and even be asymptomatic. COVID-19 has a very high viral load and is shown to be most active in the nasopharynx -located behind the nasal cavity- and sputum-located by the mucosal glands- for at least 7 days, which allows transmission to occur through droplets released from the nasal cavity and throat. However, after the 8th day, although coronavirus RNA was still present in these areas, the virus was no longer live/infectious. Coronavirus RNA was also discovered in the stool of patients a month after transmission but was infectious as well (Mousavizadeh & Ghasemi, 2020). Due to the high transmission, infectivity and severity of COVID-19, appropriate measures such as wearing masks must be practiced decreasing transmission rates until it is eradicated. With many forms of PPE being implemented into stores, such as mandating facial masks, sanitizing hands, and social distancing, those factors alone are difficult to facilitate specially to stores that receive heavy forms of traffic every day. It becomes difficult to regulate what counts as an “effective” face mask since many people may wear them incorrectly, rendering the PPE useless (Haischer et al., 2020). In addition to that, there is a large percentage of people who fail to follow WHO's recommendations for appropriate mask measures (Machida et al., 2020) Various forms of technology have been developed to try and find more effective ways of identifying proper PPE or COVID symptoms. Some companies have looked more into models that integrate deep learning to help identify if people are wearing their masks properly. By using a set of images of masks being worn and not worn as a reference, the model is able to train itself to recognize new images with about 99% accuracy (Loey et. al, 2020). Other companies have been looking into developing methods through thermal cameras too, and while they do provide accurate results for surface temperature, the accuracy decreases when used for large groups, so finding new ways to design this is currently under development (FDA, 2021). There are also methods of looking into crowd control, in order to comply with government regulations and promote a safer environment. For companies focusing on this aspect, such as Footfall Cam, an electronic counter is used along with screens that display the occupancy in the stores. If full capacity is exceeded, a staff member is alerted. An application is also used to show customers current occupancy and predicted wait times (FootfallCam, 2021). While this tool is effective, it fails to account for other aspects such as PPE usage or temperature that may allow those at risk to slip by undetected.

A company who has offered a potential solution to said aspect is Category 5, a Canadian business that has developed an effective screening technology that monitors temperature, proper mask usage, and more. This is done through the usage of a thermographic camera that can detect temperatures with a high accuracy, within 1-2 seconds. The pros of this technology are that it also allows group scanning, making it faster to allow entry way into and out of the store. Should a high temperature be detected, it will notify employees (Category 5, n.d.). In addition to that, another company called PredictMedix has implemented a similar screening technology. It also keeps an eye out for other COVID-like symptoms, such as coughing or a heavy breathing rate, while only requiring a bandwidth of 25 Mbps to operate (Predict Medix, n.d.). However, the problem with these existing designs is that, unlike Footfall Cam, there are no ways of controlling whether the infected individual can enter the store or not. These current designs say that they leave it up to the business owner to determine what will happen when they are notified and say that an employee can approach the customer and politely ask them to leave. This means direct exposure, and since they were alerted in the first place the customer has a high chance of COVID or there is a large crowd. This provides a high chance for the employee to contract the virus too.

Thus, in order to ensure that customers are wearing their masks properly, and that they are screened for COVID in a non-contact like manner, some sort of system would need to be implemented that is purely technological and autonomous. This prevents employees from being directly exposed to customers, and also allows for a safer and friendlier approach to confront those who are wearing their masks improperly. Doing so can reduce anxious feelings within employees, as well as other customers. The store can also continue operations smoothly, and these features can be used as a selling point to attract customers due to the increased level of safety provided that other stores lack. In addition, finding a method to analyze other symptoms of COVID can be another design aspect to prevent those who have it from entering the store and potentially spreading the disease even more.

1.3 SCOPE OF PROJECT

The problem dealt with in this project, in short is the spread of COVID-19 in public frequented places like retail stores and grocery shops. The project aims to ensure that the checking of temperature, mask, and the number of people in a store is done effectively and efficiently without a front-line worker being exposed to all the customers entering the store. Working on this aim, this project's scope is to create an engineering solution that would help store owners operate in a safer environment and provide a sense of security to the customers by ensuring that the protocol for entering the store is followed. The design solution and its specifications are detailed in the following sections of this report.

The design includes a control system with sensors that measure temperature, detect a mask, and update the count, along with an automated barrier system that regulates the entry of people into the store. The design even includes a space for installing a hand sanitizer dispenser which would encourage hygiene before entering the store. Useful data from the system such as the current number of people within a store, would be displayed on a large screen to apprise shoppers that are passing by. The engineers at ROBOTEX aspire to optimize this process by analyzing the screening process time and the accuracy of the system, keeping in mind the government and community safety regulations. The implementation of the project design at present is focussed specifically on Ontario, Canada as this province has the highest number of total COVID cases in Canada, with about 386,608 as of April 11th, 2021. (Canada, 2021). However, as the project is flexible, it can be implemented furthermore such as throughout Canada with just minor changes in specifications in order to follow the laws and guidelines of that respective region. Also, as the project system contains many components where most of which are pre-existing parts, most of these components would thereby be outsourced to have standard products. These outsourced products would mostly include electrical components such as microcontrollers and motors. The only parts of the system which are nearly completely manufactured by ROBOTEX are of those which would need to be customized according to each store's/place's requirements. These components include the automated swing barriers as the size of the entrance(s) differs from store to store.

Unfortunately, there are many cases where temperature screening to detect coronavirus disease has proven ineffective as infected individuals can also either be asymptomatic or in an incubation period (W.H.O., 2020). In this case, it lies outside the scope of this project. Additionally, this project does not extend to ensure that people within the store are wearing their masks the entire time as it depends on the type of cameras being used within the store, angle and range of detection, and access to data. Ultimately, this project's main scope is to create a system that is automated which can be used at the entrance of stores in place of a front-line worker to reduce the risk of COVID-19 transmission.

1.4 CONSTRAINTS AND CRITERIA

The selected constraints and criteria are dedicated to protecting front-line workers, the environment, and everyone in the community. To make the device highly accessible, the team promotes the device by making it safe, accurate, and cost-effective. ***Table 1*** and ***2*** below demonstrate the constraints and criteria of the design solution set to design a successful device that helps with the detection of COVID-19, including the justification of why they were selected and where they were retrieved from. In order to guarantee costumers a reliable design solution, all the sources used are credible sources, such as university research.

Table 1. Constraints of the Design Solution

CONSTRAINTS			
#	**CONSTRAINT**	**EXPLANATION**	**SOURCE CITED**
1	The materials used to construct the design solution must be eco-friendly.	This helps promote the device as the design solution ensures to keep the environment safe regardless of the location.	(Harvard Business Review, 2019)
2	The design solution must be safe and easy to use.	This helps promote the device as the design solution will require less training and will therefore be more widely used.	(Harvard Business Review, 2012)
3	The design solution must serve as an effective alternative compared to pre-existing measures.	This implies that the device will have an outstanding face covering detection and temperature measure performance in order to compete with other alternatives in the market.	Initiated by ROBOTEX.
4	The design solution must serve as a worry-free alternative.	The ability to function efficiently in order to perform the tasks that front-line workers have to accomplish. This will remove the burdens that some have to carry and therefore improves the overall mental health and well-being of workers and costumers surrounded by the assigned public health restrictions.	(CTV News, 2020)
5	The device must be able to use face detection.	This ensures that public health measures and restrictions are followed by everyone entering the public space.	(Cornell University, 2021)

6	The design solution must be able to count the number of people entering and leaving the store.	This ensures that the maximum capacity of the store is maintained.	Initiated by ROBOTEX.

Table 2. Criteria of the Design Solution

CRITERIA			
#	**CRITERIA**	**EXPLANATION**	**SOURCE CITED**
1	**Minimize cost of the design.**	If the cost is unreasonable, the device will not be able to be implemented or may not be widely used regardless of its effectiveness.	(Treasury Board of Canada, 2007)
2	**Maximize accuracy of mask detector.**	This ensures that the design solution protects the front-line workers by being an effective alternative.	Initiated by ROBOTEX.
3	**Maximize the temperature measurement accuracy.**	In order to achieve satisfying results, the thermometer would need to be used correctly in order for them to be as accurate as oral and rectal thermometers.	(NCBI, 2020)
4	**Minimize the complexity of the assembly of the design product.**	This ensures that the device is accessible to various stores and clinics since it is easier to carry and move around.	(Harvard Business Review, 2019)
5	**Minimize the number of components.**	Complex designs are more expensive and require high maintenance.	(Harvard Business Review, 2019)
6	**Maximize accuracy of the counter.**	False data is a concern to the government, the health professionals and everyone in the community.	(Statistics Canada, 2021)

7	**Maximize accessibility of the device.**	The design should allow for fast detection or multiple detections at once to allow for a smooth process and prevent any delays.	Initiated by ROBOTEX.

2.0 DESIGN PROCESS AND SOLUTION

This section provides the tools used and the steps taken to finalize the optimal design solution including the alternatives that were considered as a plausible solution. Furthermore, the overall working of the finalized design is depicted and explained in detail.

2.1 DESIGN PROCESS

Design process is a serious of steps that engineers follow to create an effective solution to a problem (Howard, et al. 2008). The reason behind using a design process when trying to solve any issue is to support the designer providing a firework or methodology (Howard, et al. 2008). The main steps in the design process involve defining the problem, gathering information, determining the constrains and criteria, developing possible solutions and creating a decision matrix to facilitate ranking the possible solutions and choose the best solution, and finally communicating the results (Howard, et al. 2008).

Defining the problem is the first and the most critical steps in the design process. The particular problem existed as a result of the recent pandemic of COVID-19, as the front-line workers are assigned at the entrance of the stores to check if customers are following the restrictions and measures taken to prevent the transmission of the disease including wearing a mask, regular temperature check and making sure that the allowed number of customers are in the store. Thus, the situation puts the workers at a higher risk of exposure to the disease. The proposed solution is to design an efficient, accurate, and cost-effective automated device that performs all tasks done by the workers to eliminate the risk which yields to the stated constraints and criteria to solve the identified problem. With the Research conducted, the team was able to complete the third step of the design process and finalize the constraints and criteria. Taking on board the constraints and criteria while developing design solutions, distinct designs were developed that may lead to an achievable solution. During the brainstorming meetings, different solutions were developed. Each member of the team contributed to the different steps of the design solutions by improving the main idea of the solution and giving opinions and feedback to the other ideas. The topmost three design alternatives were selected at the end of the brainstorming session in fulfilment of the criteria and the feedback from each group member. Evaluation of the design alternatives was done using a decision matrix and sensitivity analysis. This results in the designing The Automated Screening COVID Device. Multiple trials of improvements and re-evaluating the design were conducted as part of the design process.

2.2 SOLUTIONS DEVELOPED

2.2.1 DESIGN 1 - MOBILE APPLICATION

The broad scheme of the design solution is to integrate a mobile application that performs face mask detection, temperature measure, and live capacity representation for the stores. First, customers are required to answer questions regarding COVID-19 public measures that will be prompted by a survey through the mobile application. Second, customers are required to scan their profiles for the face mask detection to be sent to the ROBOTEX server on the cloud to process the image and send back a Boolean value representing the validity of the face mask coverage. A QR code will be generated if a positive feedback is returned from both assessments. The QR code is then to be scanned by the QR barcode scanning device at the store's entrance door. The counter is incremented each time the QR code is scanned to ensure the maximum capacity is not being violated. Overall, this design solution will function in a way similar to that illustrated by the sketch in ***Figure A1.***

One of the advantages for this design is the use of free open-source components which makes it a cost-effective alternative. Moreover, the complexity of the design is easy to assemble and accessible to a relatively large number of demographics. This promotes the device to be widely used by a variety of clients due to the simplicity of its implementation (Rafi, 2018). The design solution poses a face mask detection feature that is highly accurate, which possesses a major role in the detection and collection of COVID-19 data.

As mentioned before, a survey is being used as an alternative temperature measuring method due to the lack of hardware components that can measure the temperature on smartphones today, which results in a low accuracy for the temperature detection criteria. According to a research done by Brock University, only 257 out of 451 participants were honest about their COVID-19 symptoms and social distancing when being asked (Brock University, 2021). In addition, despite smartphones and internet access being available to most of the population, a fraction of the community that is worth to be considered might have limited access due to the lack of these tools (Government of Canada, 2018).

2.2.2 DESIGN 2 – EXISTING SURVEILLANCE CAMERA

This design incorporates the use of existing closed-circuit television (CCTV) or Internet Protocol (IP) cameras of a store for mask detection and for counting the number of people. The real time feed received by the surveillance cameras at the store's entrance would be run through a software that would assess the data for masks and for the number of people entering or exiting the store. For the measuring of body temperature, a separate thermal imaging camera would be placed at the entrance of the store. In the case of either no mask or temperature greater than the normal body temperature the store would be alerted of that person(s) upon which security workers may isolate these individuals for further action. When the store reaches its allowed maximum capacity, the entrance doors can be monitored or even closed until the number starts to decrease again. A block diagram of how the CCTV/IP cameras would be used for counting and mask detection can be seen in ***Figure E2*****.**

Advantages include quick screening process rate, reduced cost as it makes use of the surveillance cameras that are already used by shop owners, and the simplicity of the design as it requires only the installation of a thermal camera and the uploading of a software. Despite these a major drawback for this design is that in the case of a store without an automatic entrance door, a worker must be assigned to monitor the door when the maximum capacity has been reached or when an individual is identified to have a temperature or no mask, the worker must isolate them from the store. This puts the worker's health in risk due to such exposure. Other drawbacks include that this design is for only stores that have been using CCTV/IP cameras at their entrances, and that the resolution and the visual field of the surveillance camera may vary from store to store. The resolution and field of the camera are important factors that contribute to the accuracy for counting and mask detection (Rosebrock, 2020).

2.3 DETAILED FINAL DESIGN

The COVID Screening entrance device solution implements three major functionalities: face mask detection, temperature measure, keeping a count of the total number of customers in the store and controlling the flow of customers into the store. The overall system is represented by the figures below. ***Figure 1*** shows the SOLIDWORKS design of the overall system**,** and ***Figure 2*** represents a block diagram of the overall system consisting of three sub-systems labeled 1,2 and 3 in both figures. The customer is required to pass by the station shown in ***Figure 1*** prior to entering the store. First, the visitor will be required to get their face scanned by both the Raspberry Pi camera module for the face mask detection and the MLX90640-D55 thermal camera for temperature measure detection ***Figure E3*****.** In the meantime, the counter checks if the total count is below the threshold value of the store ***Figure E4*** Later if all three conditions sum to true the door barrier opens automatically ***Figure E5*** and the counter of customers increases and updated on the LCD screen.

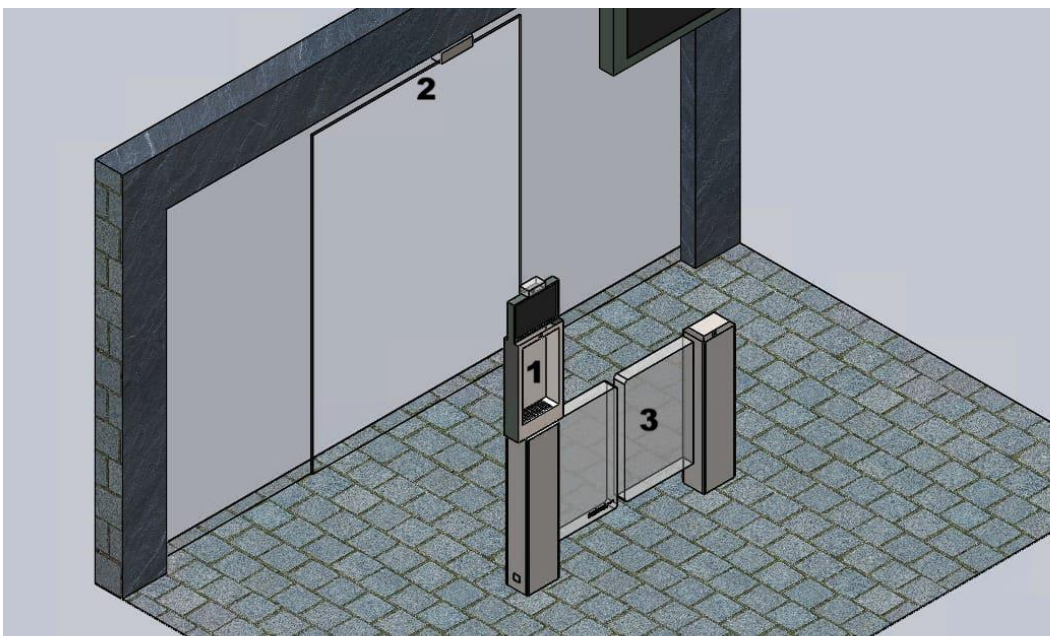

Figure 1. Overall System Designed in SolidWorks

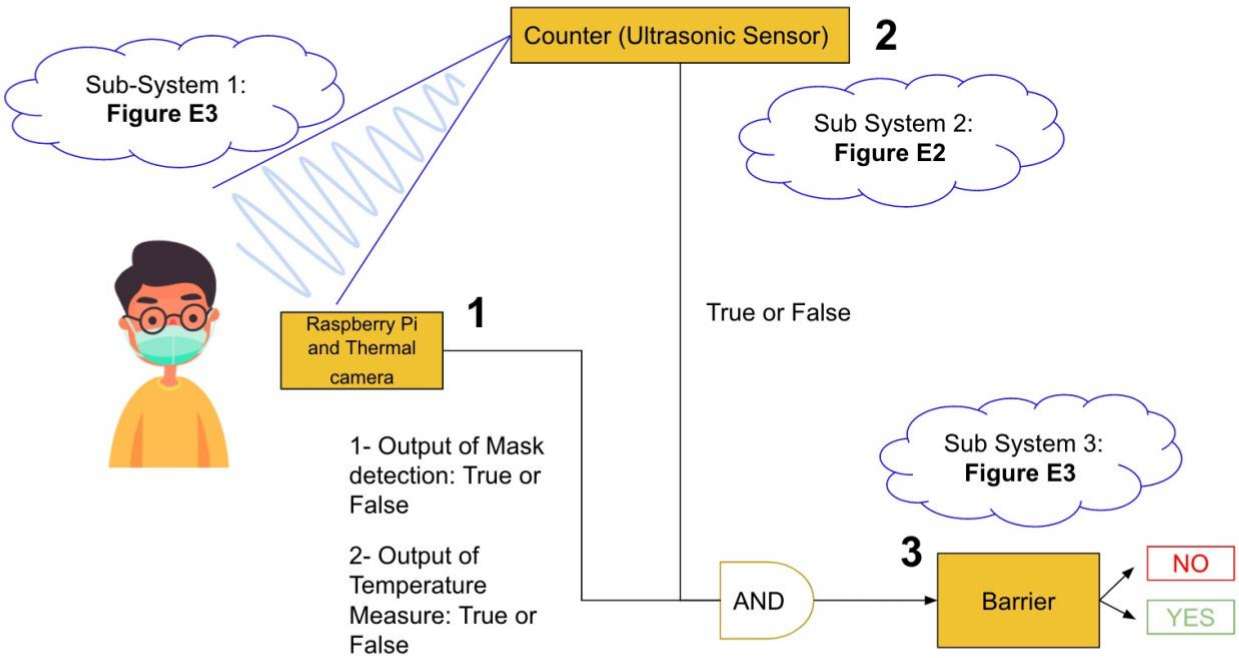

Figure 2. Overall Block Diagram of the System

The Raspberry Pi camera module is used for the face mask detection while the MLX90640-D55 thermal camera is used for measuring the temperature over a range of 5.00m. Both components are connected and covered with acrylic holder case (Acrylic holder case). The circuit diagram representing the connection of the servo motors, thermal camera and the raspberry pie is shown in ***Figure F3.*** The component represented in ***Figures 2*** and ***E3*** is to be placed at a 1.78m based on the average male height in Canada and 1.781m away from the customer (CBC, 2016). SG90 Micro-servo motors (Servo motor Micro SG90 2021) are used to move the container in both x and y directions to be adjustable for shorter and longer heights. Calculations were made to confirm the displacement of the camera is within the accepted range as shown in ***Table D1*** which will be triggered by emitting light from the Pomeronic pan tilt HAT full kit (Pan-Tilt hat). A sensor is to measure the light density and compute the current x and y coordinates of the of the camera. A Pan-Tile hat will hold the thermal camera at position A labeled in the ***Figure E3***. The 2 servo motors will be placed at positions B and C and will be connected to the raspberry pie from the bottom as labeled D in ***Figure E3***. PID controller is used to get the correction factor for both x and y directions and control both SG90 Micro-servo motors to pan and tilt to the desired x and y coordinates which was triggered by OpenCV. OpenCV is a python library used to get the coordinates of the person within the frame (Faurog et al., 2020). As shown in ***Figure E1*** representing the block diagram of the PID control system in which the Setpoint is the required coordinates. The Output must be equal to the Setpoint, else the error signal will not be zero. Error signal is represented by [Setpoint - Measured]. The three gains, Proportional, Integral and Derivative are to be summed to output a zero-error signal i.e.: [Output = Setpoint]. The SG90 Micro-servo motor is the Plant/Process. While the added disturbance is the friction to the shaft of the motor. Figure Camera represents the overall connections and components of the face mask detection and temperature measure component of the design.

