CONCEPTUAL DESIGN REPORT

MNM Consulting

Pioneering the Future

Group 2

03/05/23

Table of Contents

1 - Concept Solution 2
1.1 - Technical drawings and schematics 4
1.2 – Testing Results 4
2 - Proposed System Deployment 7
2.1 – Packaging and Parts 7
2.2 - Setup and Installation 8
2.3 – Instructions 8
2.4 – Troubleshooting 9
3 - Regulatory Standards 9
3.1 – Safety Standards 9
3.2 – Environmental Regulations 9
4 - Cost-Benefit Analysis 11
4.1 - Costs & Sensor Design Choice: 12
4.2 - Benefits: 12
Appendix I- References 14

1 - Concept Solution

The proposed solution will run using a Raspberry Pi and an Arduino. The system architecture is shown in Figure 1 - Diagram of system architecture, illustrating how the Pi will be used to run higher-level commands. This was chosen because the Raspberry Pi platform has more computing power than the Arduino, which will be necessary for using LiDAR and space mapping. In addition, the Arduino will be used for low-level control, such as the motors and sensor data acquisition. The Arduino platform is ideal for this use as it can read and write data in real time.

To operate, the robot requires several sensors. These sensors use are outlined in Table 1 - Sensors used on MNM MK1 Robot. As the proposed system architecture shows, the Arduino reads most sensor data. MNM Consulting has decided to implement three SHARP sensors in the final design as a final safeguard on the system. If the robot is too close ($d<10cm$) to any obstacle, as sensed by the SHARP sensors, the drive code will be interpreted, and the robot will move away from the obstacle. The air quality sensor will be used to measure air quality at a number of points throughout a room. This data will be plotted onto a heat map which will be output in a data report after data collection. The team has also created a PID loop to control driving. This closed-loop control will allow for more accurate data collection. The use of two encoders located on each of the rear motors. There has also implemented an LED strip to alert users of the current mode of operation.

Table 1 - Sensors used on MNM MK1 Robot

SENSOR	USE
ADAFRUIT SGP30 AIR QUALITY SENSOR	Measuring $C0_2$ Levels
LIDAR	LIDAR used for mapping space and obstacle detection
SHARP IR SENSOR	Measure distance to nearby obstacles for safety
ENCODER	Measure Wheel position

