AIR QUALITY MONITORING AT AN INDOOR LOCATION

By

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

Department of Electrical and Electronic Engineering
Brac University
June 2023

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Academic Technical Committee (ATC) Panel Member:

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Department of Electrical and Electronic Engineering
Brac University
June 2023

Declaration

It is hereby declared that

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

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Approval

The Final Year Design Project (FYDP) titled "Air quality monitoring at an indoor location" submitted by

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of Fall, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc. in Electrical and Electronic Engineering on 15th December 2022.

Examining Committee:

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Ethics Statement

Our final year design project report entails 11% plagiarism.

Abstract/ Executive Summary

This abstract presents an indoor air quality monitoring project using IoT technology. The project utilizes various sensors to continuously monitor the air quality parameters in indoor spaces. The collected data is transmitted to an IoT analytics platform for further analysis and visualization. The system aims to be cost-effective and user-friendly, making it suitable for a wide range of indoor locations. By regularly monitoring indoor air quality, this IoT-based project has the potential to improve the overall air quality and create healthier indoor environments.

Keywords: IoT; Sensors, Indoor; Visualization; Health; Solution; Sustainable.

Dedication

Special appreciation to our ATC Chair, Dr. Md. Mosaddequr Rahman for his guidance during the project.

Acknowledgement

We would like to thank our ATC Chair Dr. Md. Mosaddequr Rahman, Mohaimenul Islam, and Aldrin Nippon Bobby for their tremendous guideline and unbelievable support in this project. The technical guidance under his presence is something that we can always remember to motivate us. We are truly grateful to these two respectful people for their unbelievable support, which greatly benefited our team and helped us a lot to complete each tough task easily.

Table of Contents

Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

Air is the most important element of the environment and also the most important living thing. Nowadays, air pollution is an alarming issue worldwide. Many cities in the world have the worst air quality and Dhaka is one of them. Dhaka is the most densely populated city in Bangladesh and repeatedly topped the list of bad air quality over the world.[1]

According to the Ministry of Environment and Forests, Bangladesh: Air quality of any location is measured by depending on five main pollutants-Particulate matter (PM 2.5 and PM 10), SO2, CO, NO2, O3(Ozone)[2]. Based on the averages of these air pollutants concentrations in different time parameters AQI for any location can be measured. The concentrations of indoor and outdoor air pollutants change throughout the day and even from one day to the next. The public needs timely information on air quality and other elements (such as weather conditions) that impact it in order to safeguard their health. People who have access to air quality predictions may lower their exposure when pollutant concentrations are high. This is crucial, especially for those who are vulnerable to the negative effects of certain contaminants. For instance, those who have asthma may be vulnerable to sulfur dioxide and ground-level ozone. We must first determine the goal of the monitoring before we can develop an air quality monitoring system. To identify current and potential air pollution issues, to track trends or changes in air quality, to gather data for the design of air pollution prevention projects, to monitor pollution reduction activities to see if the objectives of specific programs are being met, to develop emergency plans, to increase public awareness of air pollution, to reduce health risks from air pollution, or to develop ways to reduce air pollution. The following elements must be considered when creating the air quality monitoring program once the program's objective has been determined: What subject should the program cover? Exist air quality monitoring already in place? What local causes of air pollution are there? Which variables ought to be measured? How often should the parameters be measured?

1.1.1 Problem Statement

As a result, to observe the air quality in a real-time scenario, air quality monitoring and purifying systems can be a realistic approach. However, this procedure can be implemented to monitor the real-time air quality of a particular indoor area, notify the clients and purify the air if needed and above all raise the health concerns reading indoor air quality.

1.1.2 Background Study

According to IQAir, Dhaka was the most polluted city in the world in 2021 (US AQI-194). Air pollution happens most often because of the outflows from malfunctioning vehicles, especially diesel-controlled vehicles, brickfields, dust from streets and building destinations, and harmful gasses produced by industry. The air pollutants are carbon monoxide (CO), Ozone gas(O3), hydrocarbons (HC), nitrogen oxides (NOx), sulfur dioxide (SO2), lead compound particulates, and unburned carbon particles. Therefore, Dhaka's air pollution levels are very high. In addition, it is the monetary center point of the whole nation, so the city is liable to genuinely undeniable degrees of contamination the entire year, with a couple of short reprieve periods, making its air unsuitable to inhale lasting through the year[2].

According to the World Health Organization (WHO), every year nearly seven million lose their lives due to air pollution[3]. As a result of increasing air pollution, there are high numbers of stroke, heart disease, lung cancer, chronic obstructive diseases, and acute respiratory infections. In Bangladesh, air pollution itself creates a 17.6% high risk of death and disability[3]. More specifically, the air quality of Dhaka from 2017 to 2021 was extremely bad and unhealthy for health (WHO,2021)[3]. It is therefore important to enhance the air quality in our country, especially in Dhaka, to make our health system more effective.

According to the National Ambient Air Quality Standards (NAAQS), the AQI standard for Bangladesh is given below in the Table.

Table 1: AQI standard for Bangladesh

Air quality index (AQI) Range	**Category**	**Color**
0-50	Good	Green
51-100	Moderate	Yellow Green
101-150	Caution	Yellow
151-200	Unhealthy	Orange
201-300	Very unhealthy	Red
301-500	Extremely unhealthy	Purple

Above mentioned data indicated the categorical range to comment on environment air index quality. Our project is indoor location based but these ranges are standard and followed for all kinds of air quality monitoring processes.

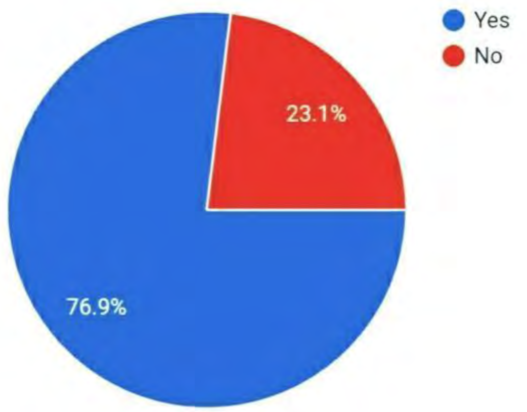
1.1.3 Literature Gap

When a topic remains unexplored and offers potential for study or additional analysis, it is known as a literature gap or research gap. Literature gap is a commonly used term in every project due to future scope and further development. In this case of Literature Gap, it can be said that the function of our current device is basically to monitor an environmental condition. That's all it does. It cannot do any analysis, or come to any conclusions about how good or bad the environment is. Our future scope is to add algorithms to it so that it understands how good or bad it is. And what should be done if it is bad. The next thing is we will create our own database to keep the data concise to us. Besides, I will create an App for everyone's use.

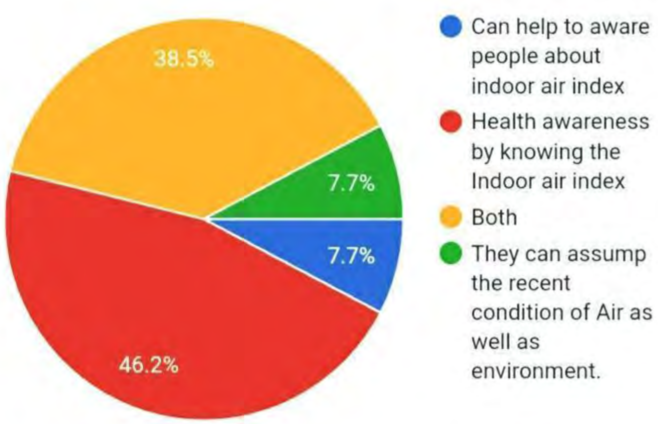
1.1.4 Relevance to current and future industry

For our project, we conducted a survey regarding our project so that we can represent a current perspective depending on different criteria:

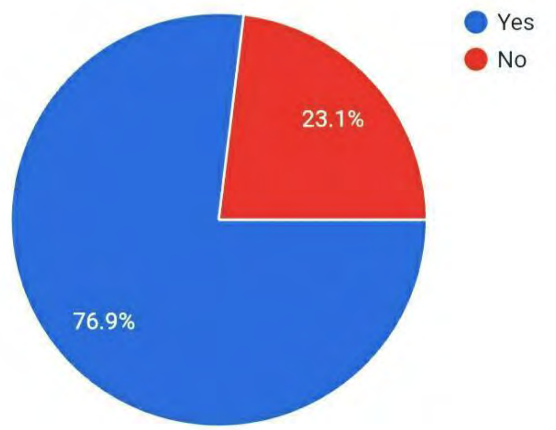
Q1. Do you feel the need to know the indoor air quality index just like the outdoor air index?



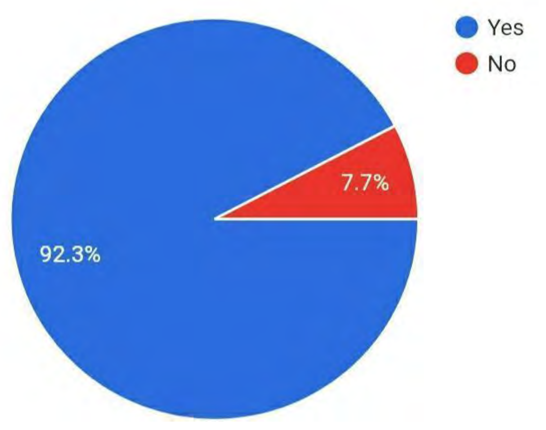
Q2. According to you, in which aspects indoor air quality index can help people?



Q3. Do you think, in the coming years, countries like Bangladesh, which are ranked in the poor category might give a closer look at the indoor air index measuring systems?



Q4. If there is a system of this kind which is affordable and can measure indoor air index and purify the air in your offices/homes/labs/hospitals/classrooms then would you like to have this system?



Regarding the future industry of our project we can say this project has some important fields. One of them is an intensive care unit where the environment needs to be closely monitored.

Another one is different types of chemical lab perspectives as many labs are sensitive due to operational work there our device can play an important role to supervise the proceedings for health concerns. In addition, this device can be used as an investigation device like places where surroundings are unknown to judge there. If we place this device then it can notify us whether the environment of this place is unsafe for visit or not.

1.2.1. Objectives

- To design an air quality monitoring system.
- Measure the AQI of the particular place
- Analyze the AQI data with the standard data.
- To make the data available to the users.
- Provide notifications or an alarm if required.

1.2.2 Requirement, Specification and Functional and Nonfunctional Requirements

Table 2: Requirement, Specification and Functional and Nonfunctional Requirements

Subsystem	Requirements	Components	Specifications
Location (Indoor)			13.550 X 6.950 sq. meter
Power System Unit	Power source and Storage	Lipo Battery, Voltage converter	**Lipo Battery 1200mAh 11.1VS** ● Voltage: 11.1V ● Constant Discharge: 30C(10.5A) ● Max discharge: 25C (10 sec) ● Dimensions : 74 x 34 x 22 (LxWxH)(mm) ● W\\ ● eight : 87 gm ● Charge Rate : 1-3C Recommended, 5C Max
Data collecting and processing Unit	Microcontroller board	Arduino, ESP32	

Monitoring and Visualization Unit	Display	Cloud storage, LCD	- Input Voltage- 5V 16 characters wide, 2 rows
Gas Detection Unit	Gas sensors, Temperature sensor, Humidity sensor, PM sensor	MQ135	MQ135: - IC Chip MQ-135 - Operating Voltage (VDC) 1-4 - Detecting Range 100 ppm to 1000 ppm
		MQ9	MQ9: - Input voltage: DC 5±0.2V - Current Consumption: 150mA
		MQ2	MQ2: - Operating voltage: DC 5 V. - The carbon monoxide detection with better sensitivity. - With a long service life and reliable stability. - Rapid response and recovery characteristics. - Range: 10 to 1000 ppm.
		Temperature and Humidity Sensor	DHT22

Communication Unit	connects to the Wi-Fi or internet	Thingspeak	• IC chip- Operating Voltage (VDC)- Range-3.7 to 4 (SIM800L) • Peak current(A)- Range-2 (SIM800L).

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

• **Lack of sensors availability:** For our project we need to use different kinds of sensors to monitor indoor air quality. These sensors are digital sensors as our solution process is based on IOT or GSM based. But different digital sensors are not available in our country for hardware setup as well as for our simulation tools we may not find the right sensors in software to showcase our circuit simulation in proteus.

• **Placements of device:** Our project needs an indoor location and for that we need to place our sensors in an indoor location accordingly. If we place our sensors on ground level then depending on the room size, the results of the sensors may vary compare to the sensors placements at the upper part of the room. Basically, air index may show complete different results we fails to identify the right place to arrange them in an indoor location.

• **Budget limitations for choosing different components**: Our project's main constraints might be the budget. As, we are choosing different sensors to identify the AQI, we definitely need highly quality digital sensors which some are costly. Even for other components we may need costly products to install this at an indoor location as we are planning to do it through IOT based. So IOT based tools are also expensive in our country and that can be a carrier for our project.

1.2.4 Applicable compliance, standards, and codes

National Ambient Air Quality Standards (NAAQS):

The United States' National Ambient Air Quality Standards (NAAQS) set limitations on the atmospheric concentration of six pollutants that are responsible for smog, acid rain, and other health risks, established by the United States Environmental Protection Agency (EPA) under authority of the Clean Air Act. Ozone (O3), atmospheric particulate matter, lead, carbon monoxide (CO), sulfur oxides (SOx), and nitrogen oxides are the six criteria air pollutants (CAP) or criteria pollutants for which limitations are specified in the NAAQS (NOx).

IEEE 1625-2008:

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

IEEE 2700-2017:

A common framework for sensor performance specification terminology, units, conditions, and limits is provided. Specifically, the accelerometer, magnetometer, gyrometer/gyroscope, accelerometer/magnetometer/gyroscope combination sensors, barometer/pressure sensors, hygrometer/humidity sensors, temperature sensors, light sensors (ambient and RGB), and proximity sensors are discussed.

ANSI/ISA-95:

This standard refers to developing an automated interface between enterprise and control systems. Also provides consistent terminology, information, and operation models of IOT.

1.3 Systematic Overview/summary of the proposed project

This project provides a process of sensing multiple gasses, also the ambient temperature and humidity where indoor air pollution levels will be measured by an air quality monitoring system, which will also provide users with information on pollution. Therefore, the users might reduce their time in interaction with the polluted air and be less vulnerable to harm from pollution. In this investigation, the PM2.5, PM10, CO, and CO2, SO2, NO2, O3 temperature, humidity, and the whole monitoring system provide a safe atmosphere for both working and living environments. To ensure proper connection with smart applications, communication across short distances (Bluetooth and Wi-Fi) will be installed. The process of gathering data during conversation is data from the application's air quality monitoring device first, then to the server. Data obtained from the device is kept on a server in the cloud that can be utilized to anticipate the air quality in the future. This air quality monitoring device can assist not only to minimize the exposure of individuals to indoor air pollution but also indirectly or directly benefit humans from harm. This project will benefit the economy, society, and environment for the creation of indoor air quality monitoring systems by integrating sensors and IOT technologies.