As shown in ***Figure H1*** the main files and folders responsible for the face mask detection functionality consist of a dataset folder containing training and testing data, classified into two subfolders: '*with mask'*: holds 2165 images for individuals wearing masks, '*without mask'*: contains 1930 images for individuals not wearing masks. Second, the *'app.py'* file as shown in ***Figure H2*** Implements the mask detection method. Third, the *'requirenmnets.txt'* file which holds the software frameworks, platforms and libraries required to be installed prior to running the algorithm. Fourth, the *'train_mask_detector.py'* is responsible for training the convolutional neural network (CNN) using the dataset folders (chandrikadeb7, chandrikadeb7/face-mask-detection).

The counter functionality represented in ***Figure E4*** and ***Figures 1*** and ***2*** labeled 2 is implemented using an Arduino Uno microcontroller (2 Arduino's and 1 LCD sharing I2c) for counting the number of customers entering and exiting the store and displaying the value on an LCD screen (Team, "Hello world!"). Two microcontrollers are to be placed at the entrance and exit door of the store. A circuit diagram representing the connectivity of the circuit is shown in ***Figure F1. Figure H4*** represents the implementation of the Arduino code that is responsible for incrementing the counter when a customer enters the store. The other Arduino will implement a similar algorithm with a change in line 50 in which the counter is to be decremented when a person is detected exiting the store.

The Arduino Uno (Arduino, n.d) microcontroller is known as modular circuit boards, which implies that components can be attached to the pins to create a unique circuit. The physics law that governs the functionality of the Arduino are Kirchhoff's Current Law which implies that all currents entering a junction equal the current exiting the junction, Kirchhoff's Voltage Law states that the sum of the voltages at every point in a loop is equal to 0, and

Ohm's Law which states that the voltage at any given point is product of the current and the resistance (V=IR) (The Actual Physics, n.d).

Ultrasonic sensors (Voltatek, n.d) emit and receive signals in the form of soundwaves. They emit soundwaves and measure the distance based on the time it takes for the wave to hit the sensor back. The formula used to calculate the distance from the sensor is Distance = ½ T x C, where T = Time in seconds, C = the speed of sound. The speed of sounds However varies depending on the temperature and humidity, so this calculation must be adjusted accordingly. For example, the speed of sound in dry air at 20 °C = 344 m / s (Speed of sound in air).

Lastly, the automated barrier operates with the integration of the outputs from the counter, thermal and mask detection represented in ***Figures 1*** and ***2*** labeled 3. Depending on these inputs the barrier is controlled. The Arduino controller is used to control the voltage supply to the motor depending on the inputs received from the counter and the mask and temperature detection.

Figure E6 represent a block diagram of the overall functionality of the software code. Full implementation of the code can be referred to in ***Table H1*** which represents the AND logic that is responsible for controlling the gates as shown in ***Figures 1*** and ***2***. Circuit in ***Figure F4*** consists of using an H-bridge to open and close the barrier by controlling the power provided. The barrier is assumed to rotate $0° \; to \; 90°$. In order to accomplish that the servo motor library is used in the code to increment or decrement the angle accordingly until the respective value $0° \; to \; 90°$. ***Figure E5*** represents the sub system connectivity of the barrier functionality of the design solution.

3.0 DESIGN DEFENSE

In this section the final design is defended in areas such as its primary function, safety of users, economics of the design, the design's environmental and social impacts. Each of these areas are thoroughly explained and are supported with related calculations and reliable resources.

3.1 PRIMARY FUNCTION

The automated COVID screening design has more than one function. It is designed to reduce the separation of COVID-19 and ensure that the customers follow the restrictions through detecting the face mask. Also, it measures customers' temperature. If the customer did not meet one of these requirements, he/she would not be allowed to go to the store using the barriers. This design checks for the restrictions and ensures the people's safety and the staff inside the stores. This design is also capable of counting the number of customers in stores, and it is programmed to not let people in if the maximum number of people allowed are inside the store.

3.1.1 DEFENSE OF RASPBERRY PI V2 CAMERA (FOR MASK)

Minimizing the design's complexity is one of the design team's goals by choosing simple, easy to implement, low cost and practical components such as the raspberry pi camera. As shown in ***Figure 1,*** which shows the overall design, the camera used to detect the face mask is placed in a container that can be tilt based on the person's height. This process requires a small and not heavy camera is required. The raspberry camera was the best option since It is small, around 25 mm x 24 mm x 9 mm, and it weighs 3 g (Raspberry Pi n.d.). The small size of the camera is critical for the tilting, but it is also more straightforward when it comes to manufacturing.

It has a resolution of 8 megapixels (Raspberry Pi n.d.), which makes this camera very accurate in recognizing the person's face because 1 megapixel equals 1 million pixels, which means that this camera can produce images with 8 million total pixels (Mesnik, 2020). Cameras that have this feature can capture more details (Mesnik, 2020) which are required to recognize the customer's face and ensure that the customers are wearing the face mask correctly with the assist of the code. Compared with other models, this V2 camera has a minimum focal length of 3.04 mm (Raspberry Pi n.d.). The smaller the focal length, the lower the magnification and the wider the field of view (Mesnik, 2020). For the raspberry pi v2 camera, the horizontal field of view is 62.2 degrees, and the vertical field of view is 48.8 degrees with a focal ratio of 2.0 (Raspberry Pi, n.d.).

The code implemented with this camera increases its security of the raspberry camera since it does not save the videos or the customers' images. Also, there is no evidence for the raspberry pi camera to have a hazardous impact on people and the environment.

3.1.2 DEFENSE OF THE FACE MASK DETECTION ALGORITHM

The algorithm detects the accuracy of face coverage (i.e., completely or partially wearing the mask). The definition for a complete coverage is that the nose and mouth are fully covered. The algorithm was tested by one of the team members as shown in ***Table H2*** sections 1,2 and 3. The initial image represents a 100% mask coverage. While the second picture represents a partial coverage in which the detection is 77.60% of no face coverage. As a result, only 22.4% of the mask was detected. The third image represents a 100% of no face coverage.

Figure H3 represents the accuracy for both the training and testing sets. The word *'accuracy'* in the figure represents the accuracy of the algorithm tested against the training set. While the *'val_accuracy'* represents the accuracy of the algorithm tested against the testing set**.** ***Table H3*** was constructed using the values from ***Figure H3.*** The '*20 epochs'* from the figure represents the number of times the neural network runs when being trained. Each epoch consists of 120 training images in which the algorithm is going to be trained by. The data is divided into ~50% for training and ~50% for testing. CNN manages to get an average accuracy of 97.3% on the training set and 98.8% on the testing as shown in ***Table H3.***

3.1.3 DEFENSE OF BARRIERS

The automated barrier is designed keeping in mind some of the constraints like safety and ease of use along with the criteria of the design being accessible to all. To carry out the latter, the chosen design has a width of 1000 mm in order to follow the city of Guelph accessibility guidelines of having the gate width of at least 950 mm. (City of Guelph, 2015) One of the other main considerations of the design is suitable motors for swing gates as this would determine the effective speed of the motor. Upon careful calculations using engineering principles like the parallel axis theorem, Newton's second law, and full cycle fatigue stresses, the chosen motor is a DC motor of model MM312-2 12V DC. (McMaster Electric, n.d.) This conclusion was drawn based on the assumption of having the gates open/close within 2 seconds as swing barriers usually have a barrier open/close time between 1-2 seconds. (Anson, n.d.) The calculations for these are shown in **Appendix D, *Figure D4*** with the respective design parameters in ***Table D2***. Upon fatigue analysis it was found that the swing barrier gates can have at least more than 1 million cycles as the endurance limit of 316L stainless steel being used is much greater than the calculated maximum stress and this can be seen in **Appendix D** below ***Figure D4***. Additionally, some of the reasons behind choosing a brushless DC motor includes noiseless operation with lubrication for maintenance and is that it provides a good durability of holding the torque in a stationary position which would be useful in preventing the gate getting opened by someone using a harsh force like kicking the barrier gate.(Nundnet, 2020) Therefore, the automated barrier system is designed on the basis of functional requirements and has also considered different scenarios like to prevent someone kicking the gate open and to prevent fatigue failure of the hinge of the gate as it would undergo repeated cyclic stress. With all of these, the barrier gates do achieve beyond the functionality of the system in the design solution.

3.1.4 DEFENSE OF THE THERMAL CAMERA

The high temperature is one of the most significant symptoms of COVID- 19. Based on the design matrix that the team created at the very first stages of the design process, it is very important to find an accurate, affordable, low complexity, and safe design. To do so the components that have the higher scores are used. To accurately measure the temperature of human body there are many options available in the market right now.

FLIR thermal cameras is widely used to measure objects and body temperature. The accuracy of theses cameras is ±2%°C (Kirimtat et al., 2020); however, their cost is very high, it ranges from 600$ to 15000$ (Kirimtat et al., 2020). These types of cameras can make the design very expensive and unaffordable by all stores. Also, the operation temperatures of this type of thermal cameras might not be suitable to all environments since it has an operation temperature of 0°C~40°C (Kirimtat et al., 2020) which makes this option not functioning in cold countries such as Canada. All these reasons drove the design team to search for different option.

The Non-Contact Infrared Temperature Sensor, IR Sensor Module MLX90614, was another option that the design group found and tried to fit it in the solution. The accuracy of this sensor ± 0.02°C (Components101, 2021) which is great especially that it is way cheaper than the FLIR thermal cameras, only 30 $ according to Amazon this year. However, the cons of this sensor are that the distance between the object and the sensor should be between 2cm-5cm (Components101,2021). This means that the high accuracy can be found only if the device is very close to the person which is not safe because the team is trying to keep a safe distance not only between people but also between people and any other objects because COVID-19 can be transmitted through touching infected objects. This option failed to satisfy the criteria of the design solution.

Finally, the team at ROBOTEX found the option that can best meet all the requirements of the decision matrix. an accurate and affordable option which is MLX90640 thermal camera. This thermal camera has a -40 °C to 85°C operational temperature range and it can measure temperatures between -40°C to 300°C (Shawn, 2019). This thermal camera maintains high levels of precisions with its measurements delivering an accuracy of ± 1°C (Shawn, 2019). One key feature of the MLX90640 is its low cost since it does not need a frequent re-calibration which lowering the system cost and expense (Shawn, 2019). The field of view is 55°x35° is suitable to this design since there is no need to cover wide area (Shawn, 2019). The MLX90640 thermal camera consist of 768 IR pixel (Shawn, 2019) which makes it very accurate. The distance of the object and the camera is perfect for this design, it can measure the temperature of the body when the person stands in a range of 1m-5m far from the camera (waveShare, n.d). Moreover, the small size of this camera,28 mm x 16 mm (WaveShare, n.d), makes the design simpler and takes less space. It can also be easily connected to a raspberry pi Arduino which reduces the over all complexity of the design.

Since MLX90640 uses infrared system to measure the temperature body, it is safe to be used on people because it measures the light emitted from the person's body, so it does not have any radiation.

3.1.5 DEFENSE OF ULTRASONIC SENSOR (COUNTER)

One of the major constraints set for this design is high accuracy, and in this case, the accuracy of the counting component of the design. To effectively help reduce the spread of the virus, it was crucial that the chosen sensor for the design is able to provide accurate results in order to ensure that the maximum capacity inside the store is well-maintained at all times. During the designing process, the team members at ROBOTEX considered two different sensors when selecting the appropriate device that can perform the task efficiently: Infrared sensors and ultrasonic sensors. By constructing an engineering decision matrix (***Table B5***) and implementing the two sensor circuits in TinkerCAD (***Figure F1*** and ***F2***), it was observed that the ultrasonic sensor is the best option as it offers the safest, most functional and accurate results.

The perfect fit for the counter functionality is a device that is able to provide accurate data regardless of location, weather or time. Hence, HC-SR04 Ultrasonic sensors (Voltatek, n.d) are being used for human detection. They fall within a 3mm accuracy, they detect humans within a range of up to 5m with a 15-degree angle as shown in ***Figure D1***. Their working temperature range is from -20 - 80℃ which is compatible with the different seasons of the year unlike other types of sensors. This type of ultrasonic sensor is compatible with the Arduino Uno (Arduino, n.d) that is being used as part of the device. The microcontroller operates at a voltage of 5 V, with a high clock speed of 16 MHz and offers 14 digital I/O pins.

Another reason ultrasonic sensor is being used is due to the safety factor, especially when compared with its alternative, infrared sensor. Infrared sensors use infrared waves. They encompass wavelengths from the nominal red edge of the visible spectrum around 700 nanometers (frequency of 430GHz), to 1 millimeter (300GHz) (NASA Science, 2016). Too much exposure to infrared waves may cause various hazards to human body, such as damage to the cornea of the eye and skin (NASA Science, 2016). Ultrasounds, on the other hand, are by far proven to be less harmless than infrared waves. In order for ultrasounds to be considered harmful to humans, it needs to reach an excess number of decibels (120 decibels and higher) (NIH, 2018), which is an impossible task to achieve for HC-SR04, an ultrasonic sensor with only 5m human detection range.

In summary, ultrasonic sensors are currently the device used at ROBOTEX to keep count of the number of people entering and exiting the store due to its safe functionality that offers high accuracy when compared to other potential kiosk sensors.

3.2 SAFETY

The safety pertaining to the barriers include that the automated system allows sufficient time for the customers to pass through as it can be seen in the code provided in ***Table H1 #4*** in line 61. The gate gives about 5 second as it is the suggested safe time for a person to pass through. (turnstile.us, 2020) For stores that would require more than one barrier gate system, there would be a protective shield that would be placed between systems to follow the COVID-19 measures in keeping customers safe. Additionally, within the design solution there is a space allotted for a hand sanitizer and it can be seen in ***Figure 1***. This gives store owners the choice of stationing a hand sanitizer at the barriers or continuing to use the hand sanitizers that are already in place. Nevertheless, the design which includes a hand sanitizer station promotes safety and encourages hygiene.

As the design is meant to be implemented at the entrance of businesses that are used by the public, it is important that it is compliant under the American with Disabilities Act to allow for all patrons to use the device, regardless of disability. As such, some criteria designs need to be considered, such as allowing 32 inches of movability, and doors in series need to be at least 48 inches apart from each other under section 404.2.6 (U.S. Access Board, n.d.). The doors in question for this scenario are the turnstile and the main entrance door. As seen in the appendix under ***Figure A2*** when the turnstile doors are open, they give rise to about 1m, or 39 inches, of open space. Additionally, the turnstile is appropriately spaced relative to the door, about 1.45m, or 57 inches, which can be seen in ***Figure A2***. It is assumed that customers will follow the procedure accordingly, and not try to bypass the system by going through the open sides.

Since the structure will be installed into place in front of a store, ROBOTEX considered the most effective form of power for the device. In the end, it was decided that the operation will be powered by electricity provided from the store. To keep it simple and accessible for all stores, it will use a standard type B outlet seen in figure 3. This type of outlet is seen in most North American stores, and thus prevents store owners from buying special adaptors that may raise costs. This plug is compatible with 100-127V (Type B Plug & Socket, n.d.), and this will provide sufficient power to run it continuously. The wire will be insulated, waterproof and extends out of the device in a manner that isn't a tripping hazard to patrons, seen in ***Figure 1*** on the side of the stand as well, from using batteries, it allows the device to be safer for both the environment and for people, with the former being touched on in another section. With battery usage, there are many things to consider, such as how to store, dispose, maintain, and change the battery. Since batteries can pose a risk of exploding if any of these are done improperly, it can be considered that the design is safer as a result (Battery Safety, 2017). Using electricity would allow the device to be used even during hotter weathers without fear of overheating or damage.

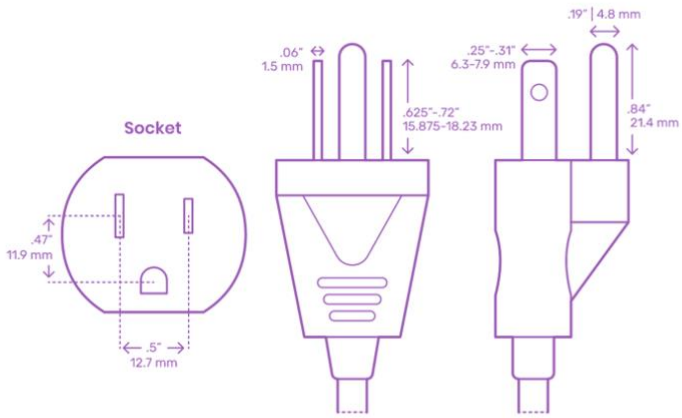

Figure 3. Plug Type B (Type B Plug & Socket, n.d.)

3.3 ECONOMICS

The Automated Screening COVID device will have positive economic impact. The design was created to replace the front-line workers and doing the job they were doing accurately. This design will not only safe those worker's life and limit the separation of COVID-19, but it will reduce the cost of forcing the pandemic regulations such as wearing face mask and measuring the temperatures. Studies show that wearing face masks could be a requirement for years according to some predictions (Nova, 2020). The rate of the workers who are measuring temperature and checking for the face mask can be range from $18-$25 (Nova, 2020) and most stores operation hours are minimum 12 hours and if a store open 7 days an estimation of the cost of checking the face mask and temperature is approximately $77,000-$108,000 spend only as a salary. As it can be seen in ***Table I8*** in the appendix which shows Total Costs required for the implementation of the design the Automated Screening

COVID device cost around $6793.51 only which is way less than the salary that the stores are paying right now.