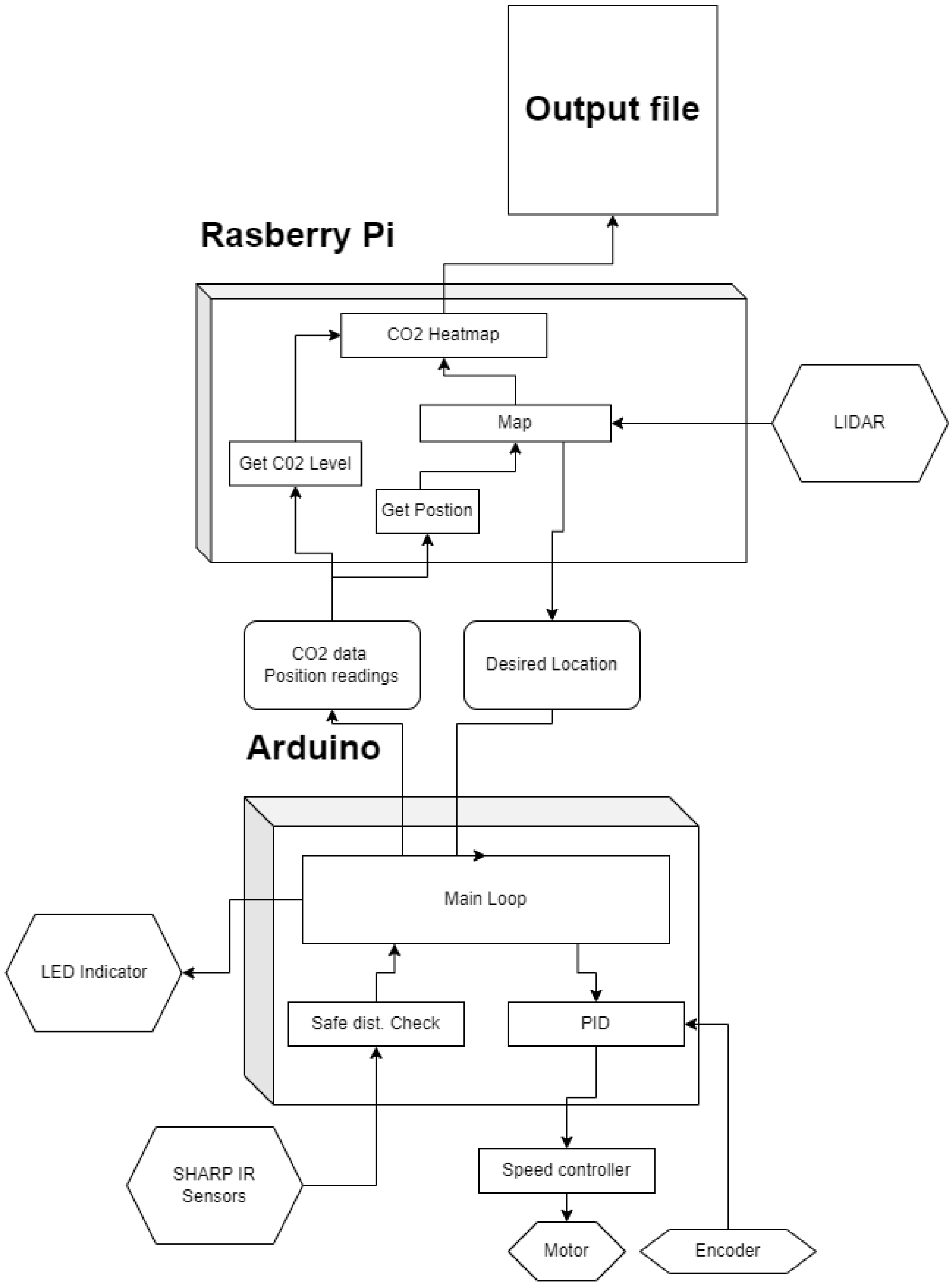

Figure 1 - Diagram of system architecture

1.1 - Technical drawings and schematics

Based on the prototype chassis, MNM consulting has created an improved model. The drawing of this chassis is shown in Figure 2 - Robot Dimensions This design has been streamlined to improve looks and functionality.