1.4 Conclusion

Our project's main aim is to create health awareness as we tend to not give much importance on air quality of indoor places. It is true that results of our project will only indicate the air quality range of that selected particular indoor location but as this product is easily accessible, high efficiency so multiple uses of different indoor places, chemical labs, pharmaceutical labs will eventually benefit people to concern about the health as well as to raise awareness about air quality improvement. Another part of this project is clear that informing the public about indoor air quality of their living and working place is one of the main focus. In order to meet the demand of knowing the real time air quality index, we are introducing our project which will enable the users to keep track of the instantaneous air quality index and the average data of previous hours and day. It will help the users to decide if the place is safe or not.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

We came up with two design approaches to showcase the expected project outcomes. First design approach is based on GSM to monitor indoor air quality and the second design approach is an IOT based monitoring system. We have researched different papers and analyzed these two design approaches to find out the main objectives of our project.

2.2 Identify multiple design approach

Design approach 1: Indoor location-based air quality monitoring with GSM

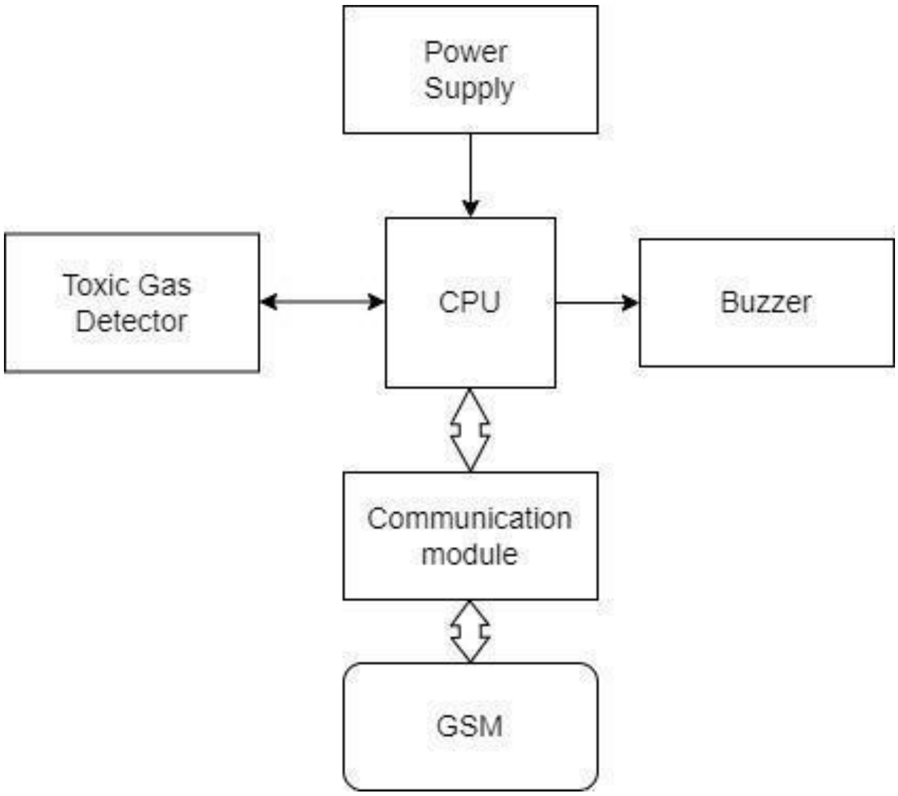


Figure 1: block diagram for design 1

- toxic gas sensors measure data for CO, CO2, NOx, SO2 and PM.
- CPU Process the data for each sensor.
- Processed data will be sent to users by GSM.

Design approach 2: IOT based air quality monitoring system for indoor location

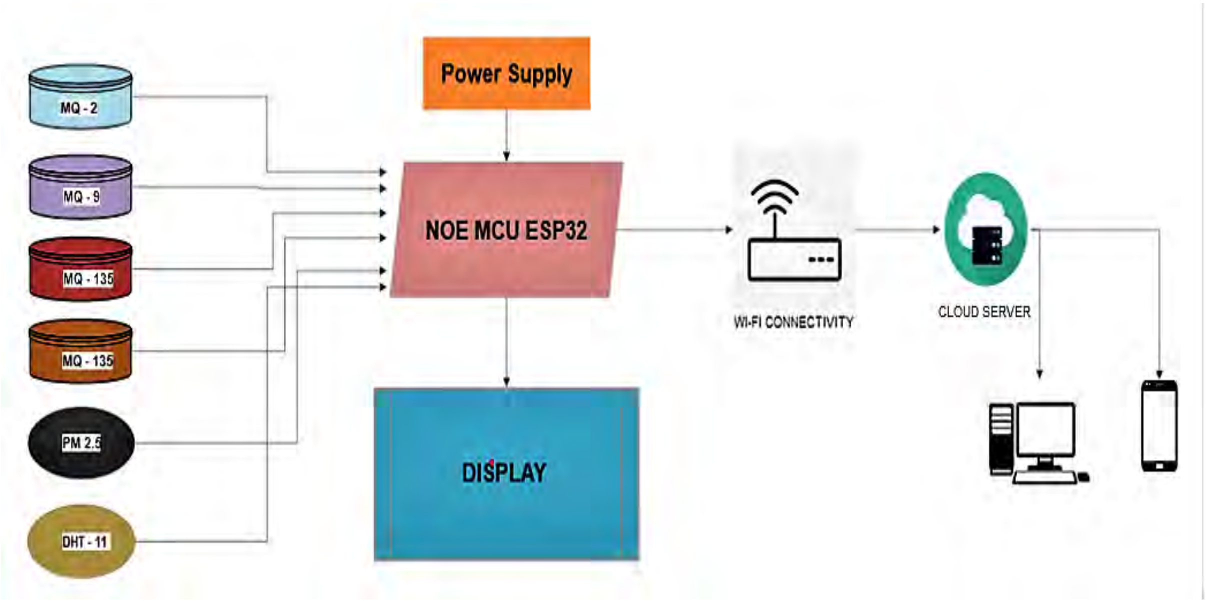


Figure 2: Block diagram for design 2

- ESP 32.
- Cloud server.
- Display unit
- Wi fi system.
- AQI measurements sensors.

2.3 Describe multiple design approach

Design approach 1: Indoor location-based air quality monitoring with GSM

In this approach we will detect toxic gas via the GSM module to showcase the output. Our aim is to notify users while the indoor air quality is bad and in this approach the buzzer will notify whether the air index in that particular location is healthy or threatening for health.

Workflow diagram to find the process we follow to approach this design:

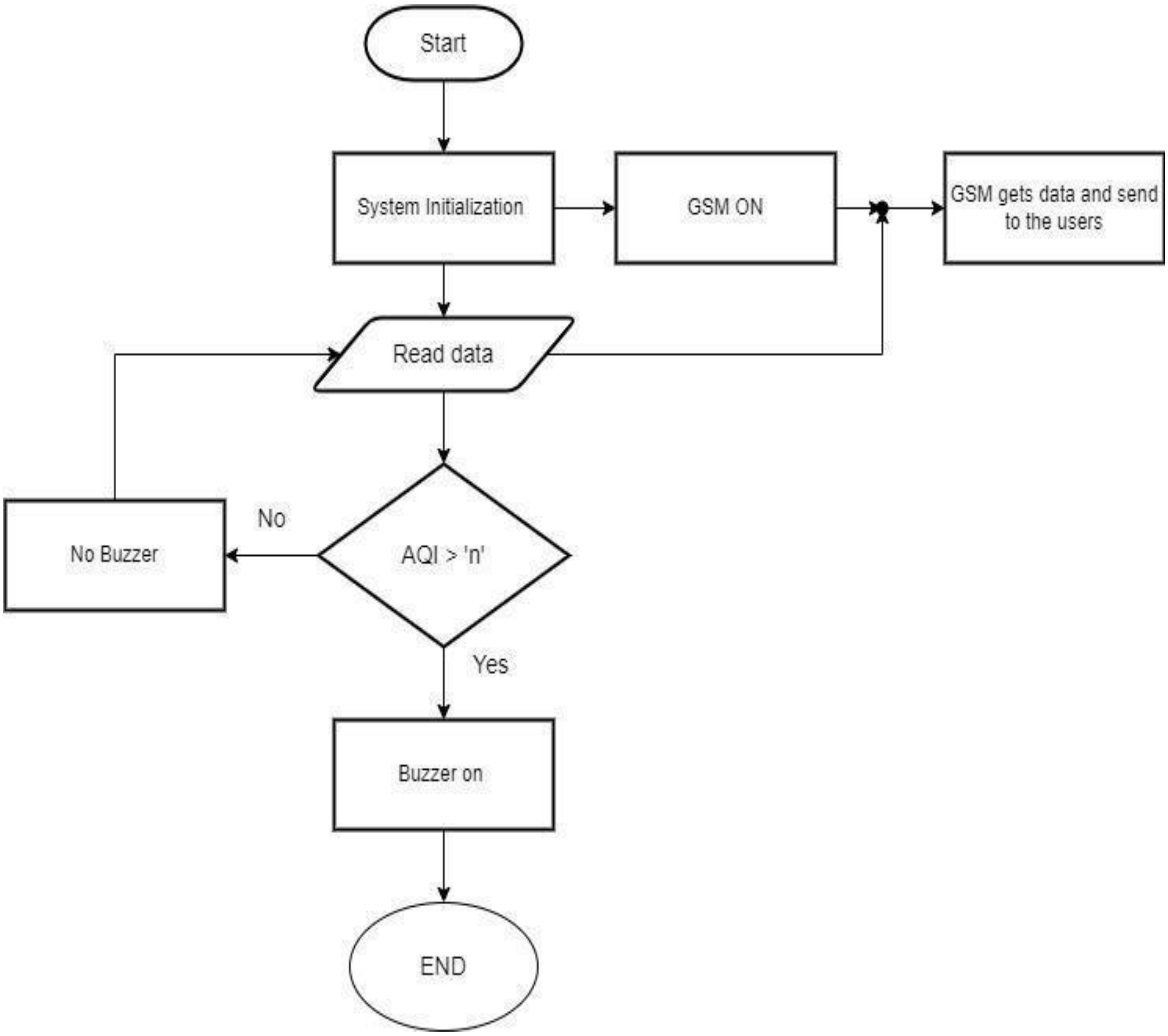


Figure 3: workflow for design approach 1

In this process, at first the design approach will initialize the needed data as well as GSM will get the data and send the data to the user. While it reads data, it will identify whether the sent data is in a safe or danger zone according to the AQI index. If the range of AQI is in the danger zone then it will notify the user about the AQI index apart from sending the data.

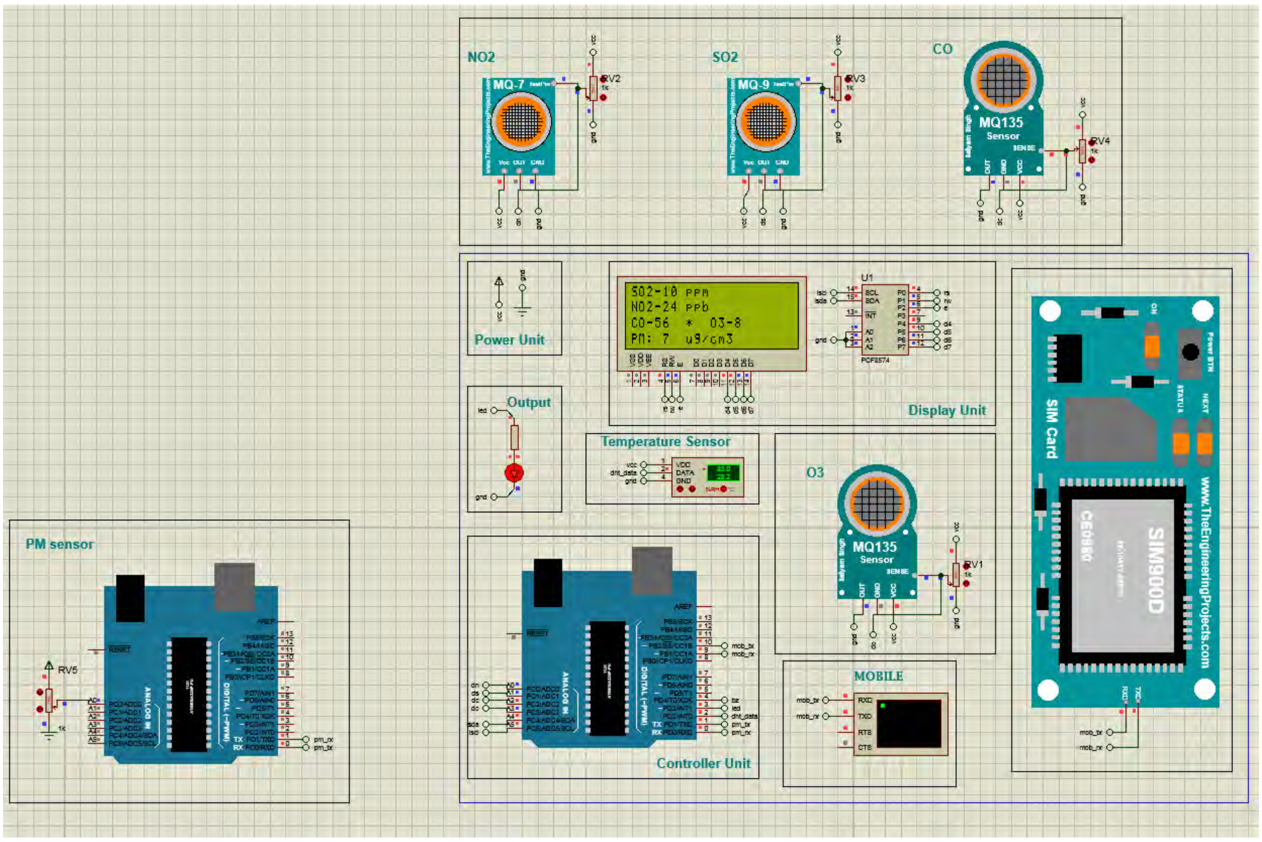


Figure 4: Schematic Diagram of Design Approach 1

Above mentioned proteus circuit will replicate the design approach we mentioned using the GSM module to detect the AQI value as well as notify the user by an alarming process to take measures. Here, we used all the specified sensors which are must for AQI calculations in the simulation process to visualize the real time project process. GSM will update all the database information and will update the users about the results via app.