3.4 ENVIRONMENTAL IMPACT

As having a low environmental impact was important during the production of the finalized design, it played a key role in determining which material to use for constructing the main frame. As seen in ***Table D3*** the carbon emissions for many substitutes were considered prior to selecting. Among other factors, stainless steel 316L and polycarbonate was chosen, with more details shown in ***Table B6*** and ***B7***. The materials are of high quality, and are rather durable, thus the useful can is longer as a result. These materials were selected to be purchased from Home Depot and Rona which encourages not only the economy but lowers the carbon emission needed to transport the design, as they are readily available throughout America and Canada. However, to allow for the design to be more just in the future, different suppliers can be examined to help promote local businesses, even if that means decreasing revenues. A greater analysis of the environmental impact can be seen in **Appendix J**, under charts ***J1***, ***J2***, and ***J3***, along with the emissions during production, operation, and end of life.

Lastly, the decision to use electricity to power the screener rather than batteries help improve the environmental impact substantially. First off, there is less waste produced, but also it removes any concerns about what would happen should it be disposed of incorrectly. Batteries are considered hazardous waste and can harm both soil and air quality as a result - impacting pregnant women and small children the most (Battery University., n.d.). Under the City of Toronto's procedures, batteries would have to be specially disposed of which could trouble clients and make it more incontinent to use (City of Toronto, n.d.). Using electricity prevents this from occurring.

3.5 SOCIAL IMPACT

ROBOTEX hopes to reduce the amount of COVID infections and promote proper COVID practices among the general public, allowing for a healthier and happier society. The center of the design was to help frontline works by reducing their chances of infection and stresses they may from working. Doing so will indirectly account for less deaths and hospitalizations, freeing up some strain for healthcare workers as a result. Some may be negatively impacted by the design- people who are currently unwilling to wear masks or follow social distancing rules. ROBOTEX hopes that by allowing this strict, non-negotiable method, users will follow protocols more seriously. Companies who were previously unable to mandate this law can now do so without fearing the safety of their employees.

With the entire process being automated and stress free, stores can quickly adapt to changing pandemic regulations and capacity limits with the customizable features. Especially for areas such as Ontario, where these values are constantly fluctuating, it ensures that clients can meet requirements without any fear of error. In addition, they can focus their manpower to enhance customer experience and satisfaction instead of assigning employees to conduct the screening process. The device will help benefit many other industry sectors such as the ore and mining sector, where parts are gathered, but it also aids other local companies such as steel manufacturing or plastic production. With ROBOTEX as a client, it increases the demand and allows for business to improve.

4.0 RISKS AND UNCERTAINTIES

A risk is a possibility for a design to meet all the requirements and success or fail in satisfying them. Although the risk is one of the factors that every engineer is aware of and all designers working on reducing the design's risk to fail, risks are still expected in any design due to the assumptions and uncertainties made during the design process.

In general, two main types of risks can prove the failure of a design: design-related risks and usage-related risks. One significant risk related to the design is that the device is powered directly, and it does not have any external power supplies based on the assumption that the store has an electrical power switch near the entrance. The stores need to ensure that they have a backup power generator if there will be any power cut off; otherwise, if there is no power, the device will not work.

Another design-related risk is the store entrance door; the store needs to be aware that this design solution is created based on the assumption that the store has two entrance doors so that one of these doors will be used as entrance only and the other door will be used as an exit only. Ignoring this factor will result in the ultrasonic sensor stop working and, as a result, will not be able to account for the number of people in the store, which is one of the keys to open the barriers by the AND gate as it can be seen in ***Figure 2***. However, if a store has only one door, this design can be customized to meet their criteria.

As it is well known now that the COVID-19 virus can be transmitted mainly by touching the infected surfaces, the design team tried to reduce the risk of getting this virus by choosing a touch-free component in this design, MLX90640 thermal camera used in measuring the temperature. However, the customers need to avoid touching other device surfaces like the barriers and the other materials.

Additionally, any new product can face selling and marketing risks due to few unknown variables. The overall cost of the design can be considered as an example. To create such a device that can check for face masks, temperature, and the number of people in stores accurately, several electrical components are used, resulting in a relatively higher cost device than the simple and less accurate devices currently in the market.

5.0 CONCLUSION AND RECOMMENDATIONS

Overall, ROBOTEX has created this unique design that provides a solution towards addressing concerns about COVID safety. The proposed design has met all constraints and optimized the criteria selected by the team, and provides various social, economic, and environmental benefits on top of improving the health of patrons and users. In depth analysis has been done to examine the details of the camera, barriers, and sensors, along with writing code for the design to work.

For future recommendations, looking into ways to prevent people from sneaking past the screener by going through the open gaps between the sides ***Figure 1*** could be implemented. To help ensure more flexibility, slidable “walls” could be implemented so that regardless of if the store has a single or double entry point customers wouldn’t be able to bypass the system. Additionally, currently, the plan is to transport the screener directly to the client, where it’ll be assembled on site at the location using someone from the company. As businesses grow, ROBOTEX hopes to employ other companies that could help with this installation process to help encourage collaborative relations and boost the economy too.

Other future aspects can be examined to improve the efficiency of the device, such as developing a better sensor or adding additional screen procedures that will allow for other diseases once COVID conditions improve. Whatever the improvement, the effectiveness of the new design will be examined through the functional unit as defined in Appendix J- the number of people scanned per minute.

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7.0 APPENDICES

7.1 APPENDIX A: TECHNICAL SKETCHES AND DIGITAL DESIGNS DEVELOPED

7.1.1 TECHNICAL HAND SKETCHES DEVELOPED

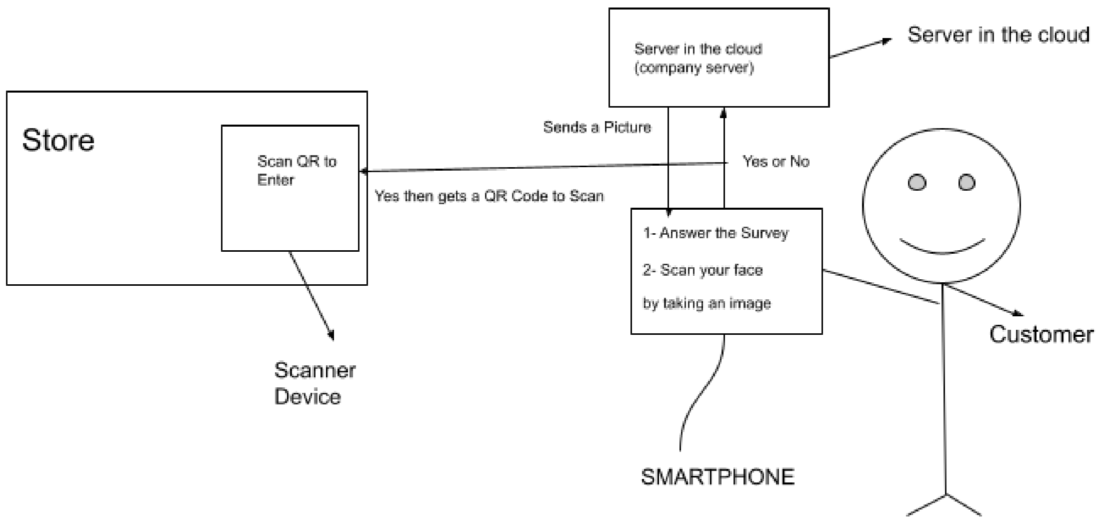


Figure A1. Technical Sketch for Design Developed 1 - Mobile Application

7.1.2 2D DRAWINGS DEVELOPED IN SOLIDWORKS

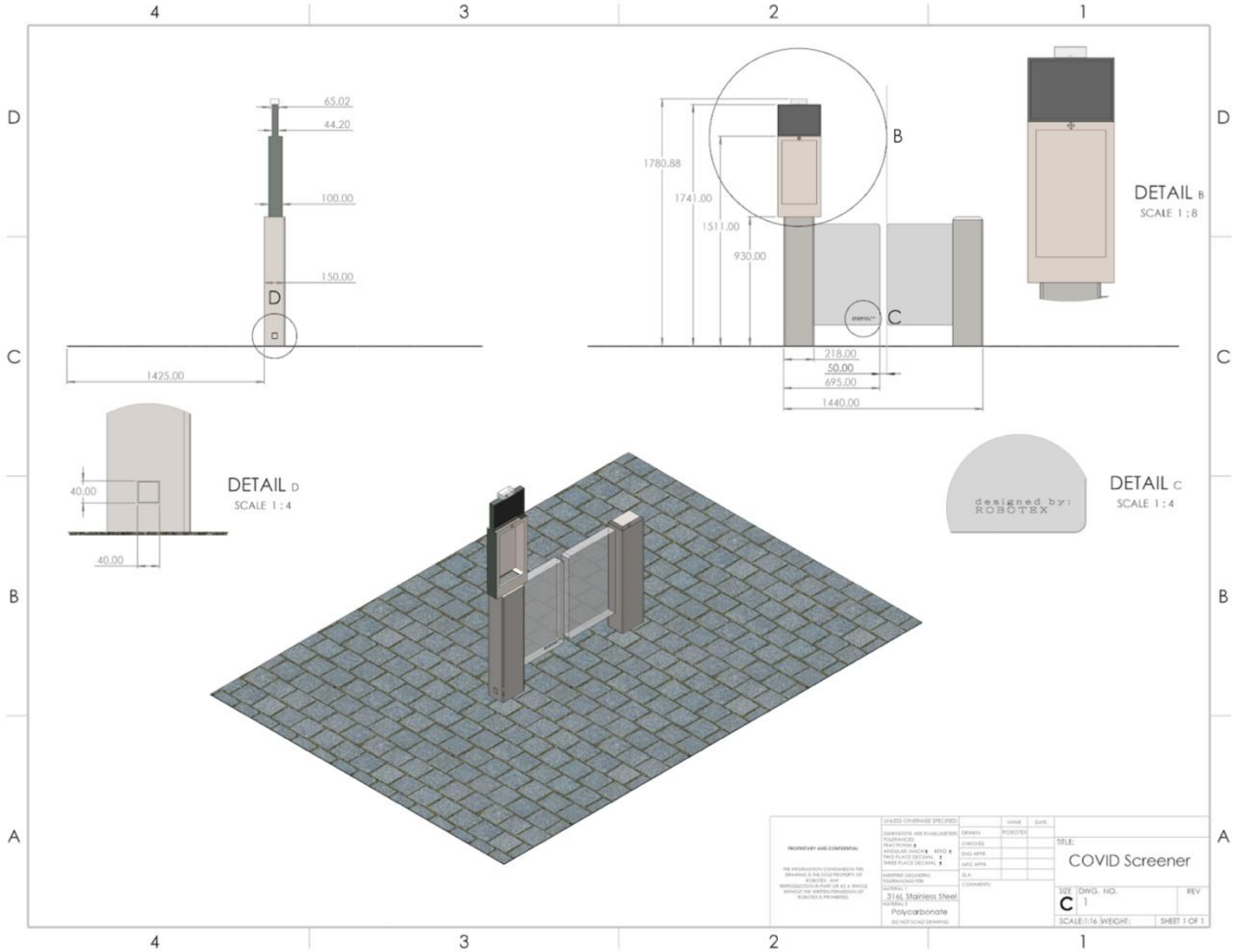


Figure A2. Detailed Design Drawing Highlighting Dimensions (in mm) of Main Body of the Device

7.2 APPENDIX B: DECISION MATRICES

7.2.1 SCORING RUBRIC FOR DEVELOPED SOLUTIONS AND FINAL DESIGN DECISION MATRIX RANKING

Table B1. Decisions Matrix Ranking

Scoring Rubric			
#	**Criteria**	**Score**	**Justification**
1	**Minimize cost of the design.**	1-3	This implies that the cost of the design solution will be greater than or equal to $2200.
		4-7	This implies that the cost of the design solution will be between $600 and $2200.
		8-10	This implies that the cost of the design solution is less than $600.
2	**Maximize accuracy of mask detector**	1-3	This implies that the accuracy of the mask detection method used in the design solution will be less than or equal to 80%.
		4-7	This implies that the accuracy of the mask detection method used in the design solution will be between 80% and 97%.
		8-10	This implies that the accuracy of the mask detection method used for the design solution will be greater than or equal to 98%.
3	**Maximize the temperature measurement accuracy.**	1-3	This implies that the accuracy of the temperature measuring method used in the design solution is +/- 1C.
		4-7	This implies that the accuracy of the temperature measuring method used in the design solution is between +/- 0.3C and +/- 1C.
		8-10	This implies that the accuracy of the temperature measuring method used in the design solution is +/- 0.3C.
4	**Minimize the complexity of the**	1-3	This implies that professional installation is required in the assembly of the design solution.

	assembly of the design product.	4-7	This implies that some assistance is needed in the assembly of the design solution.
		8-10	This implies that the assembly of the design solution only requires self-installation by the client.
5	**Minimize the number of components.**	1-3	This implies that the implementation design solution requires 10 or more components.
		4-7	This implies that the implementation of the design solution requires 4 to 9 components.
		8-10	This implies that the implementation of the design solution requires 1 to 3 components.
6	**Maximize accuracy of the counter.**	1-3	This implies that the accuracy of the counter is less than or equal to 30%. This means that the component of the device that is responsible for counting the number of people going in is poorly programmed in a way that does not offer accurate data collection within the system.
		4-7	This implies that the accuracy of the counter is between 30% and 90%. This means that the component of the device that is responsible for counting the number of people going in is programmed in a way that offers partially accurate data collection within the system.
		8-10	This implies that the accuracy of the counter is greater than or equal to 90%. This means that the component of the device that is responsible for counting the number of people going in is programmed in a way that ensures accurate data collection within the system.
7	**Maximize accessibility of the device.**	1-3	This implies that the design solution is not accessible to people of all demographics. The evaluation should take people of different ages and financial abilities into account, which in this case shows a low accessibility rate. Therefore, this category signifies an accessibility rate that is less than or equal 40%.
		4-7	This design solution implies that it is moderately accessible, signifying an accessibility rate that is between 40% and 80%.
		8-10	This implies that the design solution is highly accessible to people of all demographics. This means that the design solution is accessible to people of different ages/generations and different financial abilities. Therefore, this category signifies an accessibility rate that is higher than or equal to 80%.

7.2.2 DECISION MATRICES FOR SOLUTIONS DEVELOPED

Table B2. Solution Developed 1 Decision Matrix

#	Criteria	Ranking Weight (%)	Score (1-10)	Weighted Score (Score x Ranking Weight)	Explanation
1	**Minimize cost of the design.**	15	8	1.20	This design solution is made of components that are free open sources which highly optimize the price of the solution. In addition, the access control system is considered highly affordable in comparison to the client's financial abilities. However, the cost of the component responsible for the QR scanning with a relatively high performance approximately ranges between $350 and $600.
2	**Maximize accuracy of mask detector.**	18	8	1.44	Convolutional Neural Network (CNN), a deep learning algorithm, was used to implement the mask detection for the presented solution which resulted in a 98% accuracy.
3	**Maximize the temperature measurement accuracy.**	20	1	0.2	For the proposed design neither a thermometer nor a thermal camera is being used to measure the temperature of the customers. A survey is used as part of the proposed design to take the precautions and ask relative questions in regard to the COVID measures. The recommended component of the design solution relies heavily on the honesty of the customers which according to the research, only 57% of people were honest when answering COVID-19 surveys (Brock University, 2021).

4	**Minimize the complexity of the assembly of the design product.**	6.5	3	0.195	For the suggested solution, all components that make up the design solution are internally connected to control the door, transfer and update the data for the customers which implies that a professional installation is required for the assembly of the solution on the client's sites.
5	**Minimize the number of components**	6.5	8	0.52	The design solution consists of three main components: a mobile phone, a QR door access control, and sensors to help with the counter functionality of the design.
6	**Maximize accuracy of the counter.**	19	8	1.52	The design solution uses a QR scanner device that is connected to a database which will be incremented and decremented accordingly (codeREADr, n.d.). The mobile application and the database update time will have some lag which will cause an inaccuracy
7	**Maximize accessibility of the device.**	15	8	1.2	A smartphone and an internet connection are required by the customer for the face mask detection and to fill the survey. That being said the other components of the design are highly accessible for the customers as they will be embedded in the client's sites. However, the lack of a smartphone with an internet connection will limit the accessibility of the customer to the store (Government of Canada, 2018).
TOTAL:				**6.275**	

Table B3. Solution Developed 2 Decision Matrix

#	Criteria	Ranking Weight (%)	Score (1-10)	Weighted Score (Score x Ranking Weight)	Explanation
1	**Minimize cost of the design.**	15	3	0.45	The design mainly relies on the CCTV/IP cameras that are used currently at the store. The only other main component to be purchased would be a wall mounted thermal image body temperature camera. The price of such a product can be approximated to around $2,800 (Brick House Security, n.d.)
2	**Maximize accuracy of mask detector.**	18	7	1.26	The mask detection software which is incorporated in this design uses an AI network and through implementation the accuracy was found to be 97%. (App Store, n.d.)
3	**Maximize the accuracy of the thermometer.**	20	9	1.8	This design alternative consists of a separate thermal body temperature camera where it uses an AI thermal imaging technology to perform with a high accuracy of ±0.3℃ up to a range of 10 feet (Brick House Security, n.d.)
4	**Minimize the complexity of the assembly of the design product.**	6.5	4	0.26	The only component that requires installation would be the thermal camera at the entrance of the store as one of the assumptions of this proposed solution includes CCTV/IP cameras that are already in use at the store's entrance and exit doors. Also, uploading the software onto the connected computer system to incorporate the required codes for mask detection and counting may not require a professional to set it up.

5	**Minimize the number of components**	6.5	6	0.455	This design solution comprises main components such as thermal camera to measure the body temperature, CCTV/IP cameras, and a connected computer monitoring system to operate.
6	**Maximize accuracy of the counter.**	19	8	1.52	Assuming that the visual field of the camera completely covers both the entrance and exit doors, high accuracy of the number of people currently in the store is achieved through a proper balance between object tracking, detection and recognition.
7	**Maximize accessibility of the device.**	15	8	1.2	Inclusive of all customers as there are no additional requirements needed from them. However, this design alternative restricts to stores that are already using CCTV/IP cameras at the entrance and exit doors.
TOTAL:				**6.945**	

7.2.3 DECISION MATRIX FOR FINAL DESIGN

Table B4. Final Design Decision Matrix

#	Criteria	Ranking Weight (%)	Score (1-10)	Weighted Score (Score x Ranking Weight)	Explanation
1	**Minimize cost of the design.**	15	2	0.3	The design solution consists of thermal and CCTV cameras, which are very accurate and fast, making them expensive. Moreover, this design has multiple functions (detect high temperature, face mask detection, automated hand sanitizer, controlling the doors, and displaying the numbers of people in the building).
2	**Maximize accuracy of mask detector.**	18	7	1.26	The software used in this design solution has a high accuracy since it utilized the Al network. By running the code, the accuracy of detecting the mask was found to be 97%.
3	**Maximize the accuracy of the thermometer.**	20	9	1.8	This design uses the most accurate thermal camera to measure people’s body temperatures. This camera uses the AI network which increases its accuracy to ±0.3℃ and enables the camera to take temperature measurements for larger groups of people.
4	**Minimize the complexity of the assembly of the design product.**	6.5	9	0.59	Although this design solution has multiple components that work separately, it is designed to reduce the size and make it easy to assemble; therefore, the CCTV and the thermal cameras will be held together with the automated hand sanitizer and the door controller. All that will decrease the design assembly complexity.