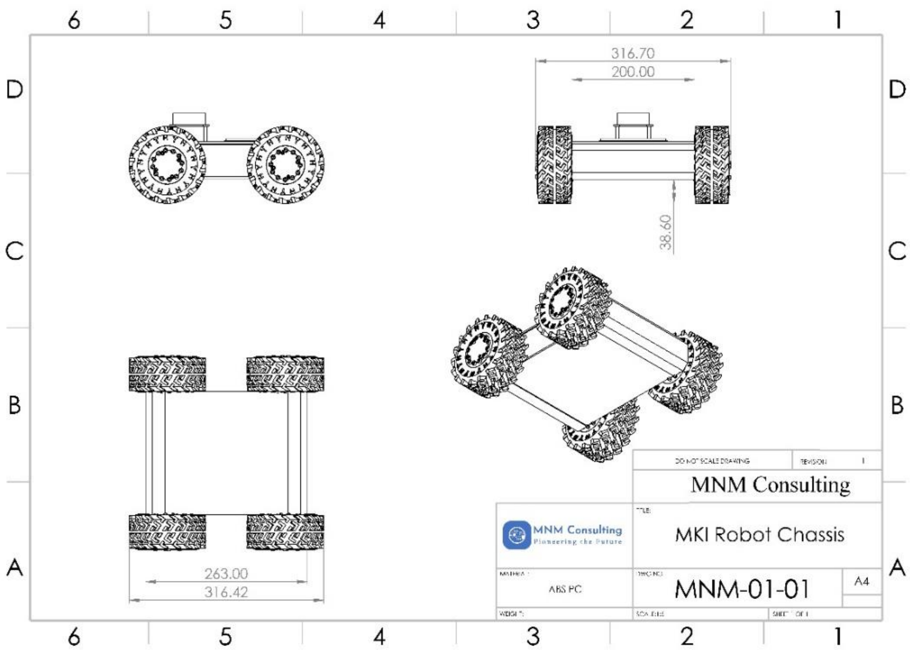

Figure 2 - Robot Dimensions

1.2 – Testing Results

1.2.1 – LED

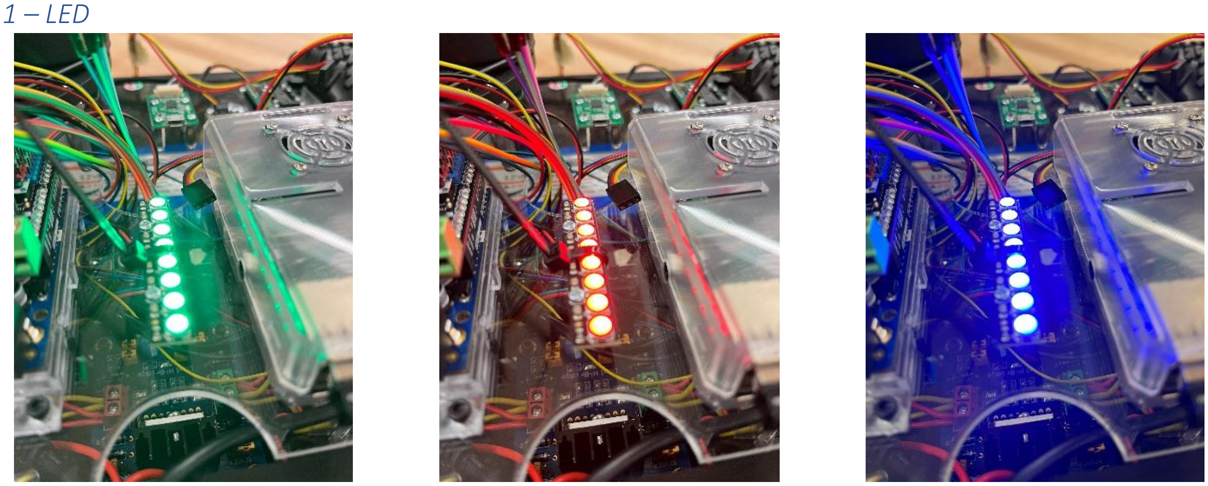

Figure 3 - LED's on robot indicating state

The LEDs on the robot seen in Figure 3 - LED's on robot indicating state are linked to the Arduino. They are controlled through a function that takes in a number from zero to four and changes the LED colours accordingly. This function will be used to indicate to the user what action the robot is performing like moving, turning, and collecting data.

1.2.2 – SHARP

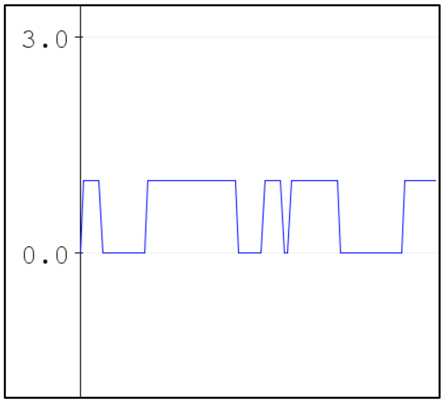

Figure 4 - SHARP sensor data

The SHARP sensor data can be seen in Figure 4 - SHARP sensor data and is linked to the Arduino. They are controlled through a function that takes in a safety distance form the front and sides. The function input is in millimetres and outputs TRUE if there is a safe distance and FALSE if something breaks that distance. This data will be used to maintain a safe environment for bystanders.