Design approach 2: IOT based air quality monitoring and purification

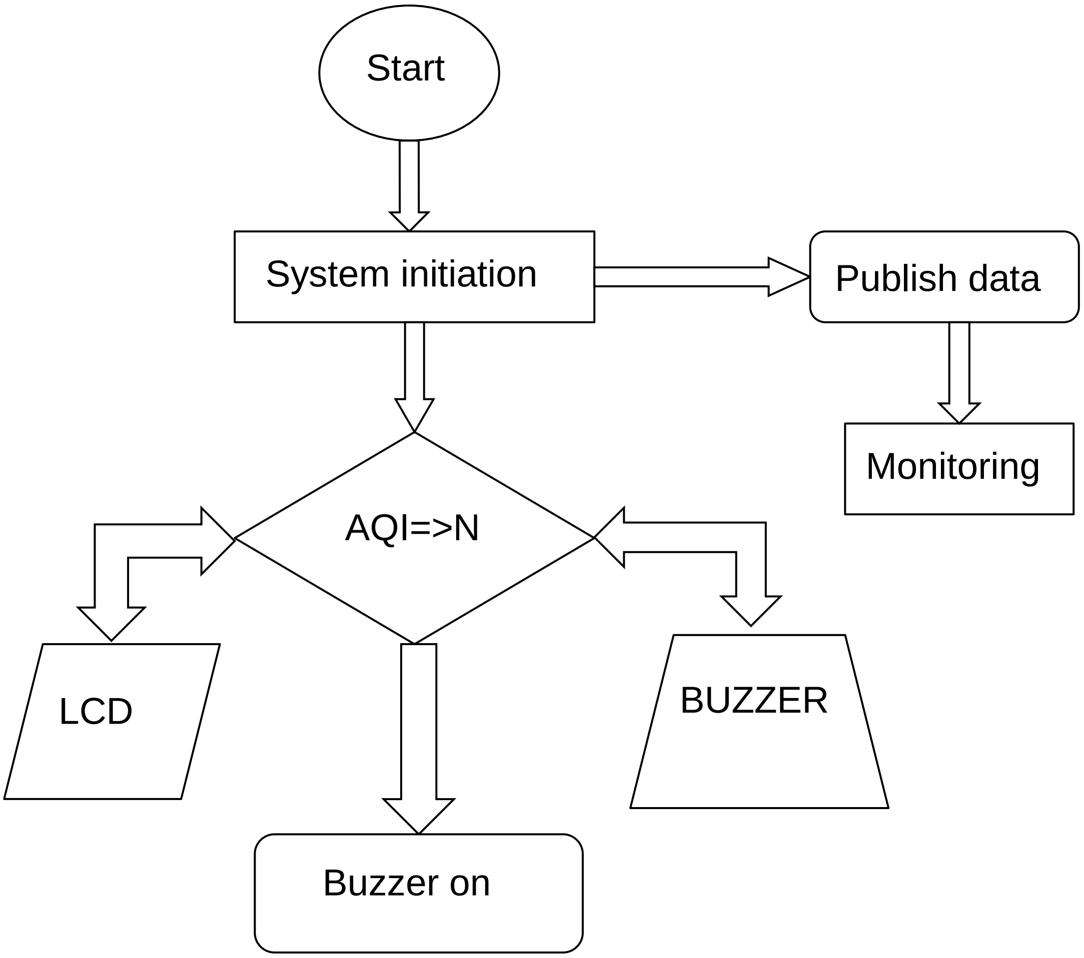


Figure 5: workflow procedure to find out results for design approach 2

Through this design approach, the first process will initialize the value it receives from the system. Then, it will proceed the data and will showcase all the AQI value concentrations in the LCD monitor. Apart from this procedure this design approach can identify the value whether it is in danger zone or not so if required a buzzer can be used to notify the user to detect the AQI danger range for indoor systems.

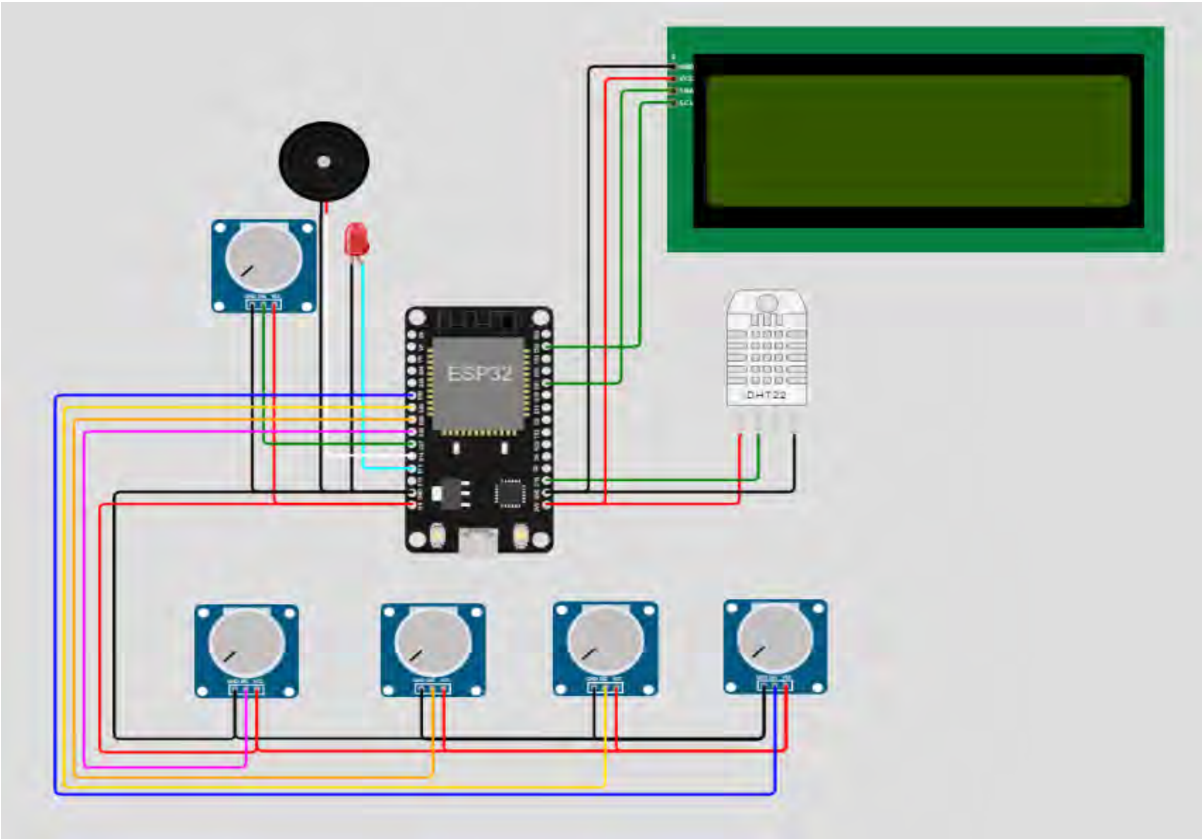


Figure 6: Schematic diagram of Design approach 2

We used WOKWI software for this design approach as we are using ESP-32 so we need to find a software which will show the response of AQI in a process that will be displayed in LCD to figure out the limits of air quality standard in a particular place. As we are not using buzzer to notify users the safety range, so we need to find the procedure to display the values of pollutants in a way where users will understand the situation a place by looking at the LCD or information provided to mobile or laptop. As wokwi is a much more efficient simulation process than proteus for using ESP32 to measure air quality index.

2.4 Analysis of multiple design approach

After analyzing both approaches we can comment that design approach 2 is a more convenient one for implementation of this project as the main objective of this project is to monitor indoor air quality so the IOT based approach is more effective for data analysis as ESP32 has high efficiency rate for AQI measurements.

Table 3: Analysis of multiple design approach

Criteria	**Design 1**	**Design 2**
Component Efficiency	Arduino has a less efficient process for air-quality monitoring components.	Long time efficiency for ESP32
Data accuracy	Data collected from the arduino is stored as 1 byte of information.	Data Collected from ESP32 stored as 4 bytes of information.
Manufacturability	This system is based on the GSM network. Which will only be applicable for particular regions.	This system is based on IOT. Which will be applicable for all around the world.
Maintainability	No internet connection in this system. But as GSM is being used there will be some maintenance in this system.	Internet Connection must be needed in this system. Without the internet it cannot be able to store data in the database.
Feasibility	As this system contains an arduino, which has 16MHz clock speed so there will be a possibility of data losses and slow data transfer rate.	This system contains ESP32 which has 240MHz clock speed and faster data transfer than Arduino
Budget	11,100tk	4,120tk

2.5 Conclusion

To sum up, we found out the optimal design approach of our project after researching, analyzing and validating the complex engineering project criteria. As we mentioned all the functionalities of two selected design approaches by showing different test cases to ensure whether these simulations satisfy our project requirement or not. Finally, we figure out design approach-2 as our optimal solution for further progress.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

Modern Engineering and IT Tool is the most frequent term in the engineering field. By research, analysis and comparison we can choose the modern engineering tool for a project. In order to choose the ideal modern engineering tool for the job, the user must conduct comprehensive study before utilizing it. Therefore, we have done the research and comparison to identify the Modern engineering tool (hardware, software and simulation) for our project.

3.2 Select appropriate engineering and IT tools

For selection of appropriate tools, we need to research and analyze the different modern engineering tools criteria to identify the justified software and hardware process for our project. We found some engineering tools for hardware and software set-up based on complex engineering projects selection methodology.

3.2.1 Software comparison table for simulation

Table 4: Software simulation comparison

Criteria	**Software**				
	Proteus	**LabVIEW**	**Sci-lab**	**Pspice**	**WokWi**
Portable	high	medium	low	medium	high
PC Specification moderate	high	high	low	medium	high
Import facilities	high	medium	low	medium	high
Library resources (based on the project)	high	low	low	low	medium

<u>Proteus:</u> If we develop an arduino based air pollution detector which combines a small-sized, minimum-cost sensor to an arduino microcontroller unit. Then, main advantages will be the detection, a reliable stability, rapid response recovery and long-life features. Proteus has a processing software which is able to analyze, showcase quality data with high precision and compatibility which can be needed for our project simulation.

<u>Tinkercad:</u> Tinkercad is an online collection of software tools from Autodesk that can help create 3D models for beginners. For our project we need to show a 3D design to visualize our main project procedure, so this 3D modeling software is user-friendly and easily accessible to create a 3D design for indoor air quality monitoring.

Wokwi: Wokwi is an online Electronics simulator. We can use it to simulate Arduino, ESP32, and many other popular boards, parts and sensors. As we are using ESP32 for our design approach to monitor air quality, we need to use this software tool. Also, for programming purposes we need to find a software which can run the desired codes for ESP32 and we didn't find any better software tools to simulate Arduino ESP32 simultaneously for air index measuring purposes.

3.2.2 Software comparison table for 3D design

Table 5: 3D design tools comparison.

Criteria	Software		
	TinkerCad	Blender	Sketch up Pro
Software Skill	low	high	medium
Design Model Availability	high	medium	low
3D design perspective	high	medium	medium
Storage Capacity	high	high	medium

We needed to design 3D tools in a manner that can represent the overall view of our project prototype. For this representation we used TinkerCad tools to showcase our final product before implementation to get the overall idea of the project we wanted to establish at the end of our hardware process. As a 3D design tools, TinkerCad has different measurements and viewing tools which is really important feature for our project's representation in 3D. As, we needed to specify the location at which sensors would be placed then measurements are must also we wanted to represent our final product in a box view where at internal part all the sensors, microcontroller would be placed and at external part LCD monitor would display all the output. So, viewing tools is another important feature and in TinkerCad we are getting all kinds of tools to represent a 3D design for indoor air quality systems.

3.2.3: Hardware and coding

ESP32: This is the microcontroller that reads the data from the sensors and processes the data by integrating the code. This MCU has memory storage of 32Mbit and it operates at 3.3V.

Gas Sensors (MQ-2, MQ-9, MQ-135): These gas sensors are used for measuring the smoke gas, CO, NO2 and So2 respectively. All of the gas sensors are low cost sensors and operate in input 5V.

GP2Y1010AU0F PM 2.5 Sensor: This PM2.5 GP2Y1010AU0F Dust smoke Particle sensor is an infrared emitting diode. It detects the reflected light of dust in the air. Additionally, this can identify between smoke and home dust based on the output voltage's pulse pattern.

LCD Display: This LCD will be used for displaying the output data. After processing the data, it is transferred to the LCD display which will show the processed data in the display.

3.3 Use of modern engineering and IT tools

After analyzing and researching papers we identified some software simulation and 3D design tools to justify our project outcome. For software simulation we found wokwi is more efficient software simulation tools than proteus as we used ESP32 for hardware setup so our simulation also should represent the outcome of the simulation process which has a more efficient process for simulating the optimal design approach. Additionally, for 3D design we used TinkerCad as we wanted to represent an overall view of the project depending on measurements and viewing tools. Last, for hardware set-up we used various sensors which we selected by analyzing the AQI measurements criteria also selected nodemcu ESP32 which has built in wifi system so that we can represent our results through mobile or computer. Also, we used IOT platform thingspeak to visualize and showcasing live data when the product is running to collect real time values.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

To gather accurate, consistent, and comparable data on the air quality of a particular location, air quality monitoring devices should be utilized. This allows to implement the necessary environmental protection measures, evaluate the effects of such efforts, and ensure that the user is appropriately informed about the status of the air quality. To implement an air quality monitoring device, conceptual design is an important step in choosing and figuring out the composition and configuration of a product, which has a big impact on cost and performance. Engineers have the most creative flexibility at the conceptual design stage to present the best design solution in terms of assembly, production, and pricing so that they can optimize a best solution from multiple designs. We discovered two design approaches to find out the desired optimal solution. First design approach is based on GSM and second design approach is based on NodeMcu-ESP 32. Both of the designs give us the similar kind of results we need for indoor air quality monitoring but based on some particular functionality, various types of test cases we choose our optimal design approach for our project.

4.2 Optimization of multiple design approach

Design solution 1: GSM Based-Indoor location-based air quality monitoring system

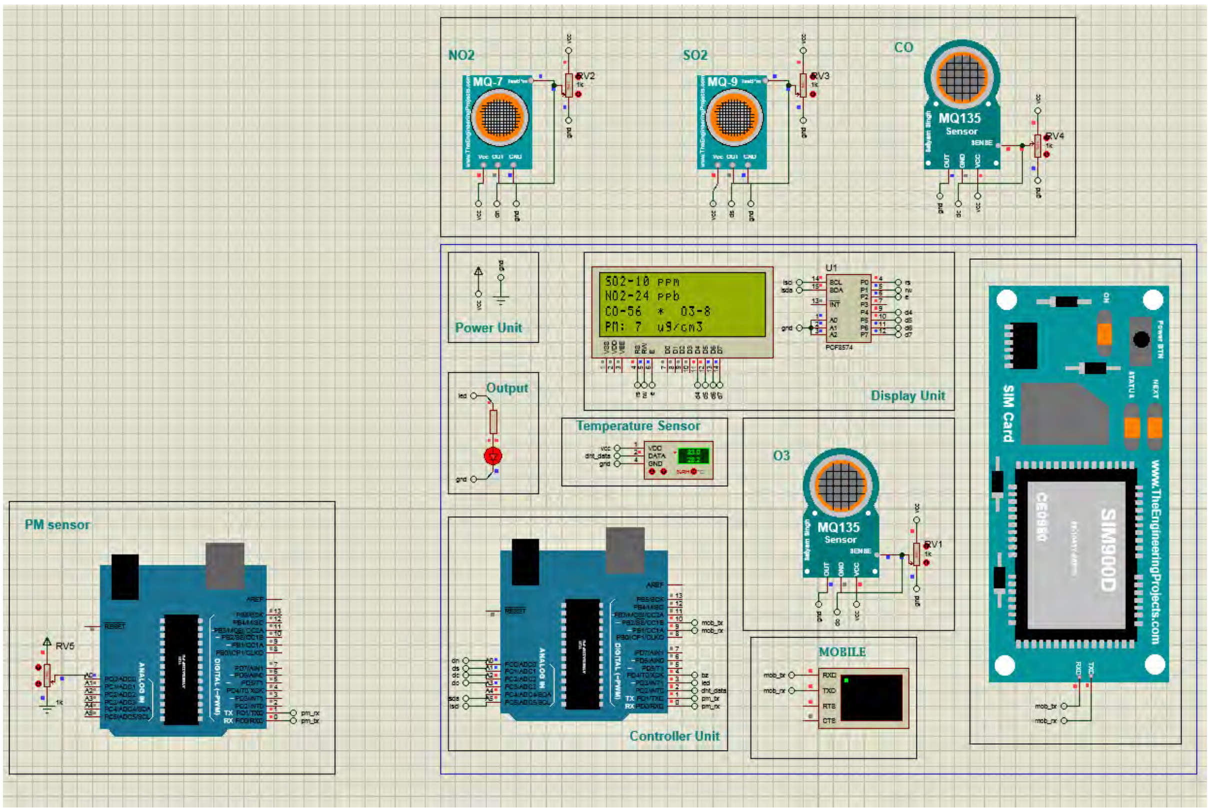


Figure 7: Circuit diagram of design approach 1

This circuit design is implemented through proteus software. As we know proteus can be easily operated with a large scale of library function to select any device to simulate a design approach. Another important element of selecting this software for simulation purposes is that all kinds of sensor libraries are available and for ESP32 it has the different sets of programming manuals to generate desired code to run the operation.