5	**Minimize the number of components**	6.5	7	0.46	The main parts of this design are put together, such as the two cameras, to minimize the number of the components and reduce the size and decrease assembly complexity, making them one component.
6	**Maximize accuracy of the counter.**	19	9	1.71	This design uses a very accurate and most advanced technology in the people counting market, The Time-of-Flight people counting technology. This technology uses a fixed sensor to the ceiling in a small and very simple device to achieve more depth of people's vision and movement than any other counting systems such as the thermal methods. The sensor sends a signal out above the area to be measured then the small device will record the reflection of infrared, which bounces back to the sensor. This makes the accuracy of this design alternative very high.
7	**Maximize accessibility of the device.**	15	10	1.5	The accessibility of this design is very high as it stands alone, which means that any buildings, institutions, or stores can buy one and use it without any restrictions because all its components, such as CCTV camera, thermal camera, and door controller, are available in this design. Also, it is highly accessible by the public since it will be programmed to utilize all the checking processes without any affords from customers.
TOTAL:				**7.62**	

7.2.4 DECISION MATRIX TO DEFEND ULTRASONIC SENSOR

Table B5. Engineering Decision Matrix for IR Sensor VS. Ultrasonic Sensor

		Type of Sensor		Justification
#	Criterion	Infrared Sensor	Ultrasonic Sensor	
1	**Effectiveness**	1	1	Both sensors are widely used for counting purposes and both imply sufficient results (IOP Conference Series: Materials Science and Engineering, 2016)
2	**Simplicity**	1	1	Constructed circuits in TinkerCAD imply that both sensors are simple to build.
3	**Cost-effectiveness**	1	0	Infrared sensors are widely used to their low cost.
4	**Accuracy**	0	1	Ultrasonic sensors are more reliable for numerical representation of distance and proximity applications due to their high accuracy (Learn Robotics, 2019)
5	**Location Flexibility**	0	1	Ultrasonic Sensors are completely insensitive to light, dirt, dust, and high-moisture environments. The functionality of Infrared sensors can be impacted by the sunlight if used outdoors (The Twenty-Sixth International Training Course, 2016).
TOTAL POINTS		**3**	**4**	

7.2.5 DECISION MATRIX FOR MATERIAL PROPERTIES OF FINAL DESIGN

Table B6. Decision Matrix of Metal Casing Material

Criteria	Material Properties				Weighting	Ranking			
	304 Stainless Steel	**5052-O Aluminium**	**6061 Aluminium**	**316l Stainless Steel**		**304 Stainless Steel**	**5052-O Aluminium**	**6061 Aluminium**	**316l Stainless Steel**
Environmental impact (kg CO2/kg i) (Refer to ***Table D3***)	6.81	1.41x10^4	1.42x10^4	5.94	20	3	2	1	4
Average Cost ($/lb) (ScrapMonster, 2021)	0.56	0.76	0.49	0.76	30	2	1	3	1
Corrosion resistant (Schweitzer, 2003)	Med	Med	High	High	5	1	1	2	2
Thermal Conductivity (Btu/hr/ft2/F) (Schweitzer, 2003)	9.4	960	900	9.3	5	3	1	2	4
Hardness	215 (Metalen, 2021)	60-61 (Matmatch, 2021)	60 (Toulas, 2017)	215 (AK Steel)	10	2	1	1	2
Density (lb/in3) (Schweitzer, 2003)	0.29lb/in3	0.097 lb/in3	0.098lb/in3	0.286 lb/in3	15	1	4	3	2
Availability in Canadian Stores (Canadian Trade Index, 2021)	3	0	4	3	10				
WEIGHTED TOTAL					**100**	**21**	**16.5**	**22.5**	**23**

Table B7. Decision Matrix of Plastic related components

Criteria	Material Properties		Weighing	Ranking	
	Abs Thermoplastic	Polycarbonate		Abs Thermoplastic	Polycarbonate
Environmental impact (kg CO2/kg i) (Dielectric Manufacturing, 2021a;2021b)	9.1e7 - 1.02e8	4.27 - 4.71	20	1	2
Average Cost ($/in3) (Baker et. al, 1999)	0.032	0.073	30	2	1
Transparency/Clarity (Dielectric Manufacturing, 2021a;2021b)	med	high	10	1	2
Thermal Conductivity (Baker et. al, 1999)	lower	low	10	1	2
Availability in Canadian stores (Canadian Trade Index, 2021)	10	13	5	1	2
Density (g/cm3) (Baker et. al, 1999)	1.2	1.18	15	1	2
WEIGHTED TOTAL			**100**	**13**	**17**

7.3 APPENDIX C: SENSITIVITY ANALYSIS

Three weighting schemes were created based on the three stakeholders identified as: the ROBOTEX team, retailers and customers priorities. A sensitivity analysis in which the weight factors were altered to help in determining the best alternative solution. Tables C1-C3 demonstrate the results of changing the ranking weight according to the stakeholder needs. The blue highlighted cells represented an increase in the weighting and the cells highlighted in red indicate a decrease in the weighted score of that feature. The weighted score of each design alternative was calculated using the scores in section 2.3.1 With respect to the ROBOTEX team, maximizing the accuracy of the three main individual components that are responsible for: Mask detection, Temperature measure and counting the number of customers in the store have the most priorities. These criteria received a weighting of 18%, 20% and 19% respectively. The optimal alternative design based on the ROBOTEX team is the automated COVID screening station which received a total score of 7.62 points.

Table C1. Sensitivity analysis ranking according to ROBOTEX

#	Criteria	Ranking Weight (%)	Weighted Score 1st Design	Weighted Score 2nd Design	Weighted Score 3rd Design
1	**Minimize cost of the design.**	15	1.20	0.45	0.3
2	**Maximize accuracy of mask detector.**	18	1.44	1.26	1.26
3	**Maximize the accuracy of the thermometer.**	20	0.2	1.8	1.8
4	**Minimize the complexity of the assembly of the design product.**	6.5	0.195	0.26	0.59
5	**Minimize the number of components**	6.5	0.52	0.455	0.46
6	**Maximize accuracy of the counter.**	19	1.52	1.52	1.71
7	**Maximize accessibility of the device.**	15	1.2	1.2	1.5
TOTAL:			**6.275**	**6.945**	**7.62**

Retailers prioritize the criteria that minimizes the overall cost and maximize the accuracy of the design alternative, delivering a solution that is more accurate and cost effective than the existing solutions that are in the market. The weight of these criteria increased by 5% from 15% and 15% to 18% and 17% respectively. Moreover, Criteria such as the complexity of the assembly and the number of components of the device are not very important to the retailer as the accuracy and the cost since the assembly can be done by the ROBOTEX team as long as it is easy to be used by the customers which is the accessibility criteria that is important to the retailers. The weights of these criteria were decreased by 5% from 6.5% and 6.5% to 4 % and 4% respectively. The ideal design alternative in favour of retailers is the automated COVID screening station.

Table C2. Sensitivity analysis ranking according to Retailers

#	Criteria	Ranking Weight (%)	Weighted Score 1st Design	Weighted Score 2nd Design	Weighted Score 3rd Design
1	**Minimize cost of the design.**	18	1.44	0.54	0.36
2	**Maximize accuracy of mask detector.**	18	1.44	1.26	1.26
3	**Maximize the accuracy of the thermometer.**	20	0.2	1.8	1.8
4	**Minimize the complexity of the assembly of the design product.**	4	0.12	0.16	0.36
5	**Minimize the number of components**	4	0.32	0.24	0.28
6	**Maximize accuracy of the counter.**	19	1.52	1.52	1.71
7	**Maximize accessibility of the device.**	17	1.36	1.36	1.7
TOTAL:			**6.4**	**6.88**	**7.47**

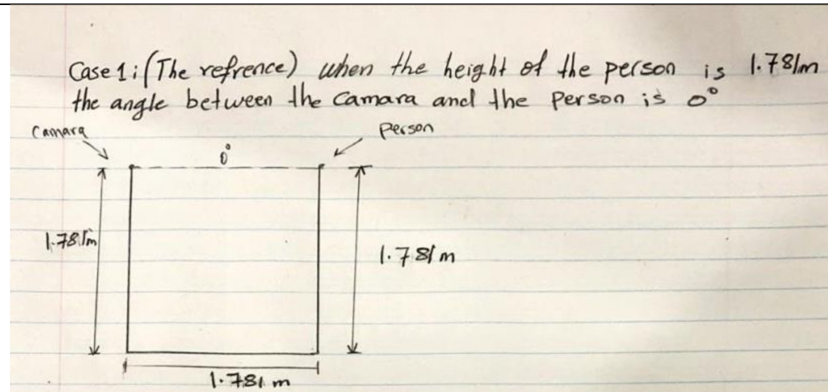
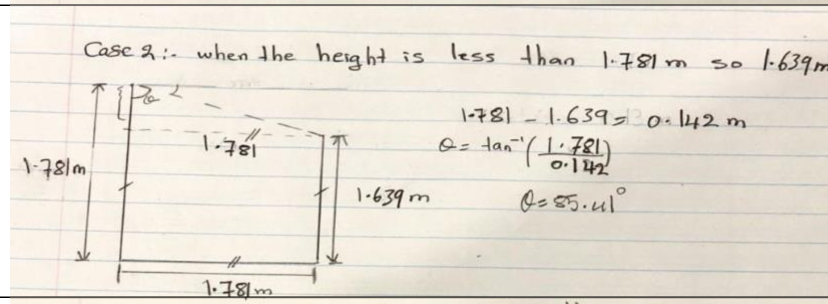
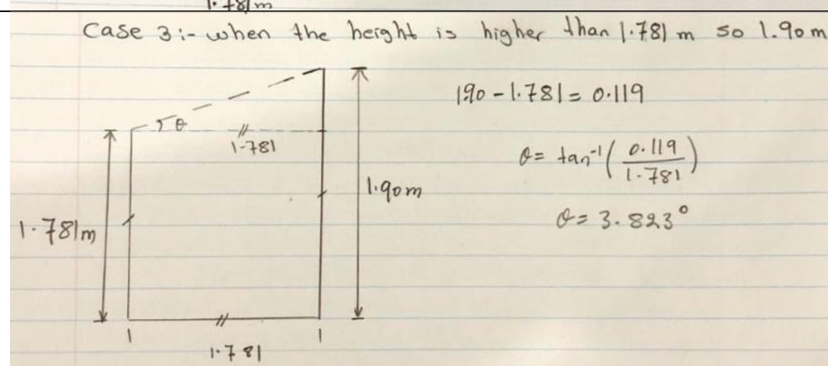
Customers prioritize the criteria that maximizes the accessibility of the device and provide high accuracy measurements as they would like to produce the least effort to visit a store safely and comfortably. The weight of these criteria increased by 5.5% from 6.5% and 15% to 7% and 20% respectively. Since the main important criteria for the customer is the high accessibility and performance, therefore criteria like the complexity of the assembly and the overall cost of the device are not important to them. The weights of these criteria were decreased by 5.5% from 15% and 6.5% to 13 % and 3% respectively. The ideal design alternative in favour of the customers is the automated COVID screening station.

Table C3. Sensitivity analysis ranking according to Customers

#	Criteria	Ranking Weight (%)	Weighted Score 1st Design	Weighted Score 2nd Design	Weighted Score 3rd Design
1	**Minimize cost of the design.**	13	1.04	0.39	0.26
2	**Maximize accuracy of mask detector.**	18	1.44	1.26	1.26
3	**Maximize the accuracy of the thermometer.**	20	0.2	1.8	1.8
4	**Minimize the complexity of the assembly of the design product.**	3	0.09	0.12	0.27
5	**Minimize the number of components**	7	0.56	0.42	0.49
6	**Maximize accuracy of the counter.**	19	1.52	1.52	1.71
7	**Maximize accessibility of the device.**	20	1.6	1.6	2.0
TOTAL			**6.45**	**7.11**	**7.79**

7.4 APPENDIX D: CALCULATIONS REQUIRED TO SUPPORT THE DESIGN

Table D1. Camera Angle Calculations

#1	
#2	
#3	

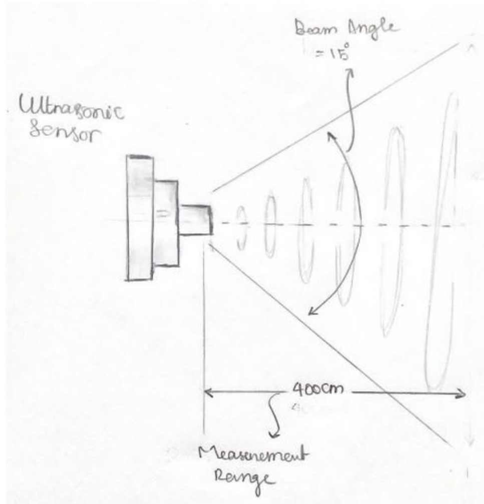


Figure D1. Ultrasonic Sensor with Beam Angle Measurement Range

Table D2. Parameters used in design calculations of barriers

$\rho_{(barrier)}$	1.2 g/cm3 (Omnexus, n.d.)
Height (H), barrier	730 mm
Width (W), barrier	475 mm
Thickness(t), barrier	1.5 mm
Full/ Maximum swing angle	0.5*pi* or 90 degrees
S_{ut}, 316L stainless steel	485 MPa (AZoM, 2019)
Time (open/close)	2s
$Tau_{f,}$kinetic friction (steel on steel)	0.62 (nyu, n.d.)

Table D3. Calculations for CO2 Emissions for Metal Materials

Material	Composition (%)	Co2 Emission for Chemical (Kg Co2/Kg I)	Calculation for Emission
Aluminium 5052	25 Mg	44.2	0.025*44.2+0.0025*20+0.9725*1.45e4 = 1.4102e4
	0.25 Cr	20	
	97.25 Al	14.5 tons * 1000kg/1ton = 1.45e4 (Saevarsdottir et al, 2019)	
Aluminium 6061	0.6 Si	4.78	0.006*4.78+0.0075*4.78+0.2*20+0.105*11.2+0.7*2.18 = 1.42e4
	0.28 Cu	3.44	
	1 Mg	44.2	
	0.2 Cr	20	
	97.92 Al	1.45e4	
Stainless Steel 304	2 Mn	3.8	0.02*3.8+0.0075*4.78+0.2*20+0.105*11.2+0.7*2.18 = 6.81
	0.75 Si	4.78	
	20 Cr	20	
	10.5 Ni	11.2	
	70 Fe	2.18	
Stainless Steel 316	2 Mn	3.8	0.02*3.8+0.0075*4.78+0.16*20+0.1*11.2+0.69645*2.18 = 5.94
	0.75 Si	4.78	
	16 Cr	20	
	10 Ni	11.2	
	69.045 Fe	2.18	
SOURCE CITED	**(JORFORS ET AL, 2020)**	**(JORFORS ET AL, 2020)**	

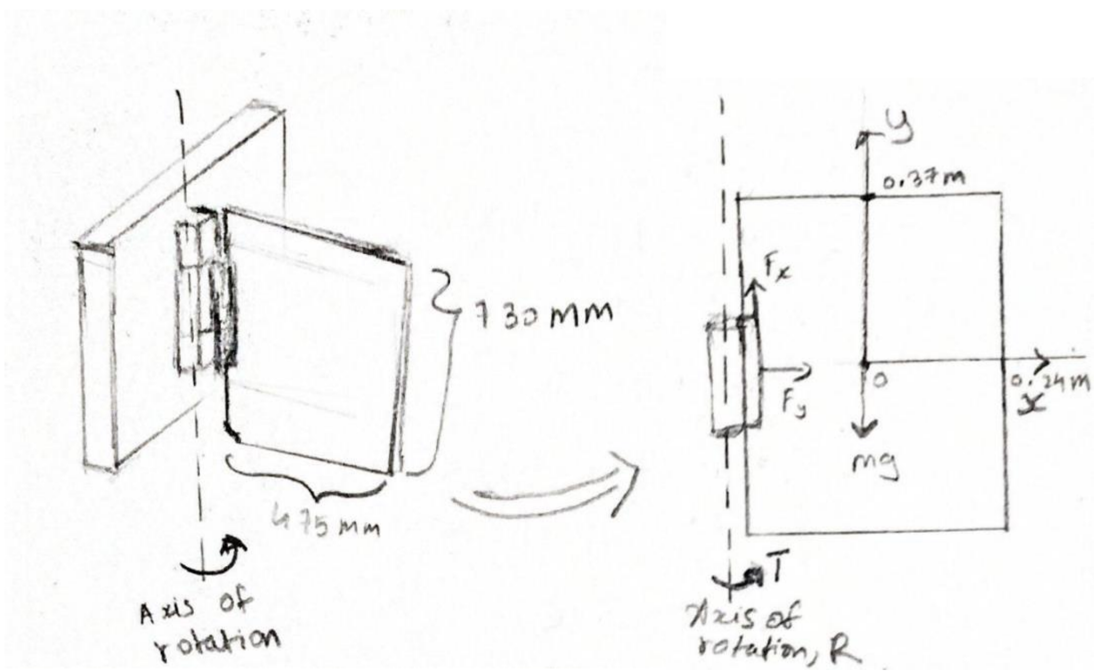


Figure D2. Free Body Diagram of Barrier

Table D4. Calculations Pertaining to DC Motor Design and Checking for Fatigue Failure

Calculations: $$I_R = I_y + md^2 \rightarrow From\ parallel\ axis\ theorem$$ $$m = V \times \rho = 475 \times 730 \times 1.5 \times 1.20 \times 10^{-3}\ [g] = 0.624\ kg$$ $$I_y = \frac{m}{12} \times b^2 = \frac{0.624}{12} \times (475 \times 10^{-3})^2 = 0.025\ kg\ m^2$$ $$I_R = 0.025 + (0.624 \times (347.5 \times 10^{-3})^2) = 0.0469\ kg\ m^2$$ Law of Conservation of Energy: $$\frac{1}{2} I({\omega_t}^2 - {\omega_{t'}}^2) = \tau_f\ (\Theta_t - \Theta_{t'}), where\ \tau_f\ = 0.62, is\ the\ kinetic\ friction\ for\ stainless\ steel\ on\ stainless\ steel$$

$$\Theta_t = \frac{\pi}{2} \quad \Theta_{t'} = 0 \ \omega_{t'} = 0$$

$$\therefore \omega_t = \sqrt{\frac{2}{I}\tau_f\left(\Theta_t - \Theta_{t'}\right)} = 6.44\frac{rad}{s}$$

$$n = \frac{60}{2\pi} \times \omega_t = 61.52\ rpm$$

From Newton's 2nd Law: $\sum T = I\ddot{\theta}$

$$\therefore T_{motor} - mg\omega\sin\big(\theta(t)\big) = I\ddot{\theta}(t)$$

Assuming the desired target where t=2 s and $\theta(t) = 0.5\pi \quad \ddot{\theta}(2) = 0$

$$\therefore T_{motor} = 0.624 \times 9.81 \times 475 \times 10^{-3} \times \sin(0.5\pi) = 2.91\ N.m$$

Based on the performance curve, choosing model MM312-2 12V DC motor with gear ratio 1:36