1.2.3 – PID

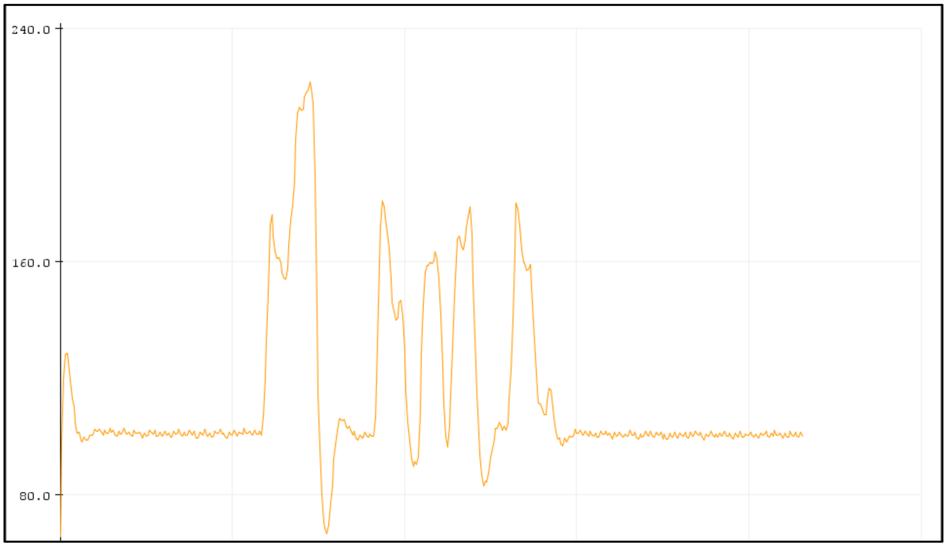

Figure 5 - PID controller for wheels

The PID controller test data can be seen in Figure 5 - PID controller for wheels. It is controlled through a function where a desired speed can be set, and using the motor encoder data, will maintain that desired speed. This function application will be used in moving the robot to ensure it moves the correct distance at a safe speed.

1.2.4 – CO2 Sensor

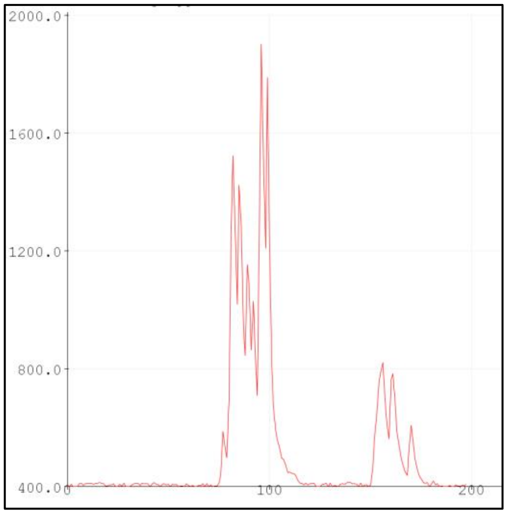

Figure 6 - CO2 measurement data (ppm)

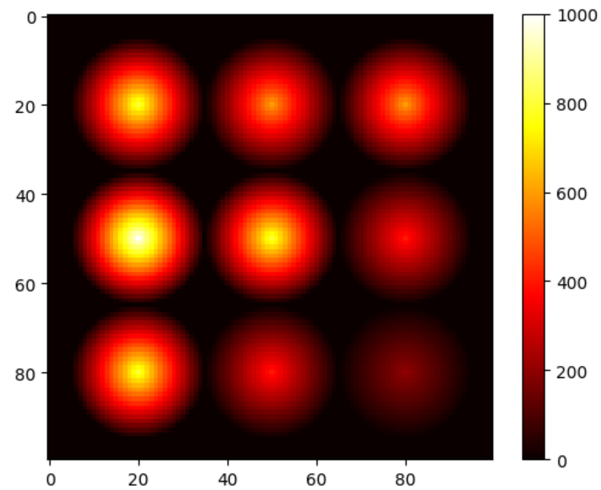

Figure 7 – Example CO_2 map of a room

To collect the CO_2 data the SPG 30 sensor will be use. Some testing data can be seen in Figure 6 - CO2 measurement data (ppm) which shows its reading at a normal environment and when breathed on. This data will be used eventually to map a room of its CO_2 levels. An example of this can be seen in Figure 7 – Example CO_2 map of a room with a prototype function plotting the data.