Results and outputs of test cases:

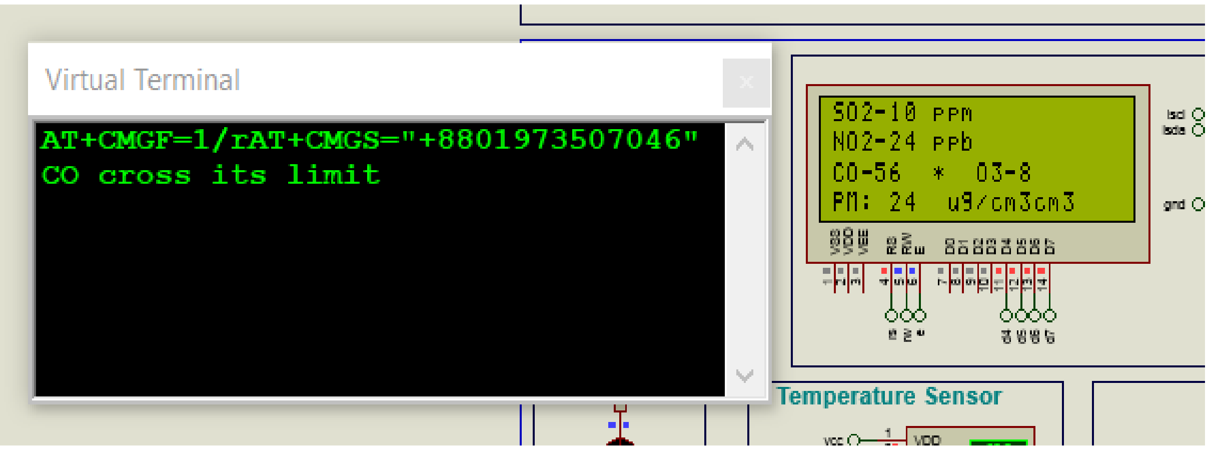


Figure 8: Test Case 1 design approach-1

Test case 1 of the simulation of design approach 1 showed all air pollutants value at the virtual terminal and results indicated that CO value crossed its limit. It is only mentioned the cross limits of CO value because other values of AQI pollutants are in the safe zone.

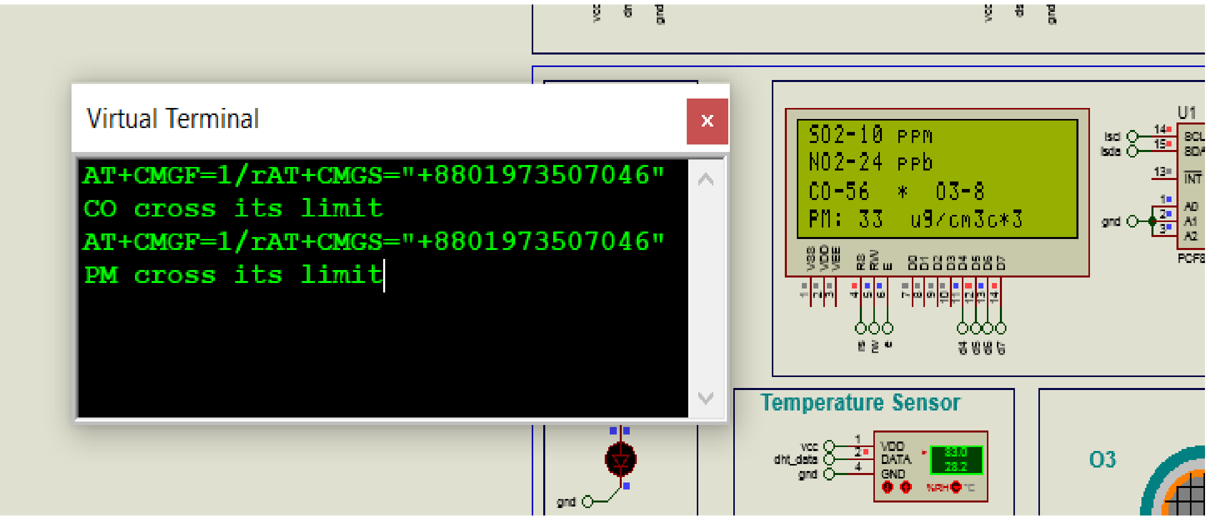


Figure 9: Test case 2 design approach-1

For this test case 2 values of AQI showed it crossed its limit for Co and PM and virtual terminal indicating that results to inform users about air quality index through this test operation. Difference from case 1 is that here virtual terminal showed at two danger range for AQI index.

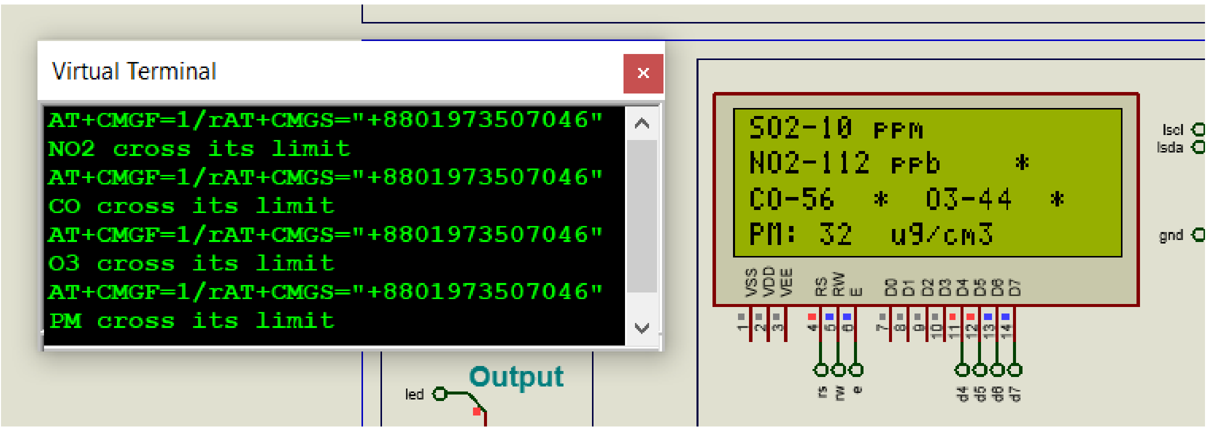


Figure 10: Test Case 3 design approach-1

For this test case we observed four values of air pollutants which are in danger level at the virtual terminal. Ranges of these test cases are measured by following the standard range for AQI. Through this case we can comment that at that time air index of that particular place was crossing its limit and unhealthy.

Design Solution 2: Indoor location-based air quality monitoring with IOT

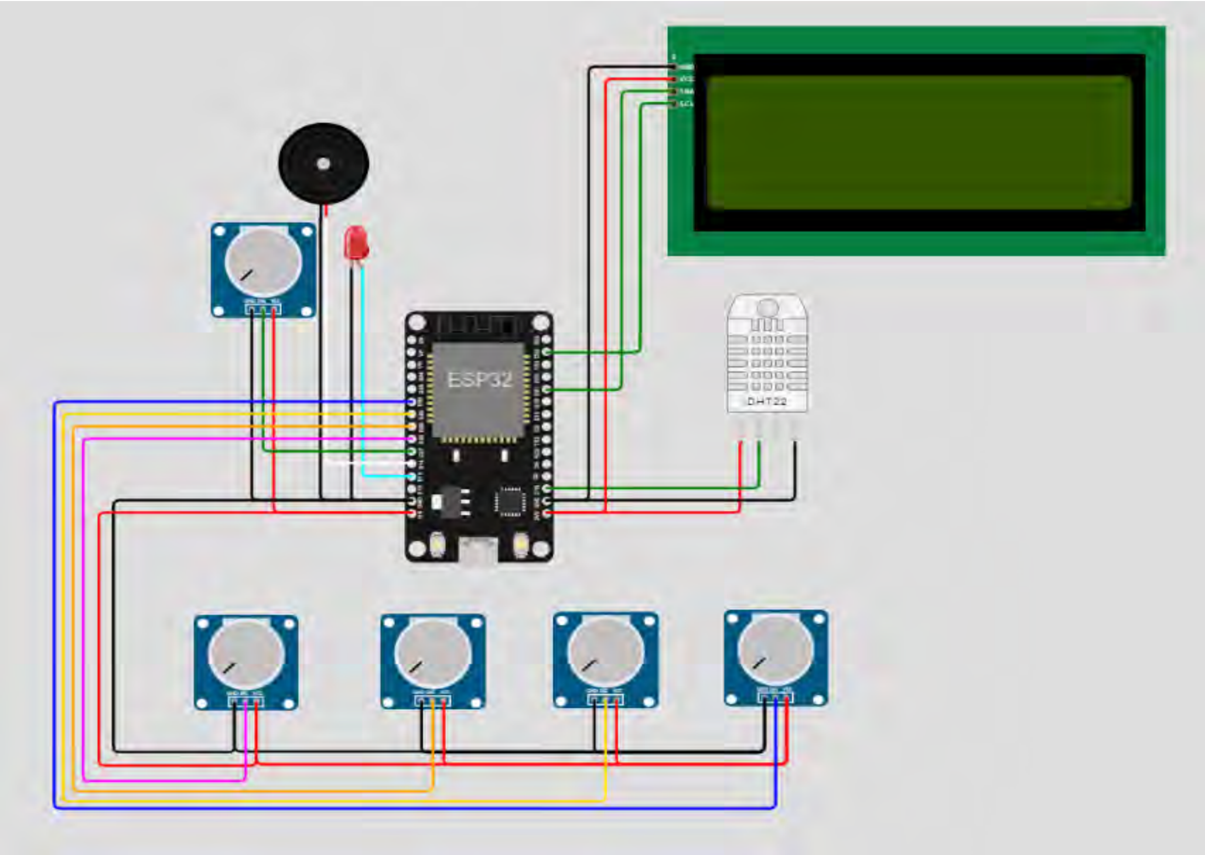


Figure 11: Schematic diagram of design approach 2

Wokwi software-based design approach to replicate the output to identify AQI ranges.

Results and outputs of Design-2 simulation:

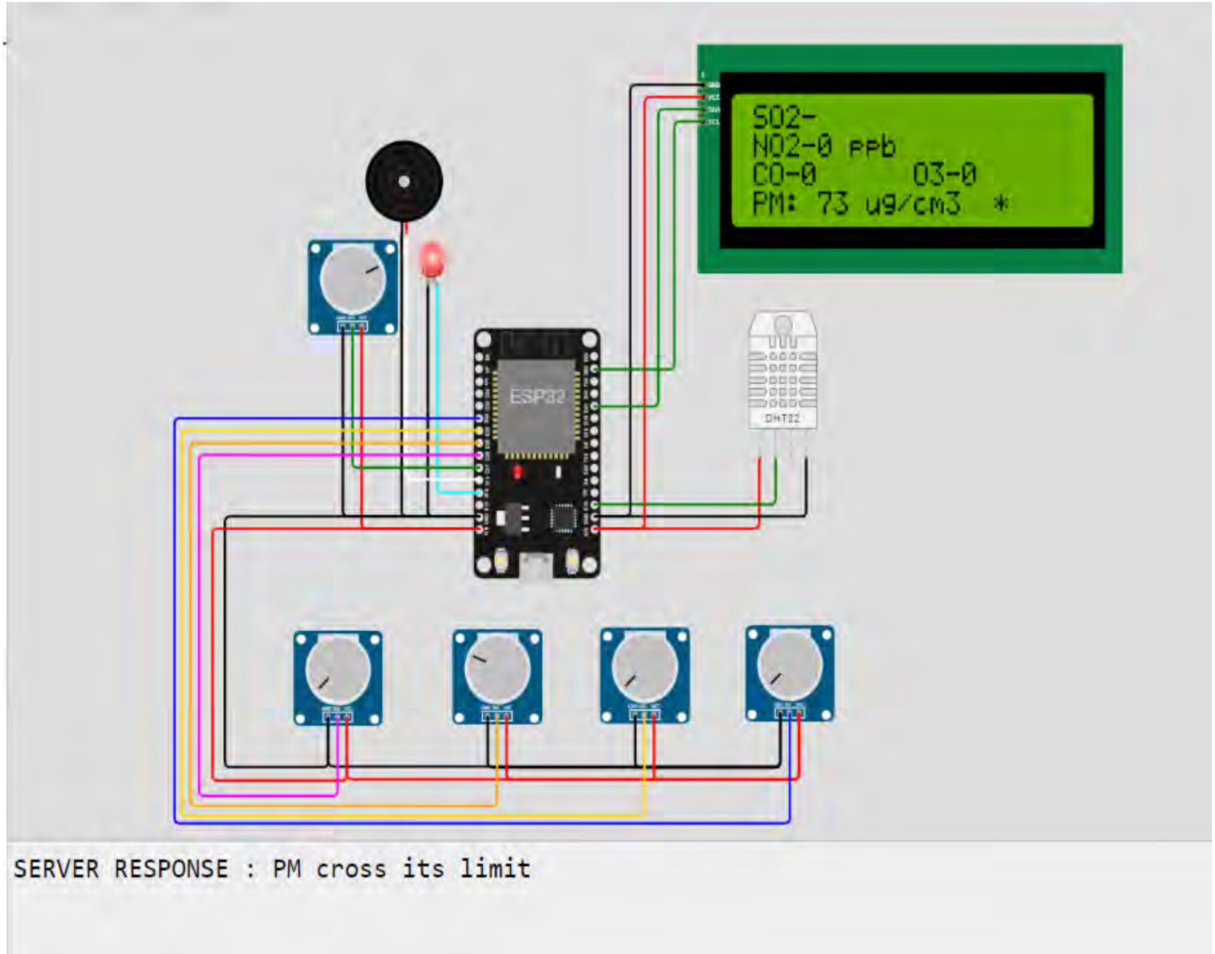


Figure 12: Test case-1 of Design approach-2

For design approach-2 we used WOKWI software for simulation and the first case of this software represented that values of PM cross its limit. Server response of this simulation process is also showing the range of danger level of particulate air pollutants for indoor location.