Fatigue Analysis:

$$S_{ut} = 485\ MPa < 200\ ksi\ (for\ 316L\ stainless\ steel)$$

$$S_{e'} = 0.5\ S_{ut} = 242.5\ MPa$$

$$\frac{T}{J} = \frac{\tau}{r}$$

$$\tau_{max} = \frac{3.3 \times 39 \times 10^{-3}}{\frac{\pi \times (78 \times 10^{-3})^4}{32}} = 35.42\ kPa$$

$$S_e = C_{load}C_{size}C_{surface}C_{temp}C_{reliability}S_{e'}$$

$$where\ , C_{load} = 1\ (bending)$$

$$C_{size} = 1.198 \times d^{-0.097} = 0.79$$

$$C_{surface} = 0.88$$

$$C_{temp} = 1\ for\ T \leq 450\ °C$$

$$C_{reliab} = 0.897\ for\ 90\%\ reliability$$

$$\therefore S_e = 151.22\ MPa$$

The fatigue endurance limit, $S_e \gg \tau_{max}$

7.5 APPENDIX E: SYSTEMATIC DIAGRAMS AND FIGURES TO SUPPORT FUNCTIONALITY OF DESIGN COMPONENTS

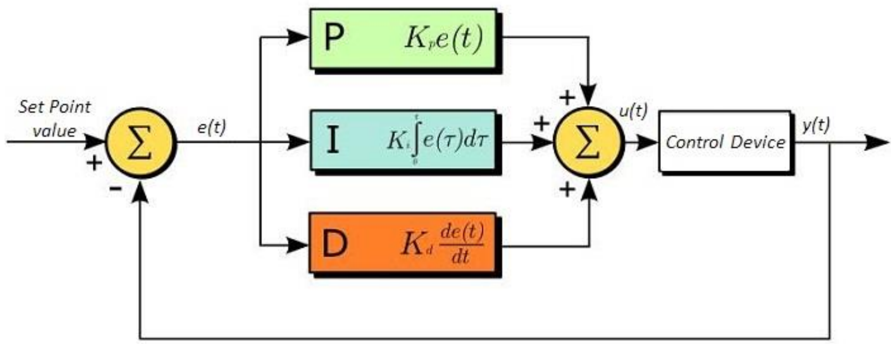


Figure E1. Block Diagram for PID Control System (Control Engineering, 2014)

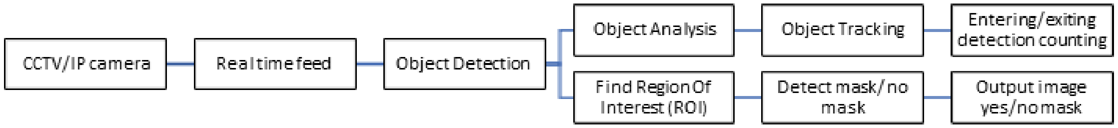


Figure E2. Using CCTV/IP Camera for Mask Detection and Counting

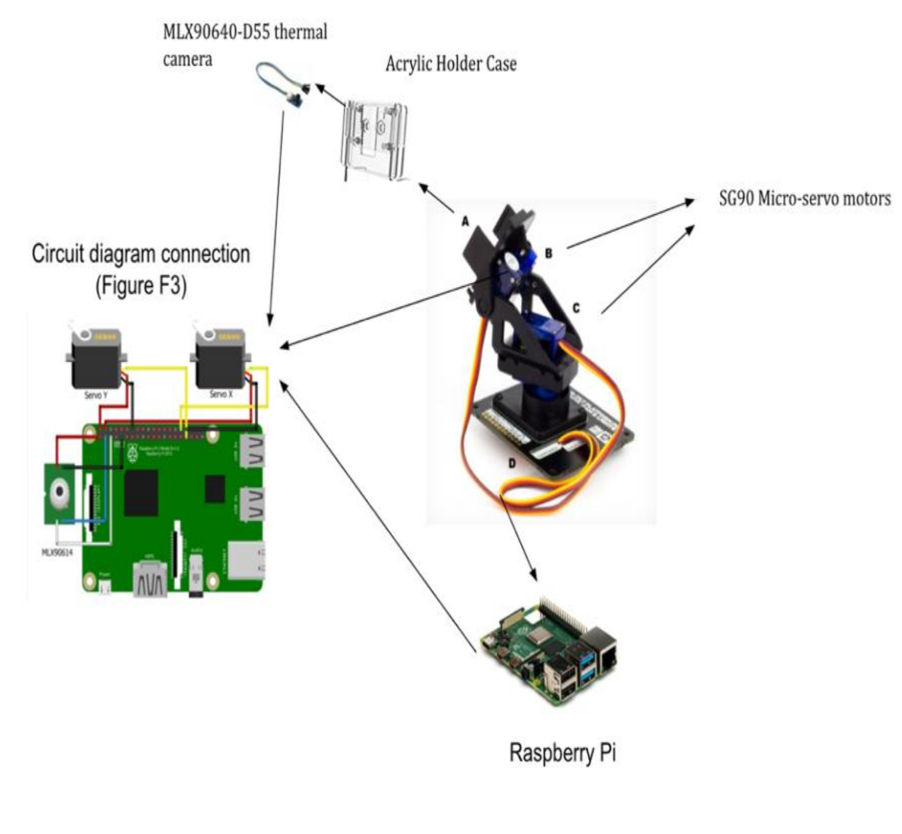


Figure E3. Camera Sub-System1

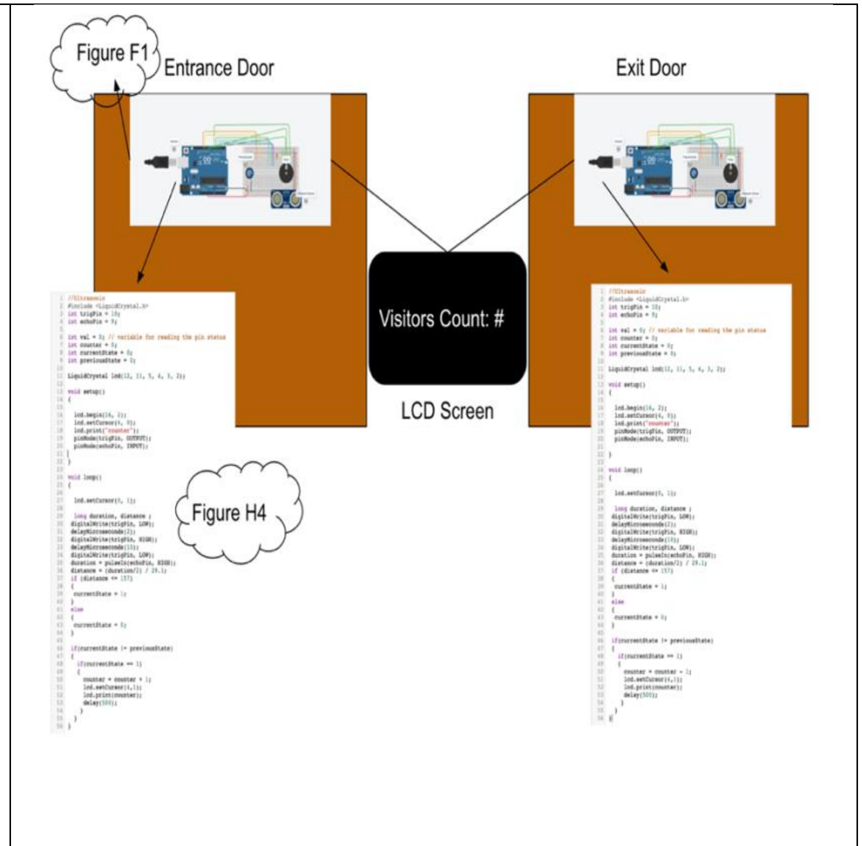


Figure E4. Counter Sub-System2

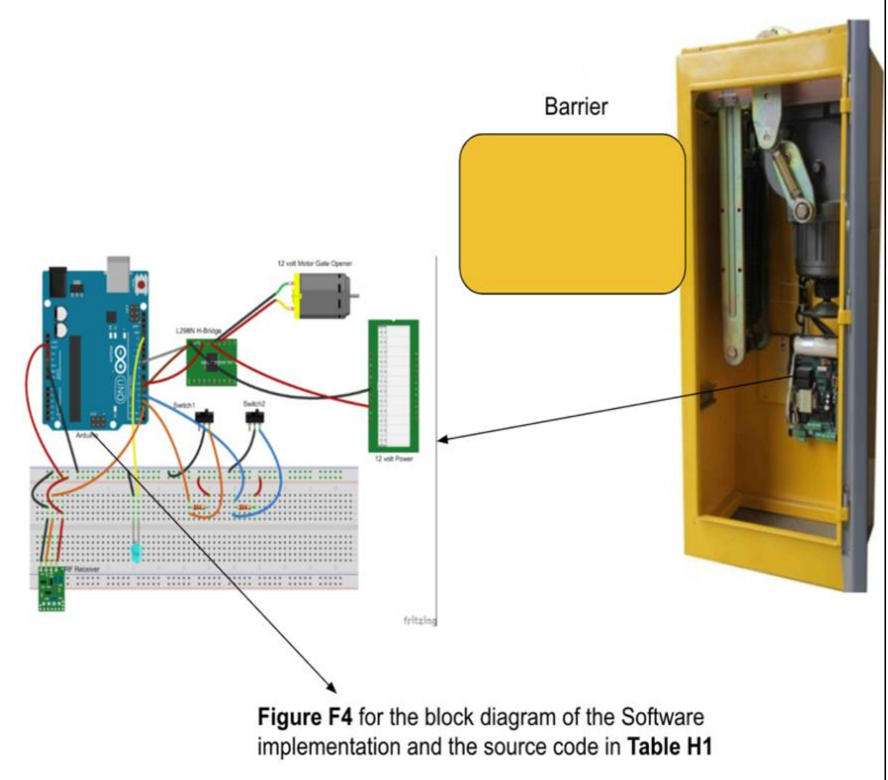


Figure E5. Barrier Control Sub-System3

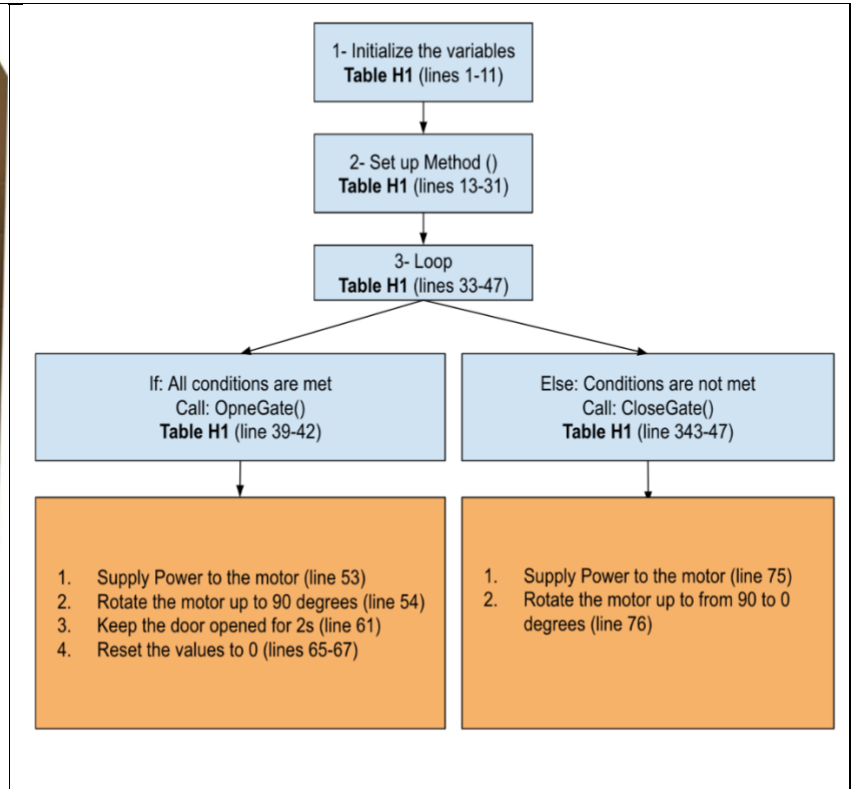


Figure E6. Block Diagram for Barrier Software Implementation

7.6 APPENDIX F: CIRCUITS DEVELOPED

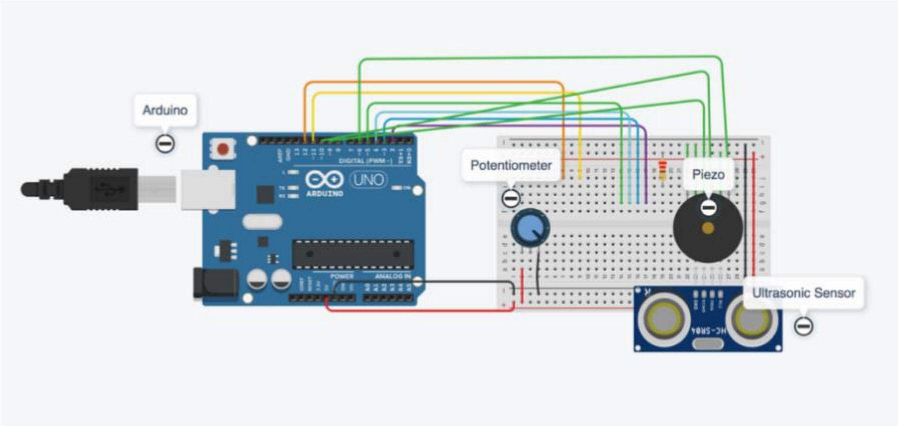


Figure F1. Ultrasonic Sensor Circuit Built in Tinker Cad

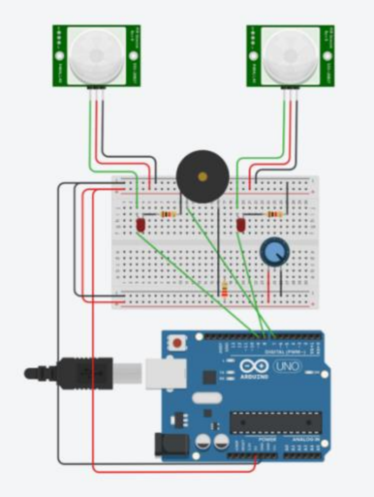


Figure F2. Infrared Sensor Circuit

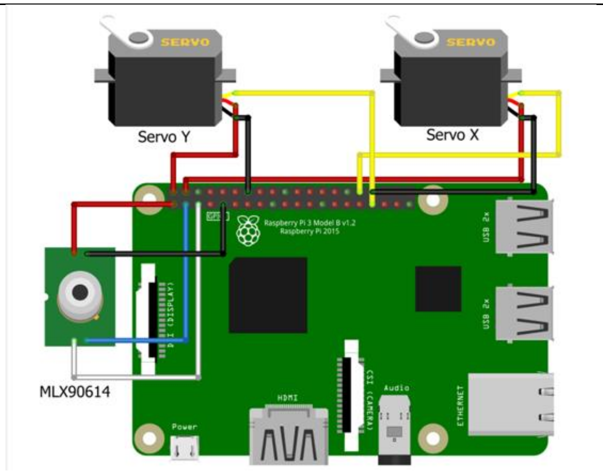


Figure F3. Circuit Diagram of Camera

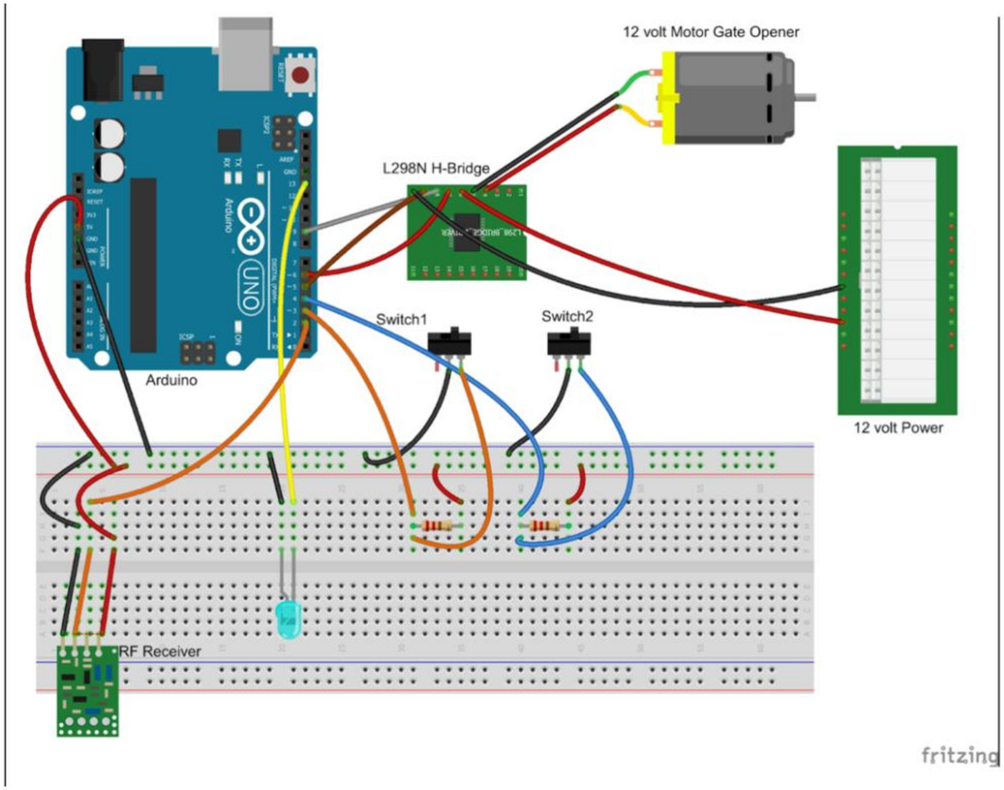


Figure F4. Circuit Diagram of the Barrier Control

7.7 APPENDIX G: ASSUMPTIONS DEVELOPED

Table G1. Engineering Assumptions

#	Assumption	Justification	Source Cited
1	Assume a distance of 178.1 cm between the camera and the person.	This assumption will help develop calculations necessary for the placement of their camera as well as the angles that it is going to adjust itself when scanning people of different heights. This assumption was set according to the thermal sensor used, referenced in this table.	(WaveShare, 2021)
2	Assume the design will always have a nearby power source.	No batteries are to be used to provide power to the cameras.	Initiated by ROBOTEX.
3	Assume no black objects are to be worked with (Applicable for IR sensors).	IR sensors do not work with black colored objects, because black fully absorbs the transmitted rays.	(university of Illinois, 2015)
4	Assume only one person is entering and exiting at a time.	This will ensure that the counter results are accurate if the sensor is performing a single detection at a time.	Initiated by ROBOTEX.
5	Assume that people will only be entering from the entrance and exiting from the exit of the store.	This will ensure that the counter results are not affected by any sources of errors, hence people entering and exiting from the wrong door.	Initiated by ROBOTEX.
6	Assume an average height of 171cm for the person being scanned by the temperature measuring and mask detection camera.	This will ensure that the temperature measuring device and the mask detector are accessible to all demographics. The average is based on the average height for men and women in Canada.	(CBC, 2016)