2 - Proposed System Deployment

2.1 – Packaging and Parts

Table 2 - List of parts that will be included with a customer purchase

 Black transport case with foam liner	 MNM Mk I Robot
 Charging Cable	 MNM User Manual

2.2 - Setup and Installation

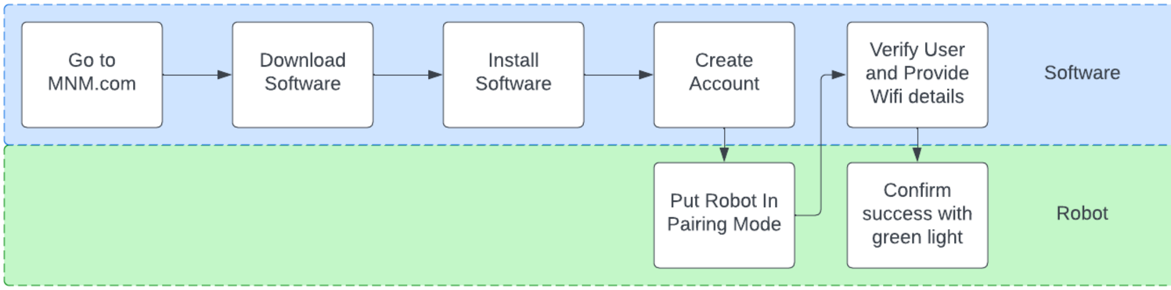

Figure 8 - Flow Diagram of Installation Process

After purchasing an MNM Mk I CO2 Detection Robot, the user will begin the setup and installation process found in the user manual included with the robot. The first step is visiting the MNM consulting website (MNM.com) to download the software after downloading the correct exe file for the user's system and running the exe to begin the software installation. After going through the installation wizard, the program will prompt the user to create an account. Once an account is set up, the software will prompt the user to pair the robot. This will be indicated by a graphic where the user holds down the pairing button on the robot until a light starts flashing. After a few seconds, the robot will display a number on the display screen, which the user must type in, followed by the Wi-Fi network and password for the robot to connect to. After this, the robot has been successfully paired and will flash green.

2.3 – Instructions

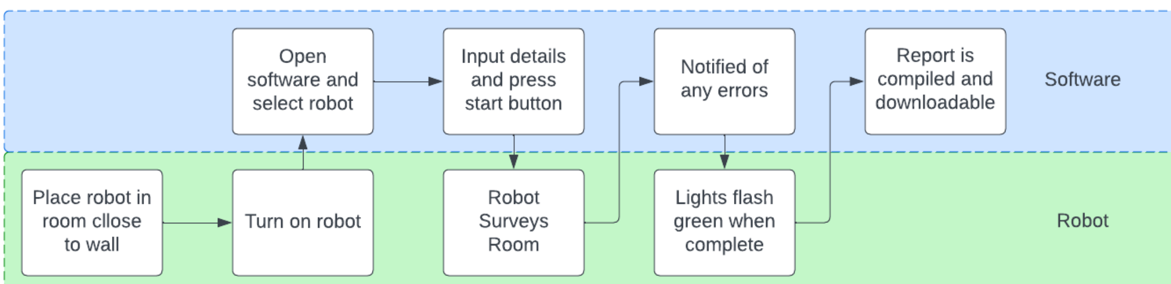

Figure 9 - Flow Diagram of Robots Instruction Execution

Once the robot has been set up, the user can take it to whichever room or floor they want to map and place it near a wall. After this, the user will turn the robot on, where they will see the status lights turn on and the display light up. Then the user will return to their computer where the software has been installed, and the robot paired. On the software, the user will select the robot and input the approximate size of the room the robot will be surveying. Then a button will appear, which the user will press to begin surveying. Based on the size of the room, it will provide an estimated completion time based on an average collected in testing. The robot will then begin surveying and can be left unattended. Once complete, the status lights will flash green, and the user may return to the computer to download a full summarized report of the data collected.

2.4 – Troubleshooting

If an error occurs with one of MNM's products, the first step for the customer would be to visit the website. There is a troubleshooting page with various common errors and step-by-step guides on how to fix them. If the user finds the error unfixable, the product can be shipped back to the company, where a specialized repair team will work to fix the robot. After this, it will be shipped back to the customer for a small charge.