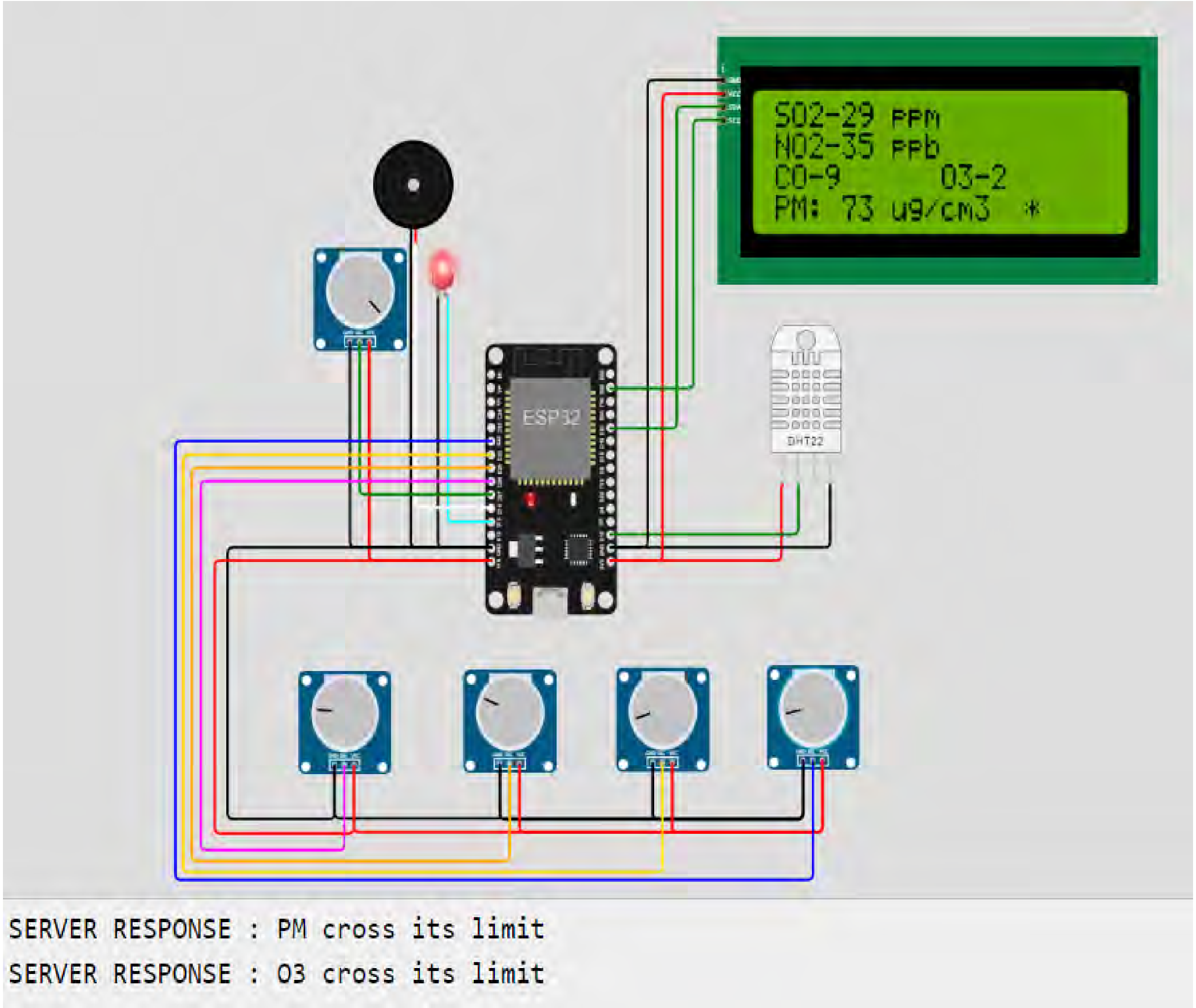


Figure 13: Test case-2 of design approach-2

Test case-2 represented server response to show outputs when air pollutants PM and O3 crosses the limit. Just like the previous case this time also servers respond when air concentrations of any pollutants values cross safe zone limit.

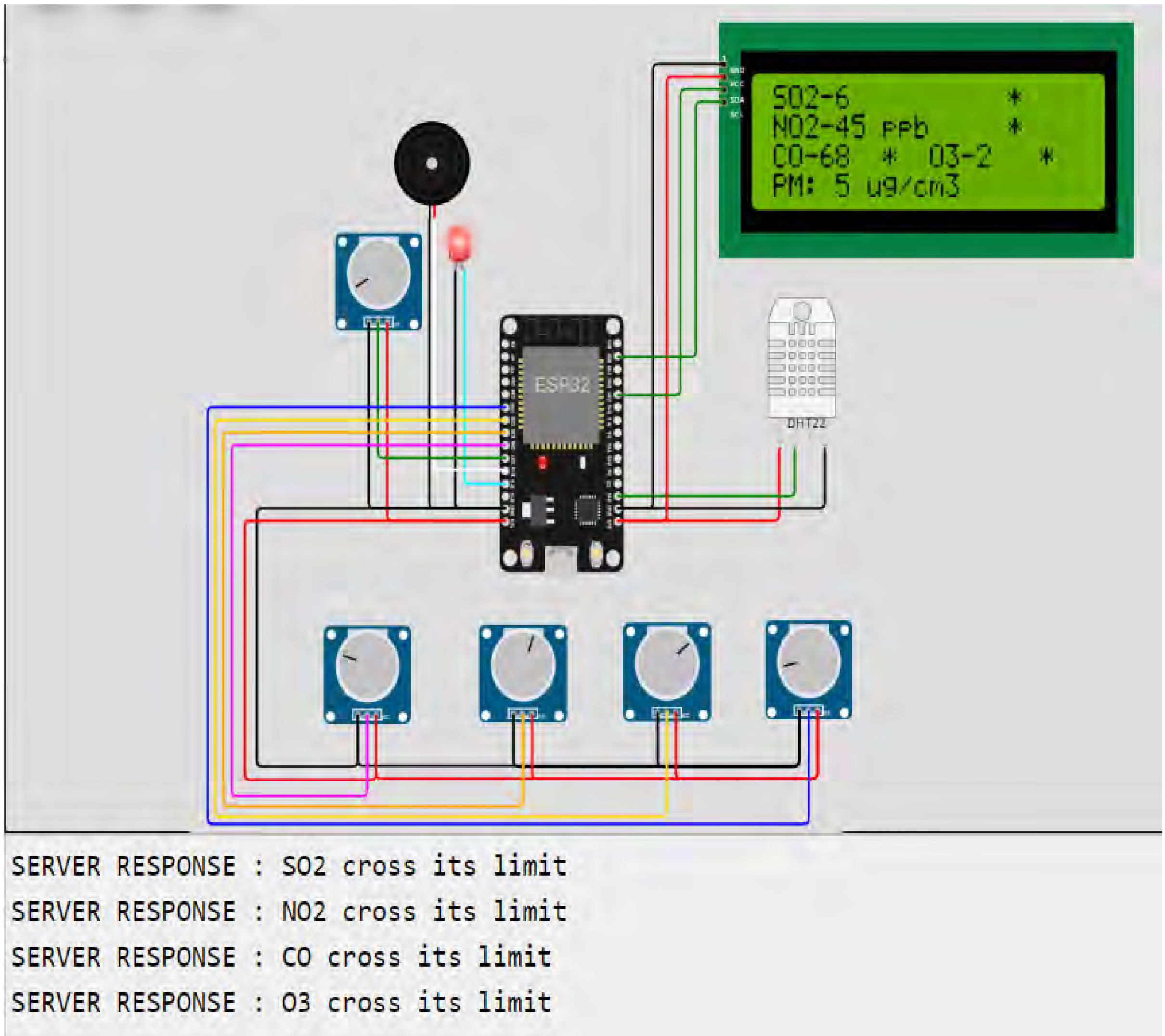


Figure 14: Test case-3 of design approach-3

At the test case-3 of this design approach we found a server showing four out of five pollutants cross its limits. These server results indicate the indoor location of that measured place is unsafe and that AQI range needs to be monitored to make it better for any sort of indoor activities.

4.3 Identify optimal design approach

After analyzing the simulation test cases of both the design approaches we prepared a table to find and comment about the optimal design approach.

Design Approach comparison table:

Table 6: Design Approach comparison table

Criteria	**Design 1**	**Design 2**
Component Efficiency	Aurdino has a less efficient process for air-quality monitoring components.	Long time efficiency for ESP32
Data accuracy	Data collected from the arduino is stored as 1 byte of information.	Data Collected from ESP32 stored as 4 bytes of information.
Manufacturability	This system is based on the GSM network. Which will only be applicable for particular regions.	This system is based on IOT. Which will be applicable for all around the world.
Maintainability	No internet connection in this system. But as GSM is being used there will be some maintenance in this system.	Internet Connection must be needed in this system. Without the internet it cannot be able to store data in the database.
Feasibility	As this system contains an arduino, which has 16MHz clock speed so there will be a possibility of data losses and slow data transfer rate.	This system contains ESP32 which has 240MHz clock speed and faster data transfer than Arduino
Budget	11,100tk	4,120tk

Above mentioned table represents the optimal solution for our project by comparing the different criteria. Hereby, we can comment that design approach-2 is the optimal solution as this approach is more efficient, cost effective and technically better accuracy providing an approach for our hardware implementation.

SWOT Analysis of Optimal Design Solution:

- **Strengths:**

I. Solution will be able to monitor the air index very efficiently, smoothly and notify the user in details for the data collection from anywhere around the world.

II. Users will be notified using the SMS system so they do not need to check meter

regularly and can get notified remotely.

III. Providing global access to the server that users can check the database from anywhere.

- **Weaknesses:**

I. Always need to connect to the internet.

II. Sensors consume small amount of energy which is not calculated

- **Opportunities:**

I. Cloud storage to monitor the data Remotely

II. App based to make it more user-friendly

- **Threats:**

I. Data loss due to load shedding.

II. Damage due to water droplet accumulation.

III. System can be tampered.

4.4 Performance evaluation of developed solution

After comparing two design approaches we came up with the conclusion that design approach-2 is the preferred design solution for our project. Design-2 results are showing all the required air quality measurements for an indoor location as well as we can determine the required output to showcase different values for air pollutants.

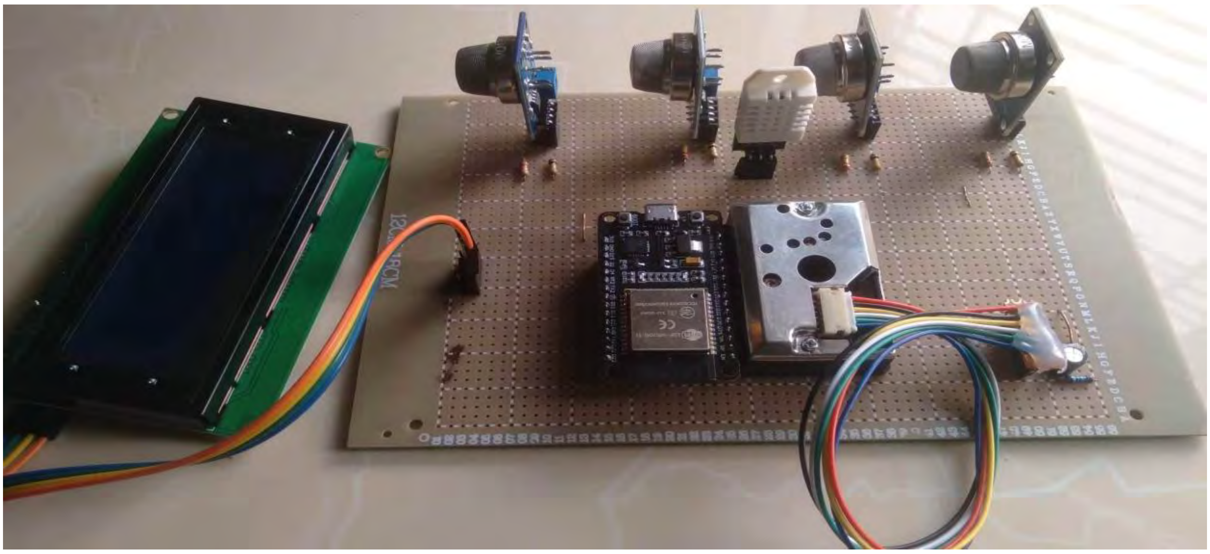


Figure 15: sensor setup and testing to evaluate performance

Figure of sensor setup constructed in a way to evaluate the performance of the project. Adding to that all the sensors were calibrated individually to find as much as accurate values for the indoor location system.

Data analysis graphs for different substances (minimum 8hrs)

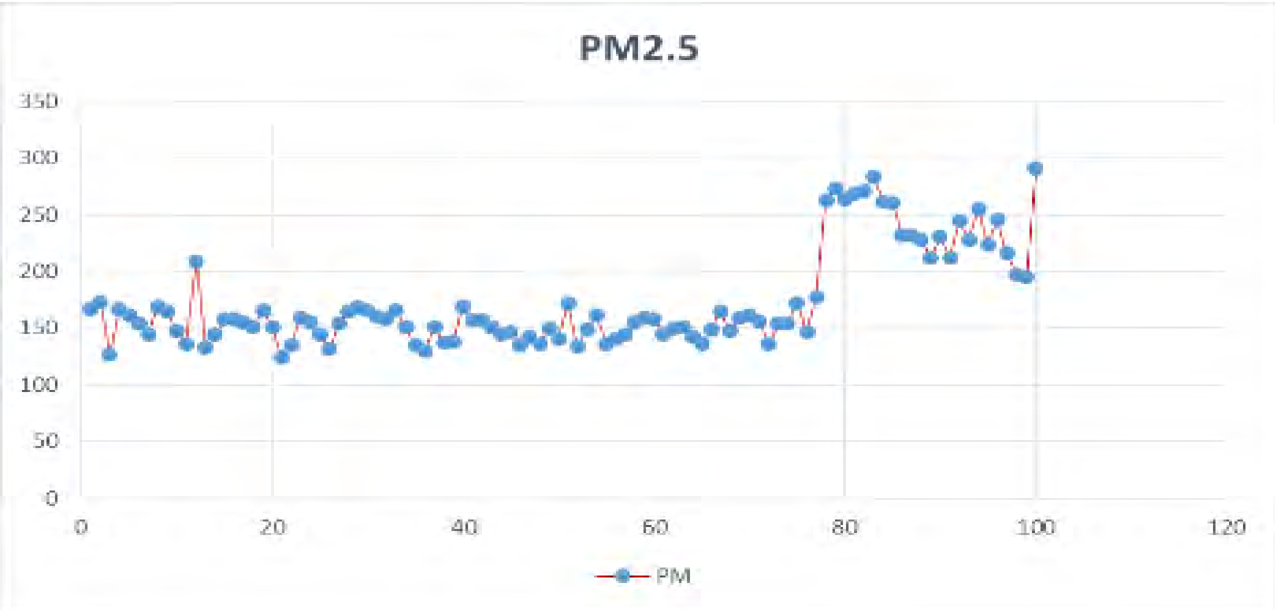


Figure 16: evaluation of PM 2.5 values for a certain time range

This graphically represents the PM 2.5 values which suggesting the results the product evaluate during 8 hours running time. Here, at X axis means the time rate and Y axis represents values in ppm.