7.8 APPENDIX H: CODES DEVELOPED

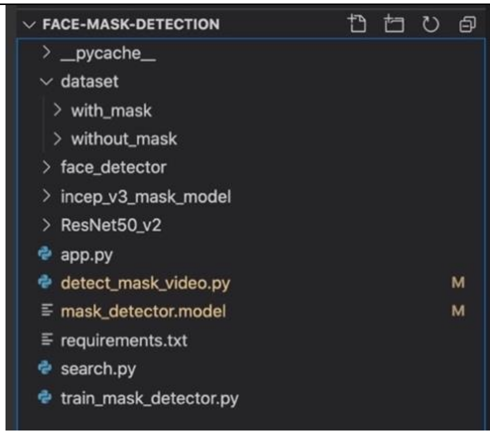
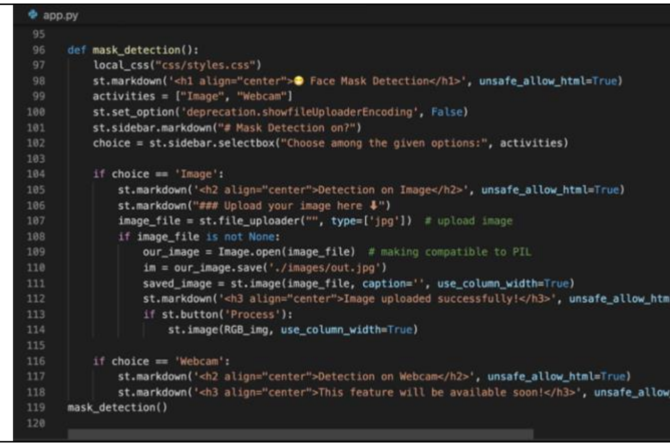


Figure H1. Overall Project Structure




```python

def mask_detection():
    local_css("css/styles.css")
    st.markdown('<h1 align="center"> Face Mask Detection</h1>', unsafe_allow_html=True)
    activities = ["Image", "Webcam"]
    st.set_option('deprecation.showfileUploaderEncoding', False)
    st.sidebar.markdown("# Mask Detection on?")
    choice = st.sidebar.selectbox("Choose among the given options:", activities)

    if choice == 'Image':
        st.markdown('<h2 align="center">Detection on Image</h2>', unsafe_allow_html=True)
        st.markdown("### Upload your image here ⬇")
        image_file = st.file_uploader("", type=['jpg'])  # upload image
        if image_file is not None:
            our_image = Image.open(image_file)  # making compatible to PIL
            im = our_image.save('./images/out.jpg')
            saved_image = st.image(image_file, caption='', use_column_width=True)
            st.markdown('<h3 align="center">Image uploaded successfully!</h3>', unsafe_allow_html
            if st.button('Process'):
                st.image(RGB_img, use_column_width=True)

    if choice == 'Webcam':
        st.markdown('<h2 align="center">Detection on Webcam</h2>', unsafe_allow_html=True)
        st.markdown('<h3 align="center">This feature will be available soon!</h3>', unsafe_allow_
mask_detection()

```

Figure H2. Face Mask Detection Method

Table H1. Barrier Control Arduino Code

#1

```cpp
#include xxxx                                   //Servo Library
Servo serv_test;                                //initializing servo motor
int angle =0;
int pwm = 9;
int firstinputpin = 2;
int secondinputpin = 3;
int openNow = 6;
int closeNow = 5;
int firststatus = LOW;
int secondstatus = LOW;
int ledPin = 13;

```

#2

```
void setup()
{
  Serial.begin(9600);
  servo_test.attach(8); // attach signal pin of motor to pin 8
  pinMode(firstinputpin, INPUT); // takes mask and temperature detection output as an input (switch 1)
  pinMode(secondinputpin, INPUT); // takes counter output as input (switch 2)
  pinMode(openNow, OUTPUT); // send openGate command to H-bridge
  pinMode(closeNow, OUTPUT); // send closeGate command to H-bridge
  pinMode(pwm, OUTPUT); // send speed command to H-bridge
  analogWrite(pwm, 0);  //make sure H-Bridge is off
  pinMode(ledPin, OUTPUT);  //setup our status LED

 if(firststatus == LOW || secondstatus == LOW) //if one of the inputs don't allow for the customer to enter
 {
  delay(2000); //delay for 2 seconds
  analogWrite(pwm, 0);      // Stops motor
  Serial.println("Please Scan");
  }
}

```

#3

```
void loop()
{
    firststatus = digitalRead(firstinputpin);  // for reading in the input 1
    secondstatus = digitalRead(secondinputpin); // for reading in the input 2
    //after checking with the mask detection and temperature detection
    //and with the counter (if both are HIGH) then it goes to openGate() function
    if(firststatus == HIGH && secondstatus == HIGH) //both counter and screening test must be passed
    {
        openGate();   //sends loop to "openGate" module
    }
    else
    {     //sends loop to "closeGate" module
        closeGate();    If not closes the gate
    }
}
```

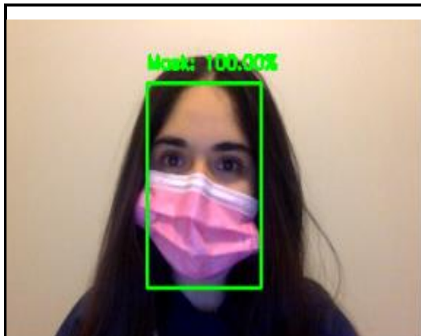
#4

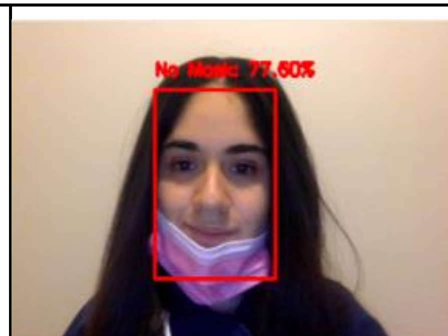
```
void openGate()
{   // opens gate till the gate meets open limit switch
    Serial.println("Welcome!");
    digitalWrite(ledPin, HIGH); //Green light 'ON'!
    digitalWrite(openNow, HIGH);
    analogWrite(pwm, 255); //maximum power //gives power
    for(angle =0; angle< 90 ; angle += 1) //move from 0 to 90 degrees)
    {
      servo_test.write(angle);            // to rotate to that specified angle)
      delay(22.222); // to obtain a total opening time of 2s
    }
    while (firststatus == HIGH && secondstatus == HIGH)
    {
      delay(5000); //kept open for 5s
      firststatus = digitalRead(firstinputpin);  // for reading in the input 1
      secondstatus = digitalRead(secondinputpin); // for reading in the input 2
    }
    digitalWrite(openNow, LOW);
    analogWrite(pwm, 0);
    digitalWrite(ledPin, LOW);
}
```

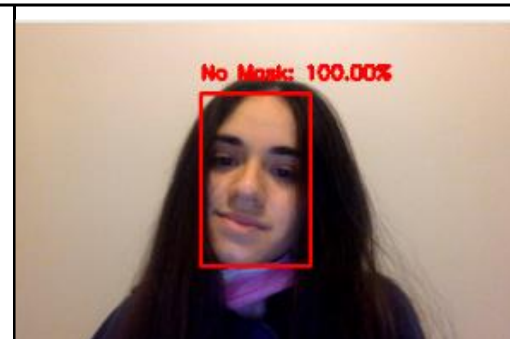
#5	

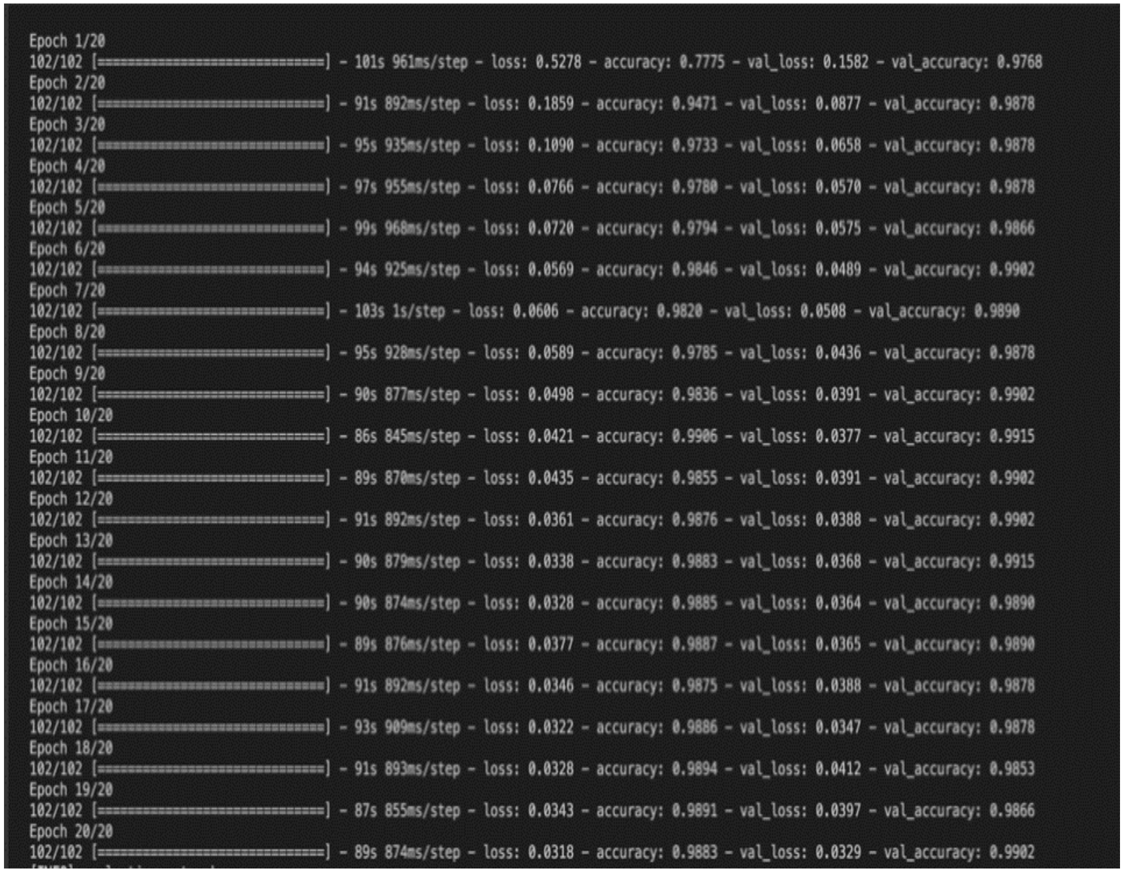
```
void closeGate()
{      // opens gate till the gate meets close limit switch
  Serial.println("Please Scan");     // for debugging purposes
  digitalWrite(ledPin, HIGH);
  digitalWrite(closeNow, HIGH);
  analogWrite(pwm, 245);
  for(angle =90 ; angle>=1 ; angle -= 1) //move back from 90 to 0 degrees)
  {
     servo_test.write(angle);             // to rotate to that specified angle)
     delay(22.222); // to obtain a total opening time of 2s
  }
  while (firststatus == LOW || secondstatus == LOW)
  {
    delay(50);
    firststatus = digitalRead(firstinputpin);  // for reading in the input 1
    secondstatus = digitalRead(secondinputpin); // for reading in the input 2
  }
  digitalWrite(closeNow, LOW);
  analogWrite(pwm, 0);
  digitalWrite(ledPin, LOW);
}
```

Table H2. Output of the Face Mask Detection Algorithm









```
Epoch 1/20
102/102 [==============================] - 101s 961ms/step - loss: 0.5278 - accuracy: 0.7775 - val_loss: 0.1582 - val_accuracy: 0.9768
Epoch 2/20
102/102 [==============================] - 91s 892ms/step - loss: 0.1859 - accuracy: 0.9471 - val_loss: 0.0877 - val_accuracy: 0.9878
Epoch 3/20
102/102 [==============================] - 95s 935ms/step - loss: 0.1090 - accuracy: 0.9733 - val_loss: 0.0658 - val_accuracy: 0.9878
Epoch 4/20
102/102 [==============================] - 97s 955ms/step - loss: 0.0766 - accuracy: 0.9780 - val_loss: 0.0570 - val_accuracy: 0.9878
Epoch 5/20
102/102 [==============================] - 99s 968ms/step - loss: 0.0720 - accuracy: 0.9794 - val_loss: 0.0575 - val_accuracy: 0.9866
Epoch 6/20
102/102 [==============================] - 94s 925ms/step - loss: 0.0569 - accuracy: 0.9846 - val_loss: 0.0489 - val_accuracy: 0.9902
Epoch 7/20
102/102 [==============================] - 103s 1s/step - loss: 0.0606 - accuracy: 0.9820 - val_loss: 0.0508 - val_accuracy: 0.9890
Epoch 8/20
102/102 [==============================] - 95s 928ms/step - loss: 0.0589 - accuracy: 0.9785 - val_loss: 0.0436 - val_accuracy: 0.9878
Epoch 9/20
102/102 [==============================] - 90s 877ms/step - loss: 0.0498 - accuracy: 0.9836 - val_loss: 0.0391 - val_accuracy: 0.9902
Epoch 10/20
102/102 [==============================] - 86s 845ms/step - loss: 0.0421 - accuracy: 0.9906 - val_loss: 0.0377 - val_accuracy: 0.9915
Epoch 11/20
102/102 [==============================] - 89s 870ms/step - loss: 0.0435 - accuracy: 0.9855 - val_loss: 0.0391 - val_accuracy: 0.9902
Epoch 12/20
102/102 [==============================] - 91s 892ms/step - loss: 0.0361 - accuracy: 0.9876 - val_loss: 0.0388 - val_accuracy: 0.9902
Epoch 13/20
102/102 [==============================] - 90s 879ms/step - loss: 0.0338 - accuracy: 0.9883 - val_loss: 0.0368 - val_accuracy: 0.9915
Epoch 14/20
102/102 [==============================] - 90s 874ms/step - loss: 0.0328 - accuracy: 0.9885 - val_loss: 0.0364 - val_accuracy: 0.9890
Epoch 15/20
102/102 [==============================] - 89s 876ms/step - loss: 0.0377 - accuracy: 0.9887 - val_loss: 0.0365 - val_accuracy: 0.9890
Epoch 16/20
102/102 [==============================] - 91s 892ms/step - loss: 0.0346 - accuracy: 0.9875 - val_loss: 0.0388 - val_accuracy: 0.9878
Epoch 17/20
102/102 [==============================] - 93s 909ms/step - loss: 0.0322 - accuracy: 0.9886 - val_loss: 0.0347 - val_accuracy: 0.9878
Epoch 18/20
102/102 [==============================] - 91s 893ms/step - loss: 0.0328 - accuracy: 0.9894 - val_loss: 0.0412 - val_accuracy: 0.9853
Epoch 19/20
102/102 [==============================] - 87s 855ms/step - loss: 0.0343 - accuracy: 0.9891 - val_loss: 0.0397 - val_accuracy: 0.9866
Epoch 20/20
102/102 [==============================] - 89s 874ms/step - loss: 0.0318 - accuracy: 0.9883 - val_loss: 0.0329 - val_accuracy: 0.9902
```

Figure H3: Accuracy of the Face Mask detection Algorithm

```
//Ultrasonic
#include <LiquidCrystal.h>
int trigPin = 10;
int echoPin = 9;

int val = 0; // variable for reading the pin status
int counter = 0;
int currentState = 0;
int previousState = 0;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup()
{

  lcd.begin(16, 2);
  lcd.setCursor(4, 0);
  lcd.print("counter");
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);

}

void loop()
{

  lcd.setCursor(0, 1);

  long duration, distance ;
 digitalWrite(trigPin, LOW);
 delayMicroseconds(2);
 digitalWrite(trigPin, HIGH);
 delayMicroseconds(10);
 digitalWrite(trigPin, LOW);
 duration = pulseIn(echoPin, HIGH);
 distance = (duration/2) / 29.1;
 if (distance <= 157)
 {
  currentState = 1;
 }
 else
 {
  currentState = 0;
 }

 if(currentState != previousState)
 {
   if(currentState == 1)
   {
     counter = counter + 1;
     lcd.setCursor(4,1);
     lcd.print(counter);
     delay(500);
    }
  }
}
```

Figure H4. Arduino Ultrasonic Sensor (Counter) Code

Table H3: Training VS Testing Average Accuracies

Echo	'accuracy'	'val_accuracy'
1	0.7775	0.9768
2	0.9471	0.9878
3	0.9733	0.9878
4	0.978	0.9878
5	0.9794	0.9866
6	0.9846	0.9902
7	0.982	0.989
8	0.9785	0.9878
9	0.9836	0.9902
10	0.9906	0.9915
11	0.9855	0.9902
12	0.9876	0.9902
13	0.9883	0.9915
14	0.9885	0.989
15	0.9887	0.989
MEAN	**0.972805**	**0.988155**
MEAN AS PERCENTAGE (%)	**97.2805**	**98.8155**

7.9 APPENDIX I: PROJECT MANAGEMENT – TIME SPENT, COST OF DESIGN AND TOOLS

Management tools were used to help the design team better plan and manage tasks. ***Table I1*** *and* ***Table I2*** below demonstrate how long each task should take as well as in which order they should be completed. As shown in ***Table I3***, an updated Gantt chart that clearly outlines the subtasks of each milestone has also been constructed to support and improve the project management. As shown in ***Table I4*** below the total estimated hours that the team will spend are expected to be around 384 hours. The hourly wage for each team member is found to be $40 per hour for a new engineer (Salary Explorer). Based on the estimated number of hours and the hourly wage, the total working and labour fees are estimated to be $15,360.

Table I1. Critical Deadlines

#	Assessment	Start Date	Due Date
1	**Design Process**	18/01/2021	12/04/2021
2	**Team and Project Selection**	22/01/2021	24/01/2021
3	**Design Proposal**	24/01/2021	5/02/2021
4	**Interim Design Report**	5/02/2021	26/02/2021
5	**Technical Memo**	26/02/2021	12/03/2021
6	**Design Presentation**	12/03/2021	19/03/2021
7	**Final Design Report**	26/03/2021	02/04/2021

Table I2. Key Milestones and Deliverables

#	Deliverables	Key Milestones Working Time Per Weeks
1	**Team and Project Selection**	**1**
	Start the process, form a group, and plan ideas.	
2	**Design proposal**	**2**
	Identify the problem, brainstorm to find a solution, estimate timeline, and fees.	
3	**Interim Design Report**	**2**
	Highlight the details for different solutions and explain the design based on the constraints and criteria.	
4	**Technical Memo**	**3**
	Explain in depth the calculations, and show evidence of the safety and functionality of the design	
5	**Design Presentation**	**1**
	Present the designed solution to the problem.	
6	**Final Design Report**	**3**
	Report the designed solution to the problem.	
	TOTAL	**12**

Table I3. Updated Gantt Chart

GANTT CHART

PASSION. PURPOSE. PROGRESS.