3 - Regulatory Standards

Ensuring the mobile robot meets Ontario regulatory requirements is of the utmost importance to guarantee that the robot complies with safety and environmental regulations.

3.1 – Safety Standards

The robot is constructed to comply to ensure it complies with the standards established by the Ontario Ministry of Labour and the Ontario Occupational Health and Safety Act (OHSA). MNM Consulting has ensured the device is safe to operate and does not present any hazard to users through the following precautions:

- Limiting potential hazards associated with the robot's use and operation such as sharp edges and exposed wiring. This has been achieved using a smooth injection mould chassis which is very durable and protects the user from coming in contact with the electrical components.
- Ensuring the materials used are non-toxic, durable, and resistant to extreme degradation over time.
- Complying with the Canadian Electrical Code (CSA C22.1:21) to ensure proper grounding, insulation, and the reducing the risk of electric shock through proper wiring.
- Proper installation of the battery to prevent short circuits, overcharging and overheating. Additionally, the use of an electric fuse to protect the electrical components from damage due to overcurrent.
- Ensuring the safety manual for the robot is up-to-date and gives detailed explanations about how to operate the robot safely. If there are any questions or concerns about the use of the robot, users can call MNM Consulting customer service to prevent confusion and unnecessary risks.

3.2 – Environmental Regulations

The robot is designed to comply with environmental regulations established by the Ontario Ministry of the Environment, Conservation and Parks (MECP) to ensure it does not emit any harmful pollutants and is designed in a way to limit its impact on the environment. MNM Consulting has taken the following steps to limit the environmental impact of the robot:

- Making sure the materials used are environmentally friendly and have long lifespans to ensure components do not need to be replaced often.
- Taking precautions to ensure the battery's health is maximized through regenerative braking which converts the kinetic energy when braking into electricity, as well as a combination of active and passing cooling systems through heat dissipation vents and a cooling fan.

- Improving efficiency of the robot by using energy efficient motors, sensors, and control systems (e.x PID loop) to make the autonomous driving and braking system as efficient as possible which improves battery life.
- Highlighting effective strategies to charge the robot in the instruction manual to minimize battery degradation. Examples include storing the robot in a cool, dry place away from direct sunlight and fully charging the battery at least once every six months for optimal performance.
- Designing the robot is such as way to minimize waste such as using reusable components (e.x recyclable plastics and wires) and efficient packaging.

4 - Cost-Benefit Analysis

Table 3 - Cost benefit analysis presenting the costs and benefits associated with each robot

MNM Consulting Cost-Benefit Analysis					
		Quantity	**Capital Cost Per Unit**	**Monetary Value Of Benefits**	
Costs					
	Adafruit SGP30 Air Quality Sensor	1	$ 17.50		
	Slamtec RPLIDAR A1 Sensor	1	$ 158.19		
	Arduino Uno Rev3	1	$ 46.60		
	Raspberry Pi 4, 8GB	1	$ 87.25		
	Sharp GP2Y0A21YK0F Analog Distance Sensor	3	$ 12.95		
	NeoPixel Stick LED	1	$ 5.95		
	Servomotors	4	$ 120.00		
	Motor Encoders	2	$ 70.00		
	Dual H-Bridge Motor Driver	1	$ 32.19		
	Lithium Battery Kit with Charger – 12V, 8000mAh	1	$ 54.40		
	IP6518 Full Protocol fast Charging Moard Module	1	$ 8.51		
	Sporttraxx Talon Tires	2	$ 82.00		
	4.3inch Capacitive Touch Display for Raspberry Pi	1	$ 35.99		
	Plastic Injection Mold Chassis	1	$ 4.00		
	Waterproof Hard Case	1	$ 163.00		
	5V Brushless DC Cooling Fan - 40mm	1	$ 3.95		
	Glass Fuses	1	$ 0.50		
	Toggle Switch	1	$ 6.23		
	DF Robot I/O Expansion Shield	1	$ 8.90		
	Product Repair	N/A	$ 65.00		
	Total Employee Pay	N/A	$ 19,200.00		
	Other materials & miscellaneous expenses	N/A	$ 119.35		
	Total Costs		**$ 20,302.46**		
Benefits					
	Prevents health problems related to poor ventilation			$ 8,000.00	
	Improved indoor air quality monitoring			$ 5,000.00	
	Early detection and notification of high CO2 levels			$ 2,500.00	
	Autonomy reduces need for human intervention, improving efficiency and saving time			$ 8,000.00	
	Total Benefit Per annum			**$ 23,500.00**	
	Benefit-Cost Ratio				**1.16**