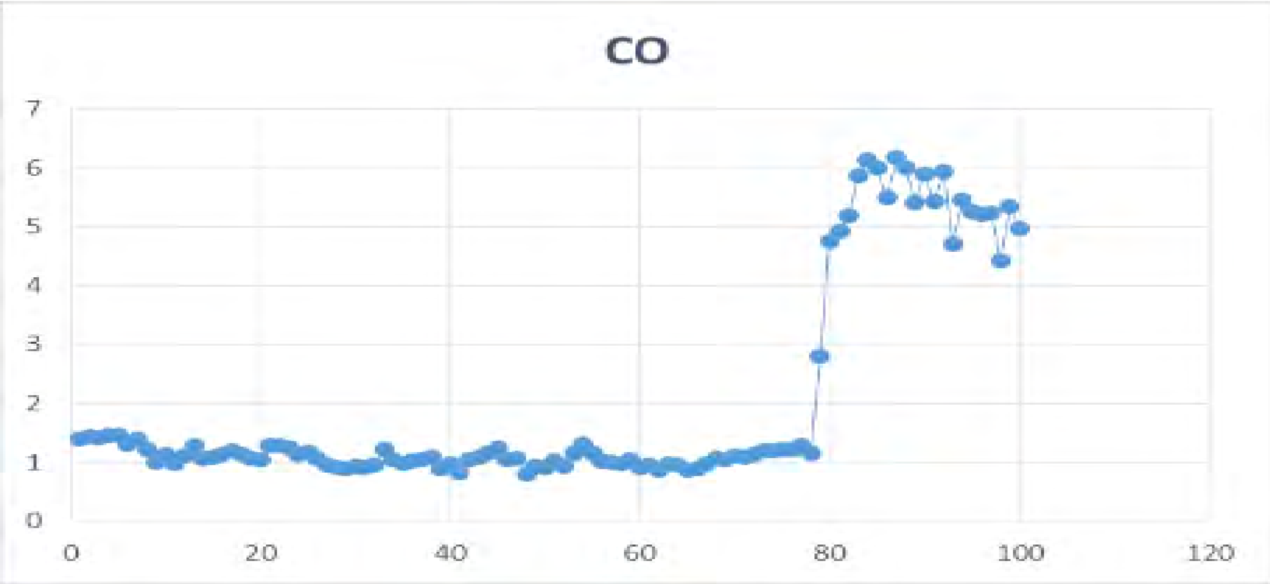


Figure 17: evaluation of CO values for a certain time range

Similarly, for CO evaluation we followed a minimum 8 hours to evaluate data to verify test outcomes. Here, X axis represents time range and Y axis means CO values in ppm.

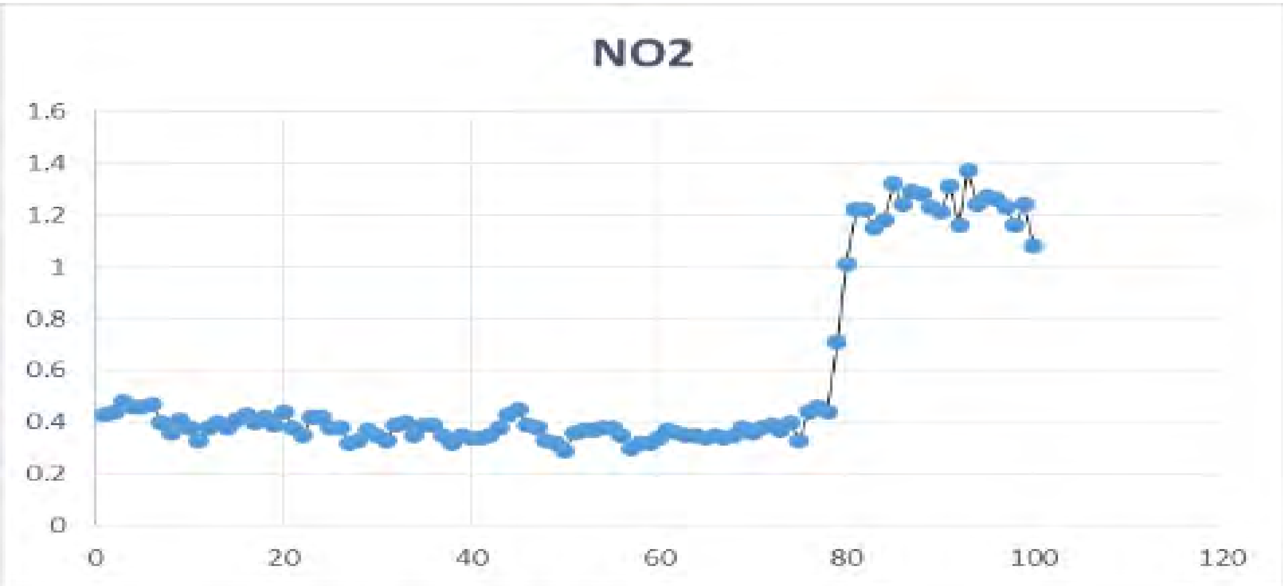


Figure 18: NO2 evaluation chart

In this scenerio, the X axis is time range and the Y axis means values in ppb not in ppm.

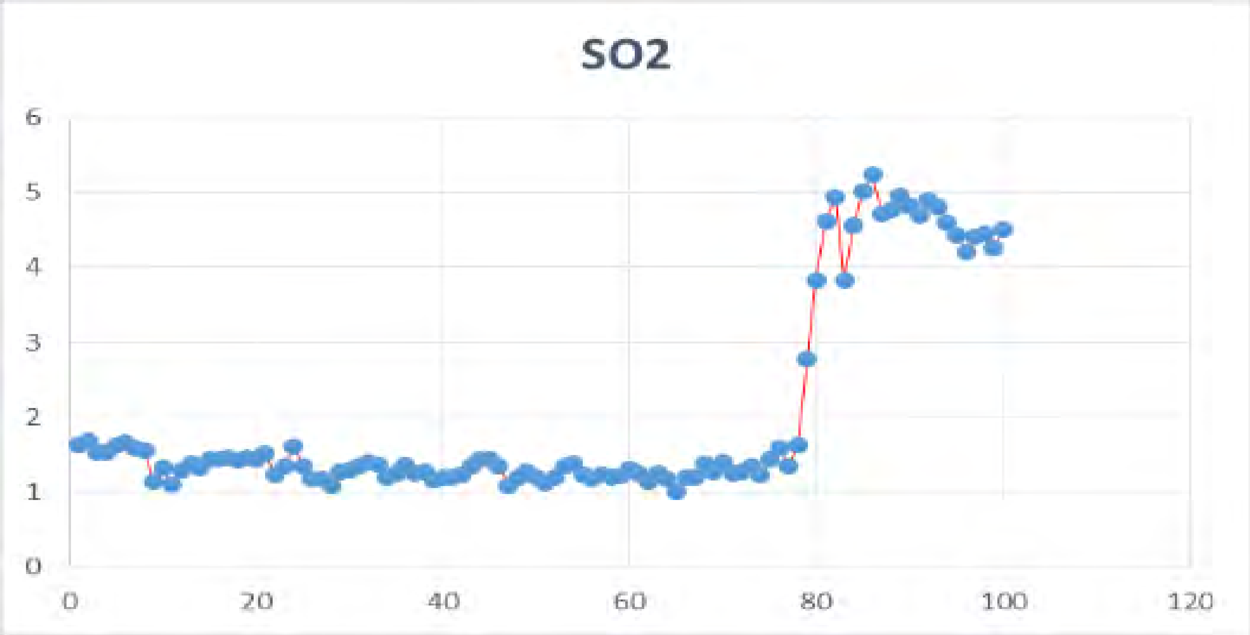


Figure 19: evaluation of SO2 for a certain time range

Here, So2 is in the ppm range to evaluate the data. Here, SO2 values at Y axis and time at X axis to highlight the indoor air index.

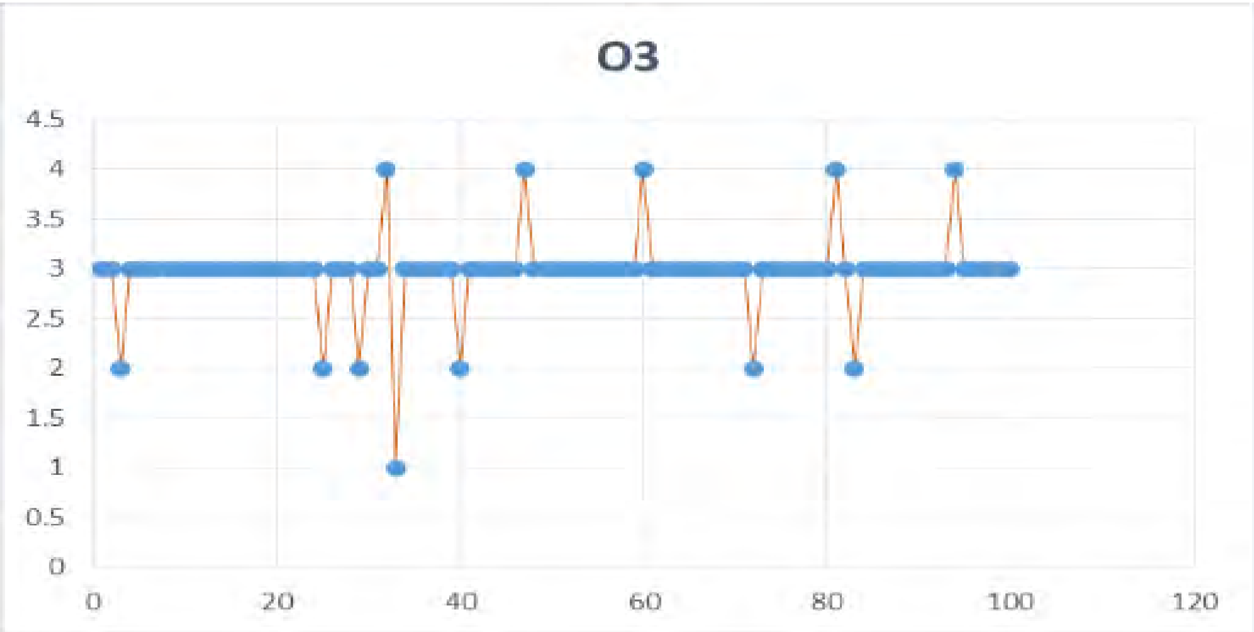


Figure 20: Evaluation of O3 for a certain time range

In this figure, O3 values at Y axis are in ppmv and time at X axis to highlight the indoor air index.

4.5 Conclusion

The proposed system is created for remotely monitoring indoor air quality. The paper provides an overview of the main air quality monitoring methodologies. In the study, these methods are thoroughly explained. One of the most popular techniques in the suggested system is a cloud-based (IoT) air quality monitoring system. A website is hosted and data is presented on it using the same cloud data. After analyzing all factors, the best possible solution for this project is NodeMCU-ESP32 based monitoring system to get all the desired results to evaluate and validate the project outcomes. We considered all kinds of aspects before finalizing the optimal solution by looking at key features, cost, efficiency rate, maintainability, sustainability and more importantly hardware functionality to complete the project.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

For the completion of our indoor monitoring system, previously we figured out the hardware design solution then we organized the tasks to select the necessary hardware components to show the valid outcome we were expecting from the project throughout our progression. Before that we also represented a 3D view of our project to visualize our hardware product before implementation. Apart from 3D design, we wanted to design our project in a box shape so that all necessary components will be placed inside the box and the final product will be easily shifted or placed anywhere to an indoor location. Also, we wanted to display our output from anywhere so wifi system made it easily accessible. Even, our necessary programming manual which is linked to Thingspeak that means we can view the full data sheet of the product continuously.

Figure 21: overall 3D view of the component

Above figure is the 3D view of our main product. Here, we can easily visualize how the hardware setup should look like to monitor indoor air quality index. The product would be a box shape where all the other components needed be placed inside so this represents an idea of the main outcomes before implementation.

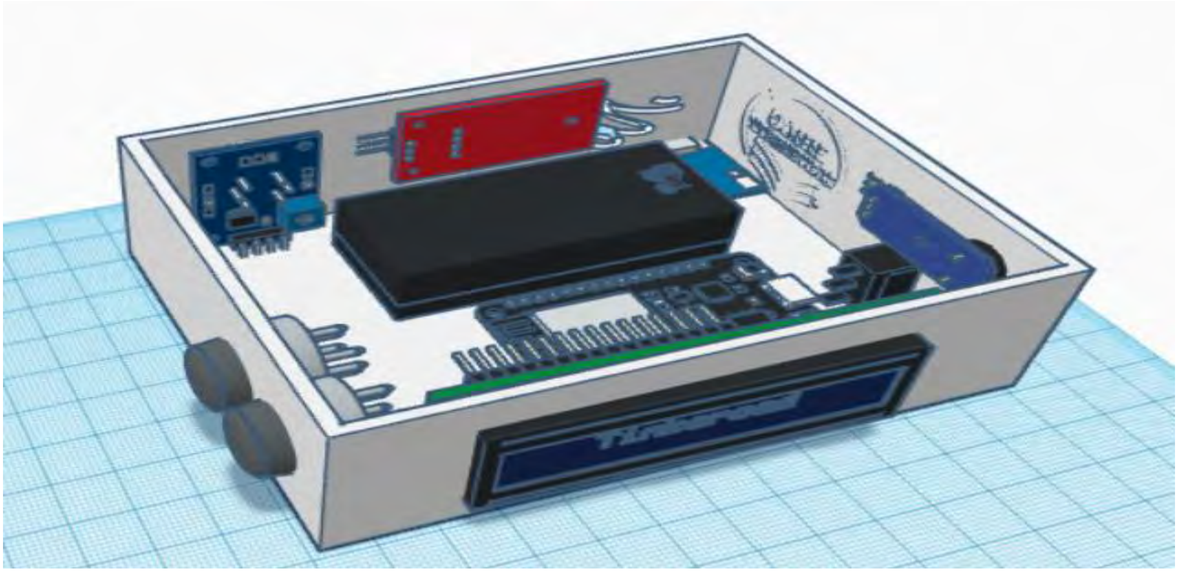


Figure 22: 3D view of sensor arrangements

In this 3D view, we showed the sensors placements inside of the box and this view also indicated a clear idea how the sensors would be placed and operated to detect air quality of that particular place.

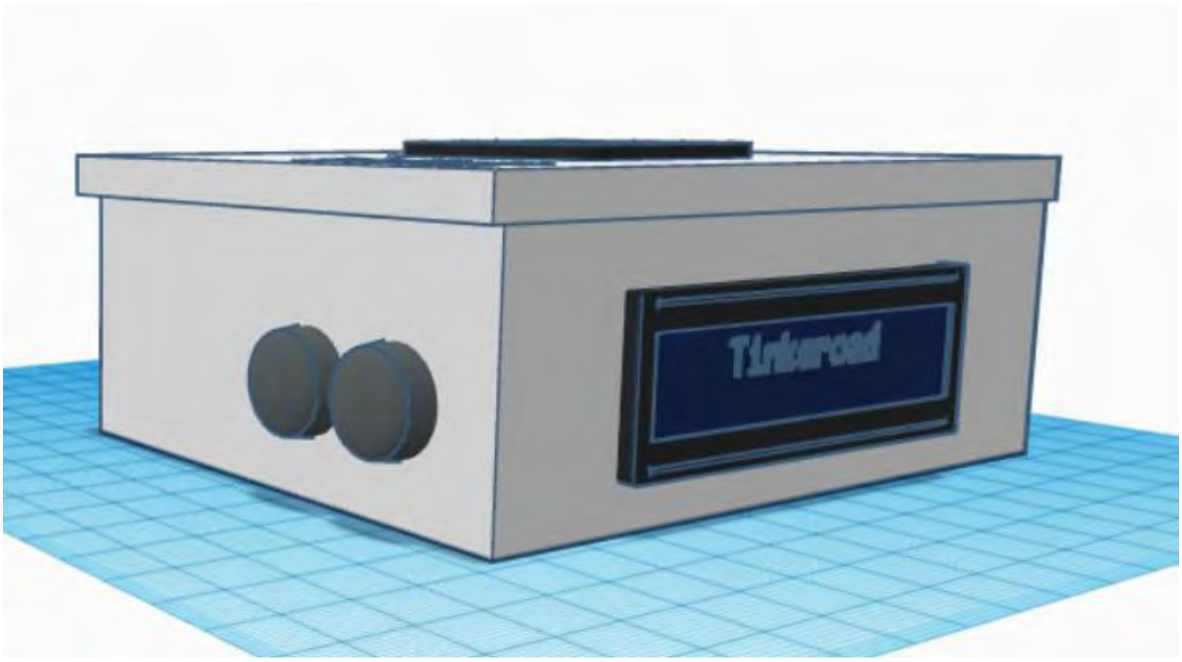


Figure 23: 3D view from the outside of the device

This 3D view is showing another side view of the product from a different angle so overall 3D views to clearly visualize the idea of the final outcome we wanted to come up with to justify our project aim.