Design Milestone | Plan Duration | Actual Start | % Complete | Actual (Beyond Plan) | % Complete (Beyond Plan)

Activity	Plan Start	Plan Duration	Actual Start	Actual Duration	% Complete	WEEK 1	2	3	4	5	6	7	8	9	10	11	12
Team/Project Selection	1	14	1	14	100%												
Define individual interests	1	7	1	7	100%												
Team selection	7	3	7	3	100%												
Coordination Meeting	10	1	10	1	100%												
Final project selection/submission	10	5	10	1	100%												
Design Proposal	15	14	15	14	100%												
Coordination meeting	15	2	15	2	100%												
Problem Definition	15	2	16	5	100%												
Research, information Gathering	16	11	16	10	100%												
Divide tasks among team members	15	1	15	2	100%												
Write and format the proposal	22	5	24	7	100%												
Final edits/submission	27	1	27	2	100%												
Interim Report	28	13	29	14	100%												
Coordination Meeting	28	1	29	2	100%												
Discuss, review and reflect on proposal	29	1	31	2	100%												
Divide tasks among team members	28	1	32	2	100%												
Write and format the proposal	37	6	39	7	100%												
Final edits/submission	40	6	42	7	100%												
Technical Memo	42	12	43	13	100%												
Coordination Meeting	42	1	43	2	100%												
Generation of the technical draft memo	45	5	45	6	100%												
Review and edit	49	2	51	3	100%												
Final edits and submission	53	0.5	55	1	100%												
Design Presentation	56	14	56	14	100%												
Coordination Meeting	56	6	56	6	100%												

Discuss, review and reflect on reports	57	2	57	2	100%
Divide tasks among team members	56	1	56	1	100%
Generation of the draft presentation	62	3	63	3	100%
Final edits/submission	68	1	68	2	100%
Final Design Report	70	13	70	14	95%
Coordination Meeting	70	4	70	6	100%
Discuss, review and reflect on all reports	71	3	72	4	85%
Divide tasks among team members	72	1	73	1	100%
Finalize the design	76	4	77	6	90%
Write/format report	77	5	78	6	90%
Final review, edits and submission	82	0.2	82	1	90%
Celebrate	83	1	80	1	0%

Table I4. Updated Fee Estimate for Design and Required Deliverables

FEE ESTIMATE										
Deliverable	Activity		Team Members					Time (H)	Cost ($)
			Layal 40 $/H	Tina 40 $/H	Lina 40 $/H	Whitney 40 $/H	Nasiba 40 $/H		
Team and Project Selection									
	1.1	Group formation	0.5	0.5	0.5	0.5	0.5	2.5	100
	1.2	Coordinating meeting	0.5	0.5	0.5	0.5	0.5	2.5	100
	1.3	Determine the field of interest.	0.5	0.5	0.5	0.5	0.5	2.5	100
	1.4	Problem definition and data collection	2	2	2	2	2	10	400
	1.5	Decide on design, criteria & constraints.	1.5	1.5	1.5	1.5	1.5	7.5	300
	1.6	Final selection and submission	1	1	1	1	1	5	200
	SUB. TOTAL							1200	
Design Proposal									
	2.1	Coordinating meeting	0.5	0.5	0.5	0.5	0.5	2.5	100

	2.2	**Gather more information about the design.**	2	1	1	1	1	6	240
	2.3	**Review the process with more research.**	1	1	1	1	1	5	200
	2.4	**Discuss and write the proposal.**	2	2	2	2	2	10	400
	2.5	**Final review and submission**	0.5	0.5	0.5	1	0.5	3	120
	SUB. TOTAL							**1060**	
Interim Design Report									
	3.1	**Coordinating meeting**	3	3	3	3	3	15	600
	3.2	**Initial ideas about each section of report**	2.5	2.5	2.5	2.5	2.5	12.5	500
	3.3	**Discuss and edit the draft report.**	4	4	4	4	4	20	800
	3.4	**Write, edit and format the report.**	3	3	3	3	3	15	600
	3.5	**Final review and submission**	3	3	3	3	3	15	600
	SUB. TOTAL							**3100**	
Technical Memo									
	4.1	**Coordinating meeting**	3	3	3	3	3	15	600
	4.2	**Create the first Memo draft**	2	2	2	2	2	10	400
	4.3	**Review the process.**	3	3	3	3	3	15	600
	4.4	**Write, edit & demonstrate required format.**	4	4	4	4	4	20	800
	4.5	**Final review and submission**	3	3	3	3	3	15	600
	SUB. TOTAL							**3000**	
Design Presentation									
	5.1	**Coordinating meeting**	2	2	2	2	2	10	400
	5.2	**Edit, review & format draft presentation.**	3	3	3	3	3	15	600
	5.3	**Add pictures, diagrams and videos.**	3	3	3	3	3	15	600
	5.4	**Record the presentation.**	3	3	3	3	3	15	600
	5.5	**Final revision and submission**	2	2	2	2	2	10	400
	SUB. TOTAL							**2600**	

Final Design Report	**6.1**	**Coordination meeting**	3	3	3	3	3	15	600
	6.2	**General draft report**	5	5	5	5	5	25	1000
	6.3	**Write, edit and format the report.**	4	4	4	4	4	20	800
	6.4	**Review and edit the final report.**	5	5	5	5	5	25	1000
	6.5	**Final revision and submission**	5	5	5	5	5	25	1000
	SUB. TOTAL							**4400**	
	GRAND TOTAL							**384**	**15360**

Table I5. Required Tools

#	Tool Name	Description	Fees
1	**SolidWorks**	Used for creating a 3D model of the product and its components (CAD MicroSolutions Inc).	Available at ROBOTEX
2	**EAGLE**	It is an electronic design automation (EDA) application software used to connect electrical schematic diagrams with printed circuit boards (EAGLE: PCB design and Electrical SCHEMATIC SOFTWARE).	Available at ROBOTEX
3	**React Native Platform**	It is a mobile application framework used to develop applications that are compatible for both Android and IOS mobile applications developed by Facebook (*React native*).	Available at ROBOTEX
4	**Software Requirements**	IDES (Integrated Development Environments), Code editors, and Virtual Environments will be used to create, edit, compile and execute codes as well as creating the mobile applications.	Available at ROBOTEX
5	**Google Drive**	It is a file storage and synchronization service developed by Google. Google drive and google documents are the major platform that is used by the team for formal writings and reports.	Available at ROBOTEX
6	**Cisco WebEx**	Cisco WebEx is a web and a video conferencing application. It will be used extensively throughout the term of the product development by the team for brainstorming and various sessions as needed.	Available at ROBOTEX
7	**WhatsApp**	WhatsApp is a cross-platform that allows users to send text messages, voice messages, video calls and share images, documents, user locations and other content. It is the main communication platform for formal and informal conversations between group members.	Available at ROBOTEX

The following Table, ***Table I6***, is a list of the items and materials required for the design. In order to ensure the table is sufficient to build a prototype, all the details regarding each component are clearly labelled. The description and the manufacturing part number given by the manufacturer of each item are clearly listed to make the shopping experience easier for the costumer and the ROBOTEX team. Additionally, in order to make ordering and shipping process easier, the sources of each component are either Canadian sources or US sources that have fast delivery to Canada available.

Table I6. Bill of Materials Required for the Design

BILL OF MATERIALS								
#	**Item**		**Description/Material/Product Name/Manufacturer Part No. as Applicable**	**Unit**	**Qty.**	**Cost (CAD$)/ Unit**	**Total Cost (CAD$)**	**Source/ Manufacturer**
1	**Ultrasonic Sensor**	**Piezo**	W5500 Ethernet Interface Arduino Platform Evaluation Expansion Board Manufact No.: 7BB-20-6L0	No.	2	0.96	1.92	By Murata Electronics via Digi.Key
		Potentiometer	Trimmer 10kOhm 0.5wW PC Pin Top Manufact. No.: COM-0.9806	No.	2	1.38	2.76	By SparkFun Electronics via Digi.Key
		Arduino	A000024 Manufact. No.: 1050-1039-ND	No.	2	32.29	64.58	By Arduino via Digi.Key
		Ultrasonic Sensor	HC-SR04 Ultrasonic Module Range Finder Sensor	No.	2	2.95	5.90	By Voltatek electronics via ROBOTEX
		Breadboard	Manufact. No.: 21-18936	No.	2	3.77	7.54	
2	**Raspberry Pi 3 Model B**		RPI3-MODB-1GB	No.	1	43.87	43.87	By Raspberry Pi via Newark
3	**Raspberry Pi Camera Module**		RPI 8MP Camera Board	No.	1	31.34	31.34	By Raspberry Pi via Newark
4	**Thermal Camera**		MLX90640 IR Array Thermal Imaging Camera, 32x24 Pixels, 55° FOV	No.	1	150.35	150.35	By WaveShare

			Manufact. No.: MLX90640-D55					
5	**Pan Tilt Kit**		Plastic PT Kit Pan/Tilt Camera Platform Anti-Vibration Mount for FPV RC	No.	1	18.80	18.80	By Exiron via Amazon.com
6	**SG90 Micro-servo Motor**		6V 1.5kg.cm 9g DC Motor Gear Box Model Manufact. No. FM90	No.	2	4.39	8.78	By Feetech via Adafruit
7	**Barriers**		Polycarbonate 48 in ×96 in Sheet	No.	1	159.00	159.00	By Lexan via Home depot
8	**Shield/Frame**		WC-21 Outdoor Enclosure with Clear Cover	No.	1	15.73	15.73	By WC Series via Polycase
9	**Counter Display (LCD Screen)**		ViewBoard IFP5550	No.	1	2,253.99	2,253.99	ViewSonic via PC-Canada.com
10	**Temperature Display (Tablet)**		Xenarc 1219	No.	1	1,503.37	1,503.37	Xenarc Technologies
11	**Stands**		316L Stainless Steel	No.	4	159.99	639.96	By Inoxia via RONA
12	**Raspberry Pi Holder Case**		Raspberry Pi Camera Board Case w/ ¼” Tripod Mount	No.	1	3.93	3.93	RobotShop via Adafruit
13	**Electrical Component of Barriers Control**	**Arduino**	A000024 Manufact. No.: 1050-1039-ND	No.	2	1.38	2.76	By SparkFun Electronics via Digi.Key
		Motor	Manufact. No.: 53W6195	No.	2	2.71	5.42	By Adafruit via Newark
		Breadboard						
TOTAL COST							**4927.54**	

The following Table (***Table I7)*** illustrates the total labor work costs that ROBOTEX has to account for during the manufacturing, packaging and installing process of the device. The estimation is based on the Canadian labor minimum wage (Salary Explorer). ***Table I8*** below illustrates the total costs, including labor costs, materials required as well as marketing percentage of 8%, assumed according to a study done by Deloitte published by the Wall Street Journal Publishers (Deloitte editor, 2019).

A Pareto chart, as shown in ***Figure I1***, is one of the main tools used for the cost analysis of the design. It is also known as the 20/80 rule, which means that 20% of sources cause 80% of problems (Amanda Greenwood, 2020). Pareto Chart is a graph that uses both bar and line graphs to show the occurrence of defects and their overall effect. Pareto charts may be used to identify the defects should be prioritized in order to achieve the greatest overall change (Amanda Greenwood, 2020).

Another useful business tool that is used to improve the project cost management is an online sales tracker, found in ***Figure I2*** below. This tool will help increase the benefits of the company by keeping track of all the sales of interest available online (Maria Bobila, 2017). The ROBOTEX team will continue to update the excel sheet as more products get produced to ensure a design with the highest cost-effective components possible.

Table I7. Manufacturing, Assembling and Packaging costs required for the design

#	Description	Time (Hr)	Cost (CAD$)/Unit	Total Cost (CAD$)
1	Manufacturing	60	18.17	1090.20
2	Assembling	15	16.62	249.30
3	Packaging			
TOTAL				**1362.75**

Table I8. Total Costs required for the implementation of the design

#	Cost of Producing	Total Cost Per Unit (Cad$)
1	Materials/Items needed, based on the bill of materials available at ROBOTEX	4927.54
2	Estimated manufacturing, assembling and packaging cost	
	TOTAL NET COST	6290.29
3	Marketing (8% of the total net cost)	
	TOTAL	**6793.51**

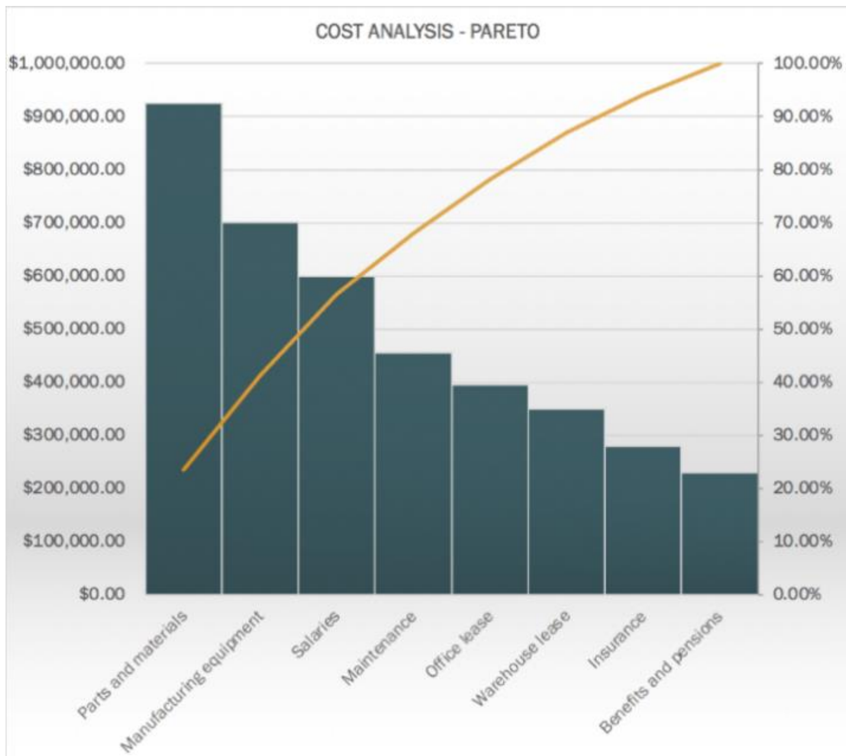


Figure I1. Cost Analysis – Pareto

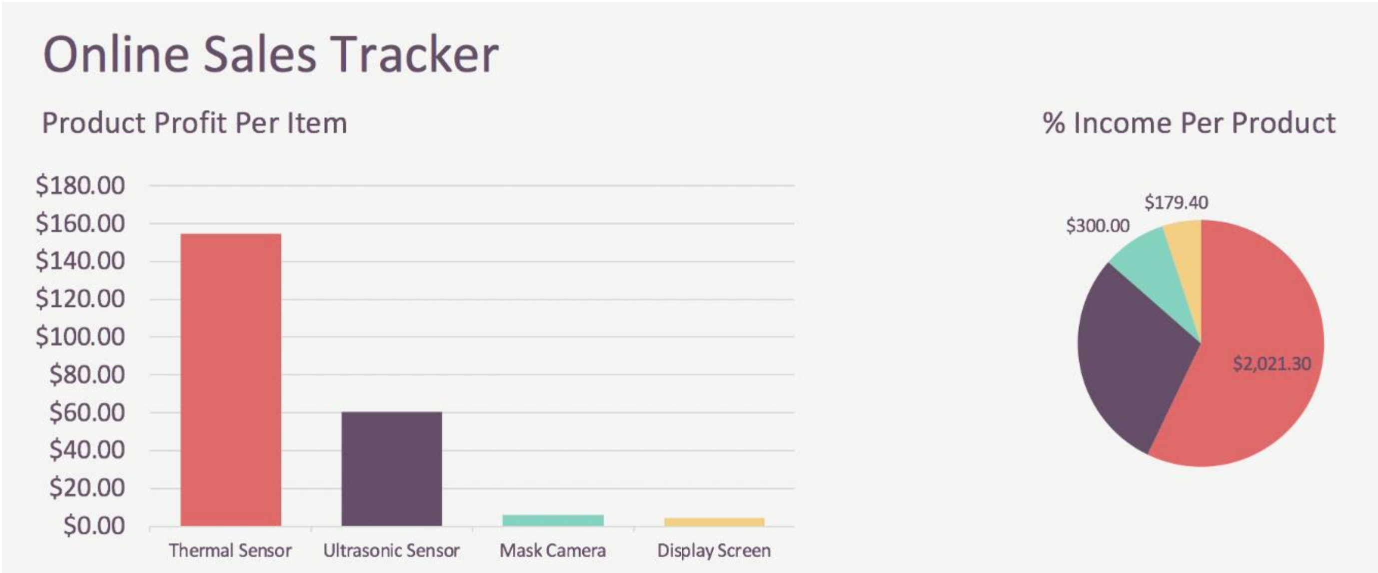


Figure I2. Online Sales Tracker

7.10 APPENDIX J: LIFE CYCLE ANALYSIS

Taking the major components of the device, the chart showcases the number of emissions, contaminants, and energy for $1M worth of equipment, or about 71 units. These values were found under the EIO-LCA online database using Industry Benchmark Canada 2002 EIO Producer Price model. The design was broken down into 4 sections: metal (for the stainless steel), plastic (such as the polycarbonate), electronic components (such as sensors), and electronic products (such as the display). Each one was assigned a general category, and then further narrowed down to obtain data. For instance, the metal was first listed under metal and machinery manufacturing but was narrowed down to fabricated metal product manufacturing - section 3320. For the plastic, it was from plastic, rubber and non-metallic mineral products to plastics product manufacturing- section 3261. Both electronics started from computer, electronic equipment, and electronic components, but were narrowed down to component manufacturing and electronic product manufacturing- sections 335A and 334A respectively (Carnegie Mellon University Green Design Institute, n.d.).

The data presented was originally for $1million for each section, however based on the calculated cost of the product, weighing was assigned for how much each section contributed to the cost. The final values are seen below in appendix tables J1-J3.

For this system, the functional unit that will be used determines how efficiently it is able to scan people accurately per minute. This functional unit is key for future designs when improving the material or processes. Due to complexity of all the design, the first sub-system boundary was limited to creating the device, and the second system concerned the process after assembling the design, shown in the system diagram in figure J1.

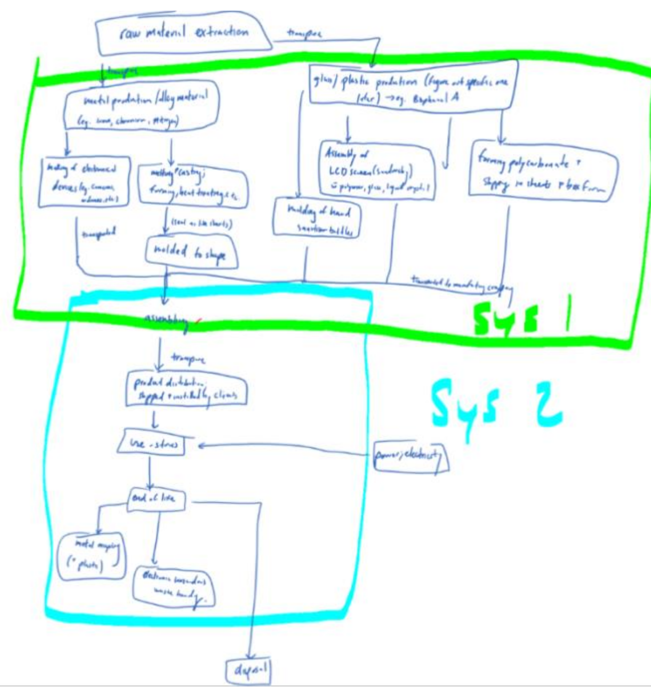


Figure J1. System Boundary Diagram of Design

The product was designed with a "cradle-to-cradle" approach, assuming that at the end of their usage, most of these materials can be recycled, allowing minimal waste into landfills. The steel can be recycled under recycling code 40, and the polycarbonate under 7 (City of Toronto, n.d.). For the electrical components and the display screen, these can be safely disposed of at a waste facility that accepts electronic waste or can be reused for other purposes. The City of Toronto currently has many facilities that can process this. Some of the key components of the design, based on the life cycle analysis from tables J1, J2, and J3, is that energy from natural gas is high, along with it producing mostly the global warming potential and CO_2, CO, and SO_2 emissions during the production. To improve for the future, further analysis of these processes is required to help reduce the environmental impact of the device.