Based on this analysis, the benefits provided by the autonomous mobile CO2-detecting robot outweigh the costs required to build it. The robot will deliver a positive net present value to QCMP and future investors. The monetary value of the benefits is attributed mainly to the savings the robot provides, as extensive repairs may not be required due to the robot's ability to detect issues early on.

4.1 - Costs

The costs of the final robot's parts are similar to those used in the prototype. Changes to the final design include adding a 4.3-inch capacitive touch display, a plastic injection mould chassis, a brushless cooling fan and a carrying case. The touch display will relay information about the robot's mapping progress, CO2 readings and battery health to the user. Presenting battery percentage to users will help them maximize the battery health of the robot, improving its longevity. CO_2 detection readings will also be presented by the NeoPixel Stick LEDs, as colours will change depending on the actions the robot is performing. A plastic injection mould chassis will be used as the material is easily mass-produced, priced effective and has excellent strength and durability. The robot will also be actively cooled using a 12V brushless DC fan, minimizing the degradation of the electrical components and improving the longevity of the robot. The package will be delivered in a carrying case with the robot, charger, instructions, and protective foam. Costs for the total employee pay were calculated for four employees working 8-hour weeks, receiving a payment of $50 per hour for one robot. The product repair cost was calculated by multiplying the parts' average price by a scaling factor of 15% to approximate the cost of shipping materials. Lastly, the miscellaneous expenses were calculated by summing the cost of parts for one robot and finding 13% of the total cost.

4.2 – Sensor Design Choice

The sensors for the final robot largely remained the same, with the main difference being that the Sensirion SCD30 CO2 was removed from the final design. The final design will only use the Adafruit SGP30 Air Quality Sensor since it provides a complete air quality summary and measures various air quality metrics, including Total Volatile Organic Compounds (TVOC) and equivalent CO2 (eCO2). The Sensirion SCD30 CO2 Sensor is about $47.00 more than the Adafruit SGP30 Air Quality while having a smaller measurement range than the Adafruit sensor. The Adafruit SGP30 Air Quality Sensor can measure between 400 – 60 000 ppm, while the Sensirion SCD30 CO2 Sensor only has a measurement range of 400 – 10 000 ppm. The robot will be able to effectively detect changes in air quality, which can be used to estimate the CO2 concentration levels since high CO2 concentration levels are linked to poor air quality. The final design of the MNM MK I Robot will also use 3 SHARP sensors to relay information about the surroundings to the robot, ensuring it avoids hazards and navigates effectively. The SHARP sensors detect objects in the robot's path and calculate distances using infrared light. Finally, the robot can identify obstructions farther away and avoid collisions by mounting three sensors at different angles.

4.3 - Benefits

The benefits attributed to the robot are mainly due to the amount of money it can save users, related to the medical and ventilation costs due to high concentrations of CO2. High concentrations of CO2 can cause neurophysiological and respiratory health problems. If these problems worsen, more significant medical issues can arise, which require greater medical attention. On average, these medical costs are about $8 000 for a standard-sized office of employees. The robot will also be able to provide improved indoor quality monitoring and early detection of higher CO2 levels. Improved indoor quality monitoring can help determine any allergens and other air pollutants, which can help prevent medical issues and expensive repairs related to poor ventilation. Lastly, since the robot runs autonomously, human intervention is reduced, which improves efficiency and saves time. This means a human technician does not need to be paid to assess these problems, and further costs related to ventilation issues are limited. A benefit-cost ratio was also generated from the cost-benefit analysis and the ratio shows that the benefit from the robot is greater than the manufacturing costs to produce it, highlighting that it is a viable product that has great use. A benefit-cost ratio was also generated from the cost-benefit analysis, and the ratio shows that the benefit from the robot is greater than the manufacturing costs to produce it, highlighting that it is a viable product with great use.