5.2 Completion of final design

Initial stage of completing the final design, selection of proper hardware procedure and hardware components are the key parts to make sure all connections are accurate and eventually it will run smoothly to show desired outputs.

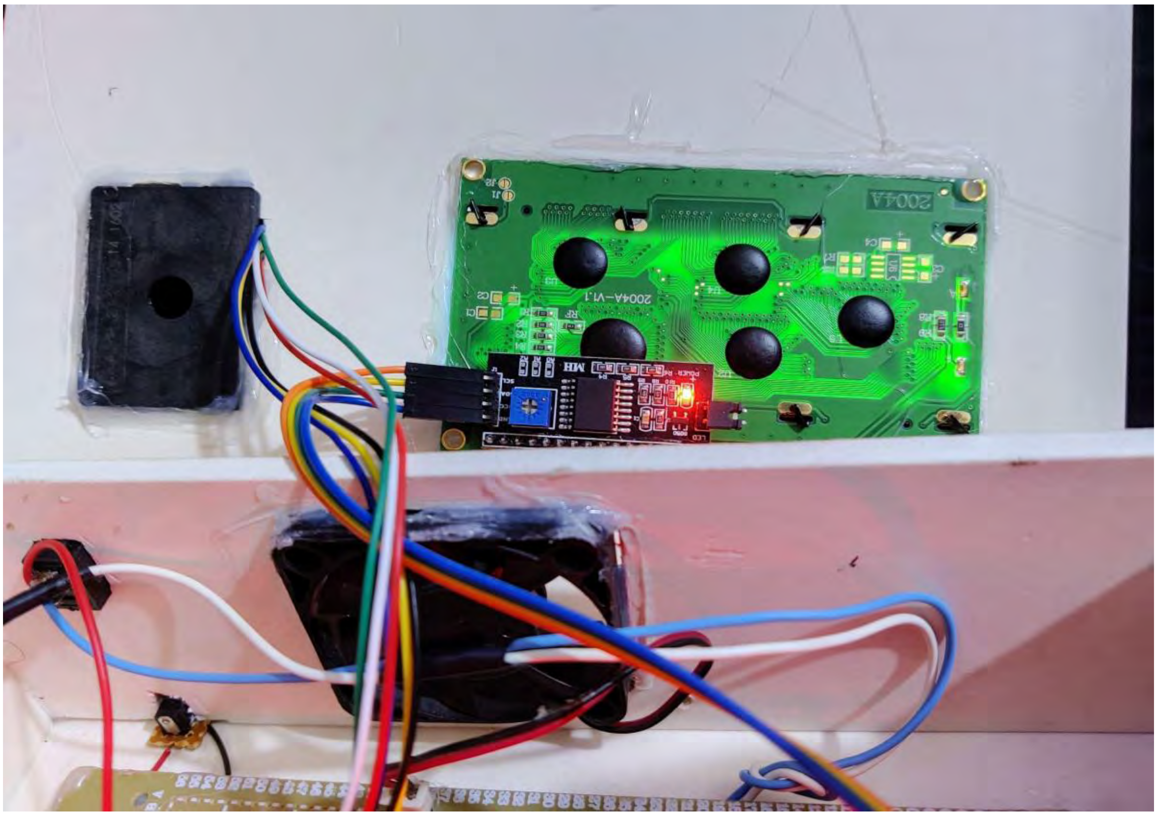


Figure 24: connection setup of external part of the box

Figure is added to understand the hardware setup of the LCD monitor to the inside body part connection and also to see how a cooling fan is added to circulate air to flow inside the box. A PM sensor is also placed beside the LCD to detect the dusk from the place. As PM 2.5 works to detect dust so it has been adjusted in the external part of the box.

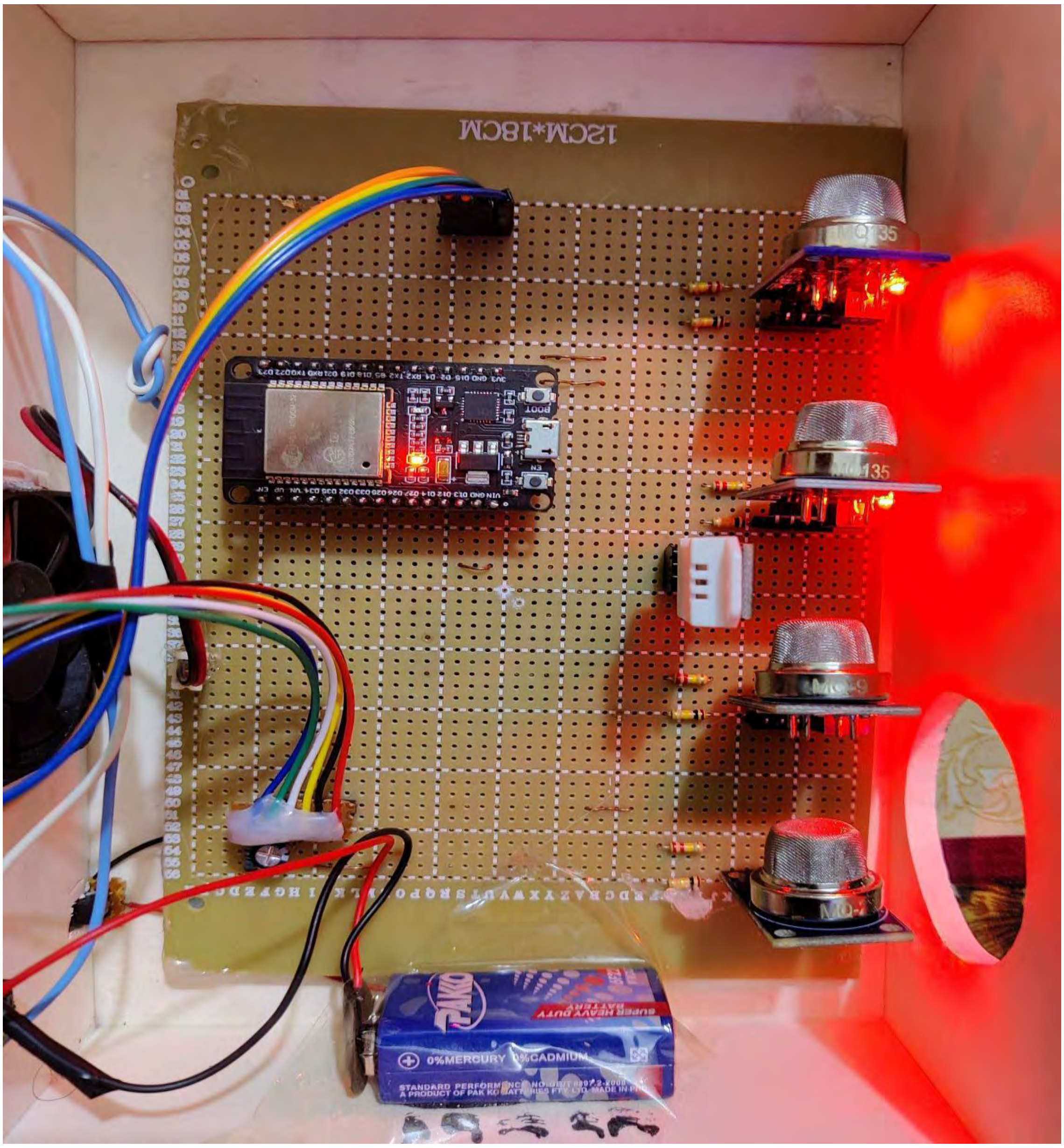


Figure 25: Connection set up for sensors at inside part of the prototype

In this figure we can see the main operational part of the project. Sensors we see are placed in order where first sensors start from upper part of the figure and are placed sequentially in order of MQ-2, MQ-9, MQ-135, MQ-135. A battery 11v used for operating cooling fan and ESP32 as a chip microcontroller with built in wifi for the main application process.

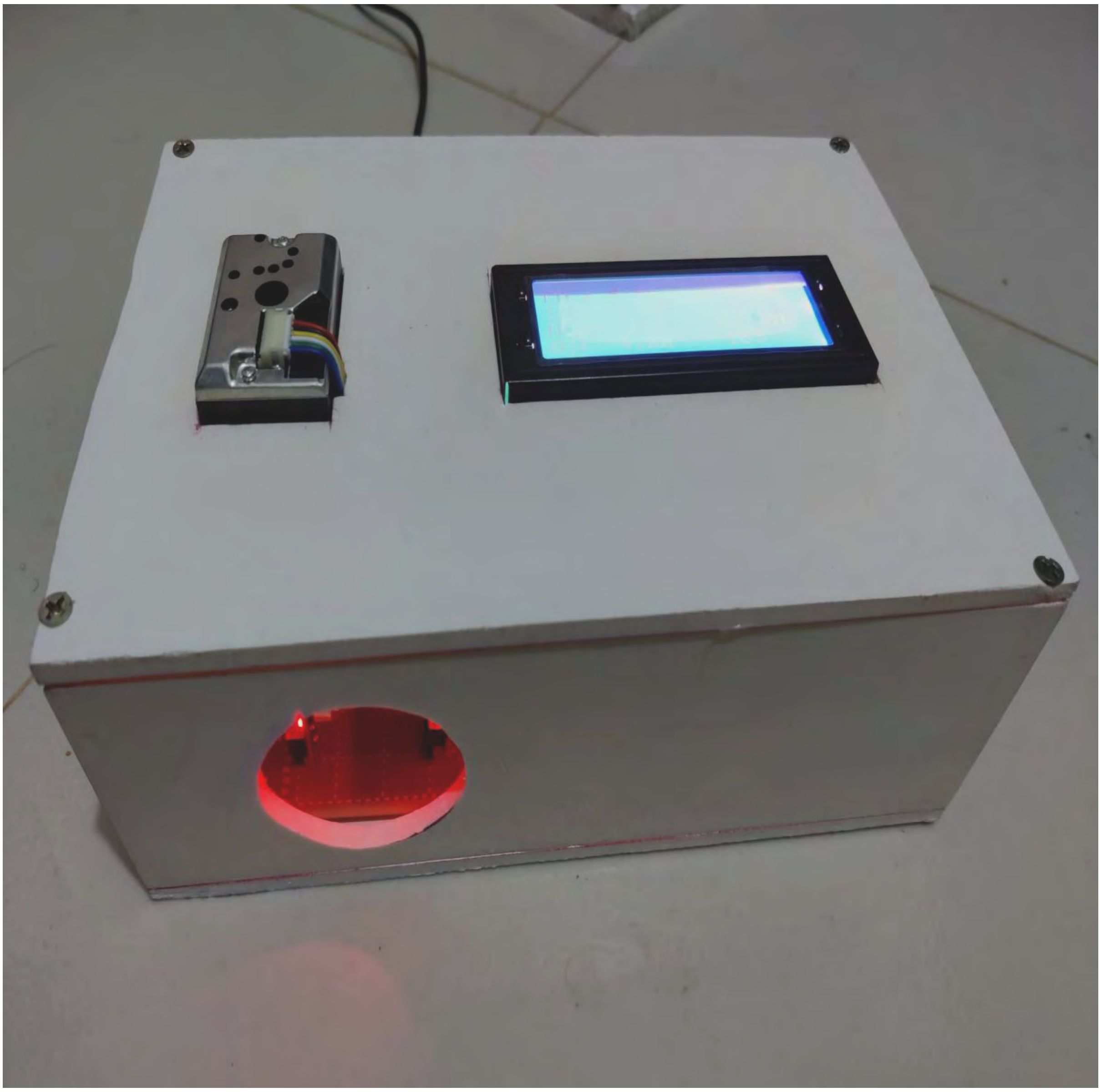


Figure 26: Product view when it is operating to collect data

Finally, the above figure shows the operational state of the main product. When we supply it to the device port then it will start running. After that it will ask for wifi connection; the moment it gets secured wifi connection then it will start collecting air pollutants of the selected indoor place by the users.

5.3 Evaluate the solution to meet desired need

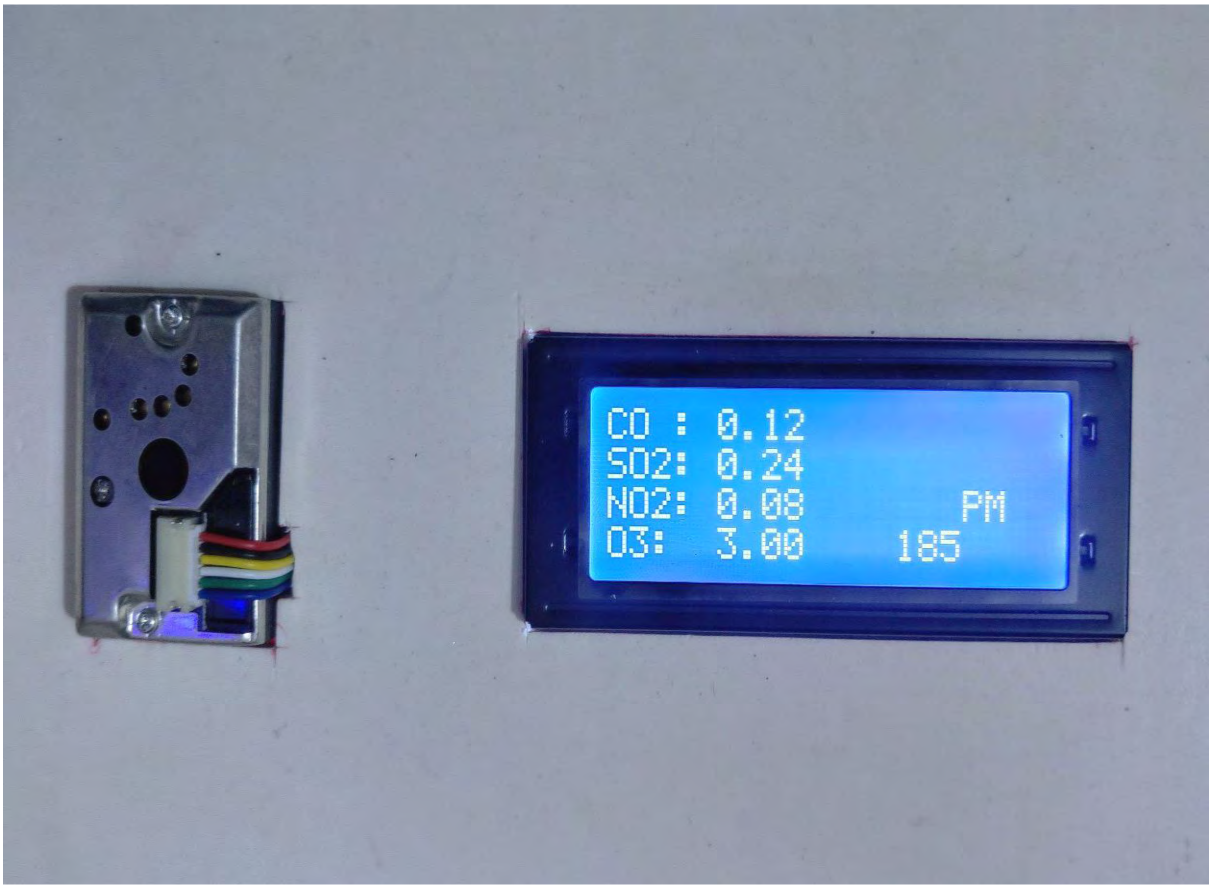


Figure 27: Data display after certain time

Displayed values are the ones which are matched with the standard AQI range that are considered safe for air quality index. According to US-EPA, safe zone CO is 0-9.4 ppm at minimum 8 hours and here we can see values are in safe zones. For SO2 value, the standard is 0-75 ppb for 1 hour and we are getting 0.24ppb after running hours so it is also in safer zone. Next, the standard value for NO2 0-100 ppb and results we see is 0.08ppb which is also considered safe. For O3 the standard range is less than or equal to 0.075ppm.