Table J1. Raw Data Obtained from EIO-LCA Database for All Components and the Conventional Air Pollutants Associated with Them

Sector			**CO2**	**CH4**	**N2O**	**GWP**
			kMTCO2E	**kMTCO2E**	**kMTCO2E**	**kMTCO2E**
		Total for all sectors	***0.881***	***0.115***	***0.031***	***1.03***
Metal	3310	Primary metal manufacturing	0.178	0	0	0.178
	2211	"Electric power generation, transmission and distribution"	0.116	0	0	0.117
	2122	Metal ore mining	0.071	0	0.003	0.073
	327A	Miscellaneous non-metallic mineral product manufacturing	0.063	0	0	0.063
	3320	Fabricated metal product manufacturing	0.06	0	0	0.06
	2121	Coal mining	0.056	0.066	0.003	0.125
	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.055	0	0.005	0.06
	4860	Pipeline transportation	0.035	0.02	0	0.055
	3251	Basic chemical manufacturing	0.028	0	0	0.028

	4820	Rail transportation	0.022	0	0.003	0.024
		Total for all sectors	**0.629**	**0.055**	**0.099**	**0.783**
Plastic	3251	Basic chemical manufacturing	0.115	0	0	0.115
	3252	"Resin, synthetic ruber, and agricultural and synthetic fibres and filaments manufacturing"	0.092	0	0.083	0.175
	2211	"Electric power generation, transmission, and distribution"	0.088	0	0	0.088
	3253	"Pesticides, fertilizer, and other agricultural chemical manufacturing"	0.078	0	0.007	0.085
	327A	Miscellaneous non metallic mineral product manufacturing	0.03	0	0	0.03
	3261	Plastics production manufacturing	0.028	0	0	0.028
	4860	Pipeline transportation	0.026	0.015	0	0.041
	2111	Oil and gas extraction	0.022	0.01	0	0.032
	2121	Coal Mining	0.015	0.017	0	0.033
	3241	Petroleum and coal products manufacturing	0.014	0	0	0.014
		Total for all sectors	**0.227**	**0.024**	**0.01**	**0.261**
Electronic Component	3310	Primary metal manufacturing	0.03	0	0	0.03
	2211	"Electric power generation, transmission and distribution"	0.028	0	0	0.028
	327A	Miscellaneous non-metallic mineral product manufacturing	0.028	0	0	0.028
	335A	Electrical equipment and component manufacturing	0.025	0	0	0.025
	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.014	0	0.001	0.015
	2122	Metal ore mining	0.012	0	0	0.013
	2121	Coal mining	0.011	0.013	0	0.024
	3251	Basic chemical manufacturing	0.009	0	0	0.009
	4860	Pipeline transportation	0.008	0.004	0	0.012
	4810	Air transportation	0.005	0	0	0.005
		Total for all sectors	*0.308*	*0.033*	*0.015*	*0.356*
Electronic Product	2211	"Electric power generation, transmission and distribution"	0.046	0	0	0.047
	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.029	0	0.003	0.032

	3310	Primary metal manufacturing	0.026	0	0	0.026
	327A	Miscellaneous non-metallic mineral product manufacturing	0.016	0	0	0.016
	4810	Air transportation	0.014	0	0	0.015
	3251	Basic chemical manufacturing	0.013	0	0	0.013
	2121	Coal mining	0.013	0.015	0	0.028
	2122	Metal ore mining	0.011	0	0	0.012
	4860	Pipeline transportation	0.011	0.006	0	0.017
	230I	Other activities of the construction industry	0.009	0		
Total						

Table J2: Raw data obtained from EIO-LCA database for all components and the greenhouse gases associated with them

Sector			**CO**	**NOx**	**SO2**	**PM10**	**VOC**
			mt	**mt**	**mt**	**mt**	**mt**
		Total for all sectors	*4.04*	*1.45*	*17.6*	*0.457*	*0.651*
Metal	3310	Primary metal manufacturing	2.82	0.125	1.16	0.05	0.048
	2122	Metal ore mining	0.623	0.321	15.3	0.228	0.041
	327A	Miscellaneous non-metallic mineral product manufacturing	0.08	0.15	0.062	0.049	0.013
	5620	Waste management and remediation services	0.057	0.016	0.008	0.004	0.028
	3113	Sugar and confectionery product manufacturing	0.052	0.085	0	0	0.003
	3221	"Pulp, paper and paperboard mills"	0.046	0.02	0.024	0.008	0.008
	3210	Wood product manufacturing	0.043	0.003	0	0.004	0.01
	3251	Basic chemical manufacturing	0.041	0.066	0.058	0.009	0.025
	3241	Petroleum and coal products manufacturing	0.039	0.016	0.052	0.003	0.01

	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.037	0.061	0.015	0.004	0.006
		Total for all sectors	*0.929*	*1.02*	*1.98*	*0.166*	*1.26*
Plastic	3251	Basic chemical manufacturing	0.167	0.267	0.237	0.035	0.104
	3252	"Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing"	0.145	0.014	0.003	0.014	0.277
	3310	Primary metal manufacturing	0.128	0.006	0.053	0.002	0.002
	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.053	0.087	0.022	0.006	0.009
	325A	Miscellaneous chemical product manufacturing	0.049	0.079	0.016	0.002	0.04
	3221	"Pulp, paper and paperboard mills"	0.046	0.02	0.024	0.008	0.008
	3241	Petroleum and coal products manufacturing	0.043	0.018	0.057	0.003	0.011
	3113	Sugar and confectionery product manufacturing	0.039	0.063	0	0	0.003
	2122	Metal ore mining	0.038	0.02	0.937	0.014	0.002
	5620	Waste management and remediation services	0.037	0.01	0.005	0.003	0.018
		Total for all sectors	*0.764*	*0.359*	*3.09*	*0.102*	*0.15*
Electronic Component	3310	Primary metal manufacturing	0.479	0.021	0.197	0.008	0.008
	2122	Metal ore mining	0.107	0.055	2.62	0.039	0.007
	327A	Miscellaneous non-metallic mineral product manufacturing	0.035	0.066	0.027	0.022	0.005
	3221	"Pulp, paper and paperboard mills"	0.02	0.009	0.01	0.003	0.004
	3113	Sugar and confectionery product manufacturing	0.017	0.028	0	0	0.001
	5620	Waste management and remediation services	0.014	0.004	0.002	0.001	0.007
	3251	Basic chemical manufacturing	0.013	0.021	0.019	0.003	0.008
	3241	Petroleum and coal products manufacturing	0.01	0.004	0.014	0	0.003

	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.009	0.016	0.004	0.001	0.002
	3210	Wood product manufacturing	0.009	0	0	0	0.002
		Total for all sectors	*0.796*	*0.496*	*3.01*	*0.107*	*0.238*
Electronic Product	3310	Primary metal manufacturing	0.409	0.018	0.169	0.007	0.007
	2122	Metal ore mining	0.099	0.051	2.42	0.036	0.006
	3113	Sugar and confectionery product manufacturing	0.049	0.08	0	0	0.003
	3221	"Pulp, paper and paperboard mills"	0.035	0.015	0.018	0.006	0.006
	5620	Waste management and remediation services	0.025	0.007	0.003	0.002	0.012
	327A	Miscellaneous non-metallic mineral product manufacturing	0.02	0.037	0.015	0.012	0.003
	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.019	0.032	0.008	0.002	0.003
	3241	Petroleum and coal products manufacturing	0.019	0.008	0.026	0.001	0.005
	3251	Basic chemical manufacturing	0.019	0.03	0.027	0.004	0.012
	3210	Wood product manufacturing	0.015	0.001	0	0.001	0.003
Total							

Table J3. Raw Data Obtained from EIO-LCA Database for All Components and The Energy Input Associated with Them

Sector			Elec	Coal	NatGas	LPG	MotGas	Diesel	LFO	AvFuel	HFO	Coke	Total
			TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	
		Total for all sectors	*4.5*	*1.49*	*5.35*	*0.6*	*0.289*	*1.94*	*0.073*	*0.223*	*0.654*	*0.965*	*14.9*
Metal	3310	Primary metal manufacturing	1.8	0.082	0.993	0.209	0.002	0.009	0.003	0	0.109	0.711	3.42
	2122	Metal ore mining	0.833	0	0.087	0.116	0.012	0.284	0.006	0	0.249	0.11	1.47

	3320	Fabricated metal product manufacturing	0.523	0	0.972	0.071	0.044	0.029	0.004	0	0.003	0	1.5
	3251	Basic chemical manufacturing	0.249	0.002	0.361	0.003	0.001	0.004	0	0	0.008	0.004	0.564
	2211	"Electric power generation, transmission and distribution"	0.165	1.08	0.235	0	0.001	0.003	0	0	0.102	0.005	1.55
	2121	Coal mining	0.147	0.241	0.122	0.011	0.008	0.383	0	0	0	0	0.872
	327A	Miscellaneous non-metallic mineral product manufacturing	0.136	0.062	0.46	0.006	0.002	0.008	0.004	0	0.025	0.079	0.745
	3221	"Pulp, paper and paperboard mills"	0.095	0.001	0.047	0	0	0	0	0	0.021	0	0.139
	3252	"Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing"	0.069	0	0.126	0	0	0.01	0	0	0.009	0	0.196
		Total for all sectors	**3.39**	**0.944**	**5.42**	**0.232**	**0.183**	**0.903**	**0.057**	**0.136**	**0.334**	**0.153**	**10.8**
Plastic	3251	Basic chemical manufacturing	1.01	0.008	1.47	0.011	0.005	0.015	0.003	0	0.033	0.015	2.29
	3261	Plastics product manufacturing	0.878	0.002	0.47	0.015	0.02	0.009	0.008	0	0.002	0	1.16
	3252	"Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing"	0.661	0.001	1.2	0.003	0.004	0.092	0.005	0	0.084	0	1.87
	2211	"Electric power generation, transmission and distribution"	0.125	0.821	0.178	0	0	0.002	0	0	0.077	0.004	1.17
	3221	"Pulp, paper and paperboard mills"	0.093	0.001	0.046	0	0	0	0	0	0.021	0	0.136
	3310	Primary metal manufacturing	0.082	0.004	0.045	0.01	0	0	0	0	0.005	0.032	0.156
	327A	Miscellaneous non-metallic mineral product manufacturing	0.064	0.029	0.215	0.003	0	0.004	0.002	0	0.012	0.037	0.349
	3253	"Pesticides, fertilizer and other agricultural chemical manufacturing"	0.052	0	0.436	0	0	0.001	0	0	0	0	0.476

	2122	Metal ore mining	0.051	0	0.005	0.007	0	0.017	0	0	0.015	0.007	0.09
	325A	Miscellaneous chemical product manufacturing	0.045	0	0.081	0	0.007	0.002	0	0	0.004	0	0.127
		Total for all sectors	**1.18**	**0.354**	**1.59**	**0.116**	**0.087**	**0.433**	**0.024**	**0.078**	**0.147**	**0.192**	**3.87**
Electronic Compt.	335A	Electrical equipment and component manufacturing	0.305	0	0.413	0.004	0.013	0.003	0.003	0	0.003	0	0.66
	3310	Primary metal manufacturing	0.305	0.014	0.168	0.035	0	0.001	0	0	0.018	0.121	0.58
	2122	Metal ore mining	0.143	0	0.015	0.02	0.002	0.049	0.001	0	0.043	0.019	0.252
	3251	Basic chemical manufacturing	0.08	0	0.116	0	0	0.001	0	0	0.003	0.001	0.18
	327A	Miscellaneous non-metallic mineral product manufacturing	0.059	0.027	0.201	0.003	0	0.004	0.002	0	0.011	0.035	0.326
	3221	"Pulp, paper and paperboard mills"	0.041	0	0.02	0	0	0	0	0	0.009	0	0.06
	2211	"Electric power generation, transmission and distribution"	0.039	0.258	0.056	0	0	0	0	0	0.024	0.001	0.369
	3252	"Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing"	0.035	0	0.063	0	0	0.005	0	0	0.004	0	0.098
	2121	Coal mining	0.028	0.046	0.024	0.002	0.002	0.073	0	0	0	0	0.167
	3320	Fabricated metal product manufacturing	0.01	0	0.019	0.001	0	0	0	0	0	0	0.029
		Total for all sectors	**1.41**	**0.535**	**1.87**	**0.161**	**0.201**	**0.691**	**0.049**	**0.216**	**0.191**	**0.174**	**5.11**
Electronic Product	3310	Primary metal manufacturing	0.261	0.012	0.144	0.03	0	0.001	0	0	0.016	0.103	0.496
	334A	Electronic product manufacturing	0.234	0	0.099	0.007	0.008	0	0	0	0.002	0	0.286
	2122	Metal ore mining	0.132	0	0.014	0.018	0.002	0.045	0.001	0	0.039	0.018	0.233
	3251	Basic chemical manufacturing	0.114	0	0.166	0.001	0	0.002	0	0	0.004	0.002	0.259
	335A	Electrical equipment and component manufacturing	0.082	0	0.111	0.001	0.004	0.001	0	0	0	0	0.178

	3221	"Pulp, paper and paperboard mills"	0.072	0	0.036	0	0	0	0	0	0.016	0	0.105
	2211	"Electric power generation, transmission and distribution"	0.066	0.433	0.094	0	0	0.001	0	0	0.041	0.002	0.619
	3252	"Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing"	0.041	0	0.074	0	0	0.006	0	0	0.005	0	0.115
	327A	Miscellaneous non-metallic mineral product manufacturing	0.034	0.015	0.114	0.002	0	0.002	0.001	0	0.006	0.02	0.185
	2121	Coal mining	0.033	0.054	0.028	0.003	0.002	0.086	0	0	0	0	0.197
TOTAL			**3.75009**	**1.25648**	**4.50792**	**0.49288**	**0.26618**	**1.63366**	**0.06688**	**0.21946**	**0.5412**	**0.77288**	**12.5167**

7.11 APPENDIX K: RESPONSE TO FEEDBACK

Table K1. Response to Feedback

#	Assessment	Section	Feedback	Response to Feedback and Reflections
1	**Design Proposal**	**Formatting and language**	The authors refer to themselves in the first person.	To maintain the report's objectivity, it is preferable that the authors avoid referring to themselves in first person pronouns. This implies that the results and conclusions made in this document are purely based on scientific research and calculations rather than personal feelings and/or opinions. In addition, replacing first person pronouns such as "our'' or "we" by "design team" or "team members at ROBOTEX" can make the writing of the report more technical and professional and gives the reader a sense of the engagement that the team has among themselves.
2	**Design Proposal**	**Executive Summary**	The section introduces the reader to aspects that should be discussed later in the report.	Since many readers only read the executive summary, it is essential that the topics going to be discussed in the report are clearly identified. This section should not discuss detailed information in regard to the design solution or device. It should be simple, clear and rather focuses on the 'big' picture to keep the reader interested.
3	**Design Proposal**	**Problem Description and Background information/literature review**	Missing environmental effects, some citation formatting, and needs a more	To ensure a better comprehension and overview of the problem, the section has been edited to include environmental effects while elaborating more on topics that were previously touched on. Within the literature review, a more in-depth description

			detailed literature review	discussing about the specifics of COVID-19 was also added
4	**Design Proposal**	**Constraints and Criteria**	Some of the constraints and criteria for the design have been misplaced.	It is important to understand what each of the constraints and criteria imply. This section has been edited according to their definitions and therefore the constraints have been updated to outline the limiting factors for the project while the criteria outlines a set of measurable terms that help ensure the success of the project.
5	**Design Proposal**	**Required information and tools**	Addition of other essential tools that are used for the project.	To better handle engineering projects, management tools along with technical tools should be used. Project management tools, such as Excel, and other communication platforms, such as WhatsApp, were used to help better plan and track the project tasks and deadlines. To show the importance of these tools to the team, a table that clearly identifies these required resources has been constructed as shown in ***Table 11*.**
6	**Design Proposal**	**Gantt Chart and fee estimate for design and required deliverables**	The charts inserted in the report are unclear due to inappropriate format, making it harder for the reader to read the elements.	To avoid distortion, the charts have been updated accordingly. This is done by inserting the charts as tables to replace the bitmaps used previously in the proposal. Though the font size of the elements in the Gantt chart is much smaller than the size used in the rest of the report, using the appropriate format to represent them ensures that they are easier to read and look more professional.
7	**Interim Report**	**Executive Summary**	This executive summary is very detailed. For the	Since many readers only read the executive summary, it is essential that the topics going to be discussed in the report are clearly identified. This section should

			final report, aim for around a page or less and only include big items from the report.	not discuss detailed information in regard to the design solution or device. It should be simple, clear and rather focuses on the 'big' picture to keep the reader interested.
8	**Interim Report**	**Scope of Project**	The project's implementation along with specific guidelines and production can be included.	As the scope of the project includes the entire process of the project, it is important to define everything that the project process would cover.
9	**Interim Report**	**Design Process**	Include strategies used like mind-mapping	It is important to keep the readers of this report informed of the details of the design process in order to justify the selected final design.
10	**Interim Report**	**Design Process**	Include standards or codes considered	The standards or codes must be included to show that the design follows safety precautions, standards and does not violate any government laws
11	**Interim Report**	**Design Evaluation**	Refer to your grading scheme in Appendix B here, since it highlights exactly how you ranked each criterion	It is best that the results displayed in the main section must explain thoroughly how these results came to be by referencing them to their respective appendix or source. This would prove useful for better understanding, support the text and remove any confusion for the readers.
12	**Interim Report**	**Updated Tasks and Timelines**	Formatting must be the same throughout	Uniform formatting throughout the project document not only gives a more professional look to the document but also keeps consistency.

13	**Interim Report**	**Conclusions and Recommendations**	Mention the name of the final design for the reader and include the feedback from the previous deliverables are found in the respective appendix.	It is vital that the communication style of the report must be informative, concise and direct. Therefore, it is necessary to have important details (such as the name of the chosen design) pertaining to a section mentioned appropriately.
14	**Tech memo**	**Consistency (formatting)**	Some figures and tables in the main body are inconsistent (e.g., some are italic, some are not)	Uniform formatting throughout the project document not only gives a more professional look to the document but also keeps consistency.
15	**Tech memo**	**Calculations inserted**	Calculations inserted are hand-written calculations.	In order to provide a clear process of the calculations, calculations inserted were modified to a digitally inserted calculations directly into the word document. This way, calculations are presented in a more professional and clearer way to the reader.
16	**Tech memo**	**References and credible sources**	Ensure references are included for each and every detail, including calculations	It is best that the results displayed in the main section must explain thoroughly how these results came to be by referencing them to their respective appendix or source. This would prove useful for better understanding, support the text and remove any confusion for the readers.
17	**Presentation**	**First slide**	First slide – Title Page	When presenting an idea, it is usually highly recommended that the name or title of the project

			Second slide- Team introduction	must be presented first before introducing the company/team members. This would capture the audience
18	**Presentation**	**Criteria and constraints**	More support of discussion instead of just a word	Points of interest and of importance to the audience must be detail oriented to provide more information.
19	**Presentation**	**Design Alternatives**	A bit more on the alternatives would have been appropriate	Describing project related process is important in justifying the hosen final design as the audience / reader would have a better understanding of all the options that were considered at first.