Appendix I- References

[1] A. Industries, "Adafruit SGP30 Air Quality Sensor Breakout - VOC and eCO2." https://www.adafruit.com/product/3709 (accessed Feb. 27, 2023).

[2] "Arduino UNO REV3 [A000066] : Amazon.ca: Electronics." https://www.amazon.ca/ARDUINO-A000066-Uno-DIP-1-5/dp/B008GRTSV6 (accessed Feb. 27, 2023).

[3] "Brushless gimbal motor with magnetic encoder - RobotDigg." https://www.robotdigg.com/product/1423/Brushless-gimbal-motor-with-magnetic-encoder (accessed Feb. 27, 2023).

[4] "Bussmann BP/AGC-25-RP Ferrule Fuse, 25A, 1/4 x 1-1/4-In pack of 5." https://www.dkhardware.com/bussmann-bp-agc-25-rp-ferrule-fuse-25a-1-4-x-1-1-4-in-pack-of-5-product-5738671.html (accessed Feb. 27, 2023).

[5] "Contrôleur de Deux Moteurs DC L298 SeedStudio," *RobotShop Canada*. https://ca.robotshop.com/fr/products/seeedstudio-l298-dual-h-bridge-motor-driver (accessed Feb. 27, 2023).

[6] "CSA C22.1:21 | Product | CSA Group." https://www.csagroup.org/store/product/CSA%20C22.1:21/ (accessed Feb. 27, 2023).

[7] "Gravity: IO Expansion Shield for Arduino V7.1 - DFRobot." https://www.dfrobot.com/product-1009.html (accessed Feb. 27, 2023).

[8] "How to Estimate Injection Molding Cost?," *Formlabs*. https://formlabs.com/blog/injection-molding-cost/ (accessed Feb. 27, 2023).

[9] "Hsiang neng geared motor HN-GH12-1634T New $30 Fast Free Shipping," *eBay*. https://www.ebay.com/itm/325321262219 (accessed Feb. 27, 2023).

[10] "Ip6518 Full Protocol Fast Charging Moard Module Qualcomm Qc3.0 Bc1.2pd - Air Conditioner Parts - AliExpress." https://www.aliexpress.com/i/4000379935004.html (accessed Feb. 27, 2023).

[11] "Pololu - Sharp GP2Y0A21YK0F Analog Distance Sensor 10-80cm." https://www.pololu.com/product/136 (accessed Feb. 27, 2023).

[12] "POWER FIRST TOGGLE SWITCH SPST TAB - Toggle Switches - GGE2VLT2 | 2VLT2 - Grainger, Canada." https://www.grainger.ca/en/product/TOGGLE-SWITCH-SPST-TAB/p/GGE2VLT2 (accessed Feb. 27, 2023).

[13] "Product," *CSA Group*. https://www.csagroup.org/store/product/CSA%20C22.1:21/ (accessed Feb. 27, 2023).

[14] "Raspberry Pi 4 Model B 8GB and Kits." https://www.cytron.io/p-raspberry-pi-4-model-b-8gb (accessed Feb. 27, 2023).

[15] "SCD30 - CO_2 accuracy of ±(30 ppm + 3% MV) @400-10000 ppm." https://sensirion.com/products/catalog/SCD30/ (accessed Feb. 27, 2023).

[16] "Slamtec RPLIDAR A1M8 2D 360 Degree 12 Meters Scanning Radius LIDAR Sensor Scanner for Obstacle Avoidance and Navigation of Robots : Amazon.ca: Everything Else." https://www.amazon.ca/Slamtec-RPLIDAR-Scanning-Avoidance-Navigation/dp/B07TJW5SXF (accessed Feb. 27, 2023).

[17] admin, "Tires & wheels, assembled, glued (2.8") (All-Star black chrome wheels, Talon tires, foam inserts) (nitro rear/electric front) (2) (TSM® rated)," Apr. 02, 2013. https://traxxas.com/products/parts/3669A (accessed Feb. 27, 2023).