Figure 28: Test case 2 of product in operation mode

This Figure shows us the reading of test case 2. In test case 2, we use some smoke and butane gas to show the real time Air quality of indoor place.

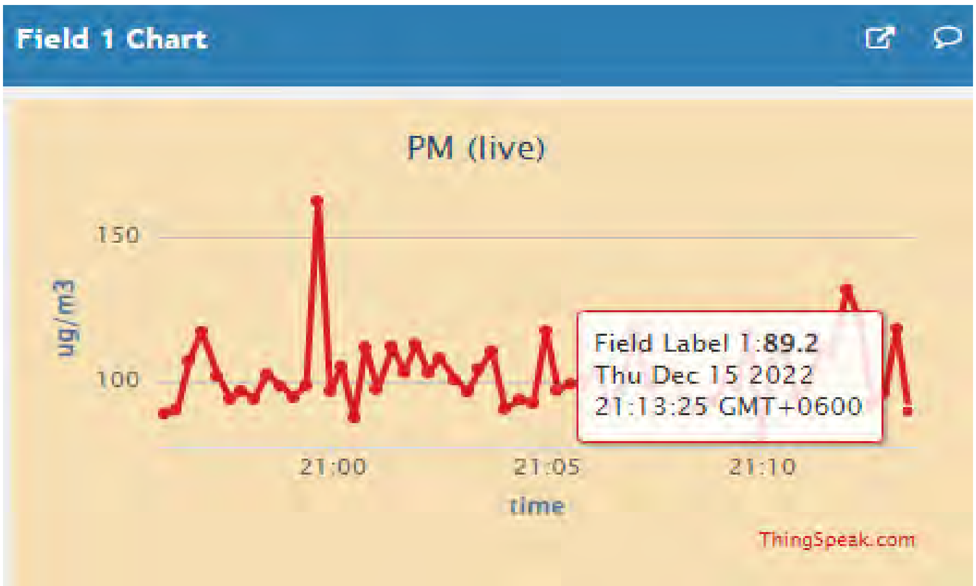


Figure 29: PM 2.5 field chart

This field chart shows the PM2.5 reading every 30 second.

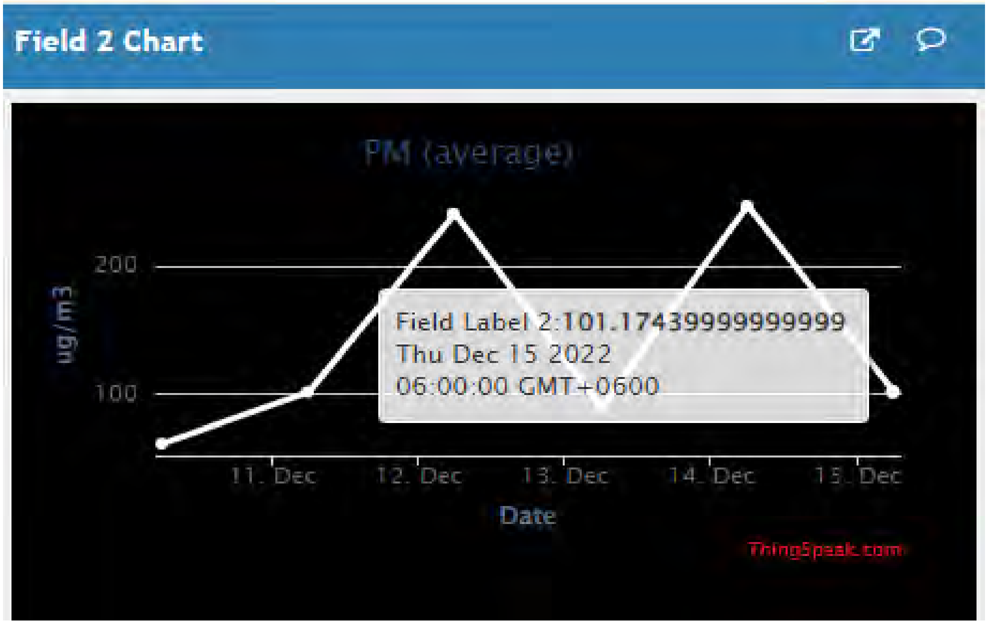


Figure 30: field chart for PM average

This chart shows the average value of PM2.5 reading in 24 hours. As, minimum time range for getting nearby accurate value of PM is 24 hours.

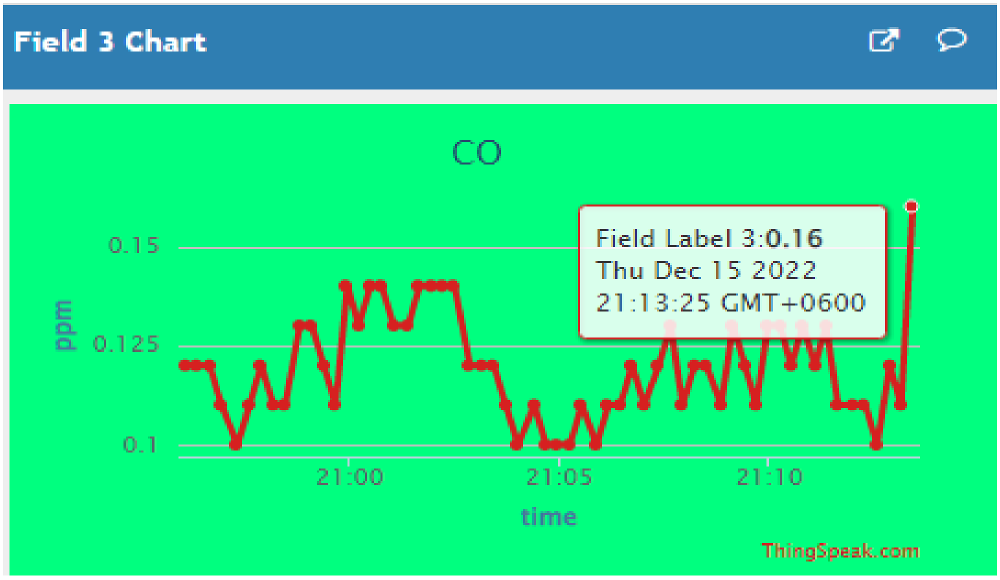


Figure 31: Field chart for CO

Figure of CO chart showing graphical outputs during the selected date and the minimum time to get the AQI standard value for CO is 8 hours according to the US-EPA index.

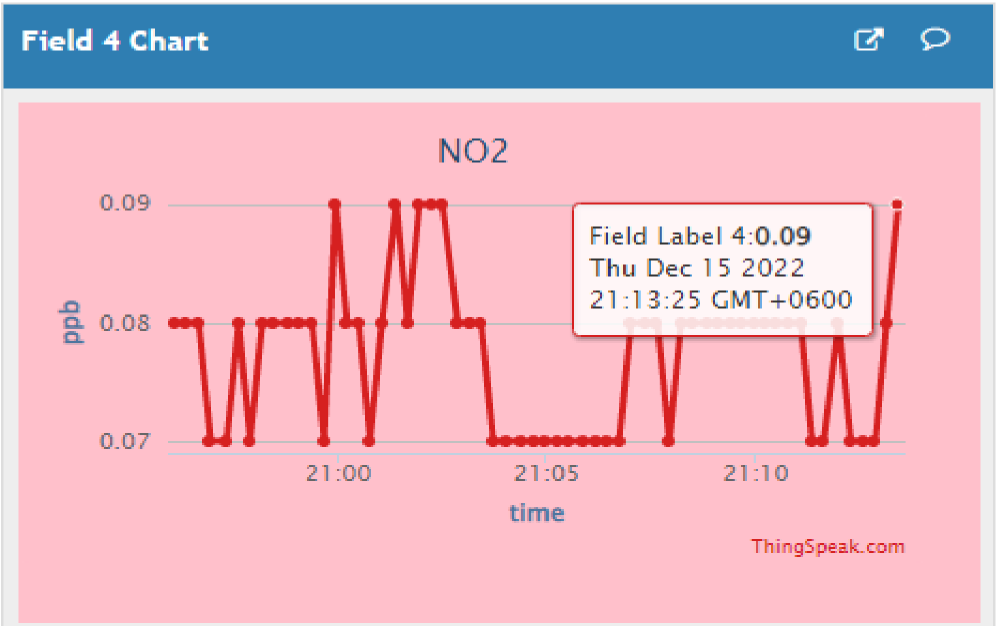


Figure 32: Field chart for NO2

The field chart of NO2 is baked on minimum 1hour standard reading to represent an overall chart.

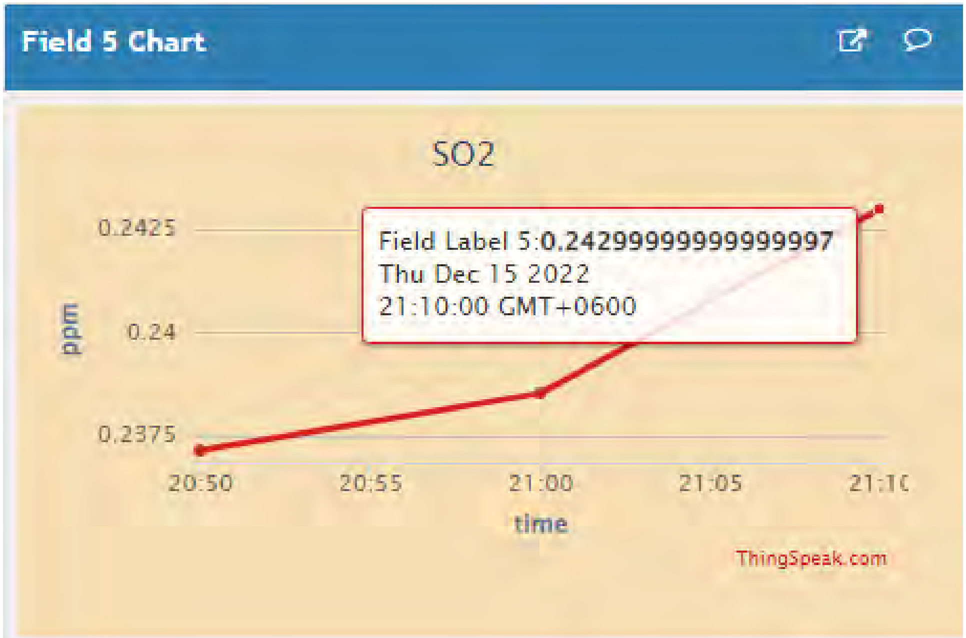


Figure 33: Field chart for SO2

This field chart is showing 1hour standard reading to justify the AQI index measurements.

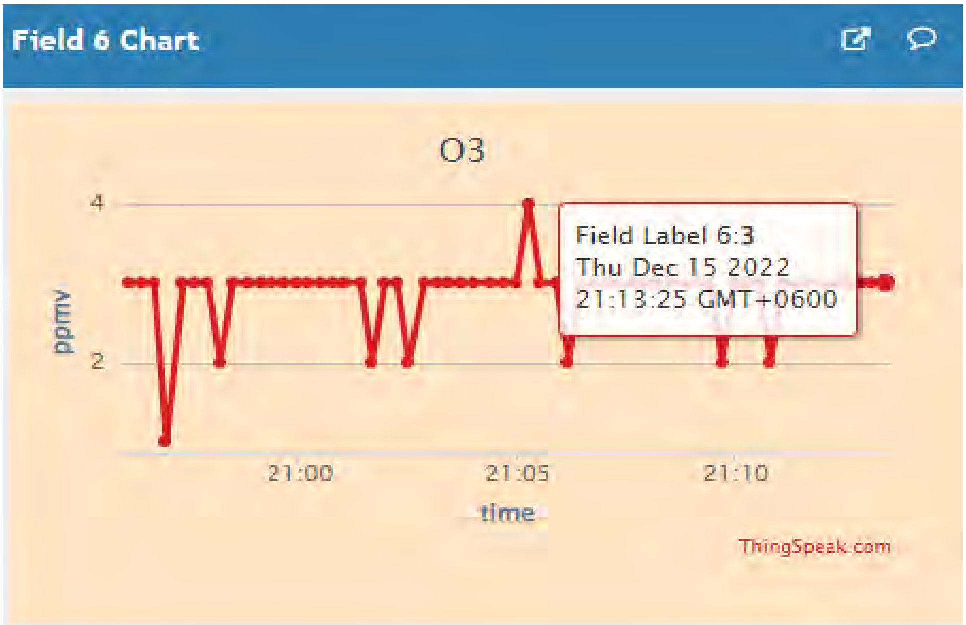


Figure 34: Field chart for O3

Above chart is in parts per million by volume(ppmv) to reflect standard value for O3 for minimum reading of 8hours.

Avg. Data Comparison between analog & digital sensors

Table 7: Avg. Data comparison between Analog and Digital sensors

Analog			**Digital**		
Substances	**Time Weighted Avg.**	**Avg. Time**	**Substances**	**Time Weighted Avg.**	**Avg. Time**
PM2.5	173.0267 ug/m3	24hrs	PM2.5	147.5657 ug/m3	24hrs
CO	2.018 ppm	8hrs	CO	3.23078 ppm	8hrs
NO2	0.5587 ppb	8hrs	NO2	2.7171 ppb	8hrs
SO2	2.0274 ppm	8hrs	SO2	6.003137 ppm	8hrs
O3	2.97 ppmv	8hrs	O3	1.419314 ppmv	8hrs

After comparing our evaluating data with digital sensors value at a similar time range we can see there are lots of similarities in collected data but there are some differences in particular pollutant concentration even if it was measured at a certain location and at the same time range

Validation graph with digital PM2.5 sensor

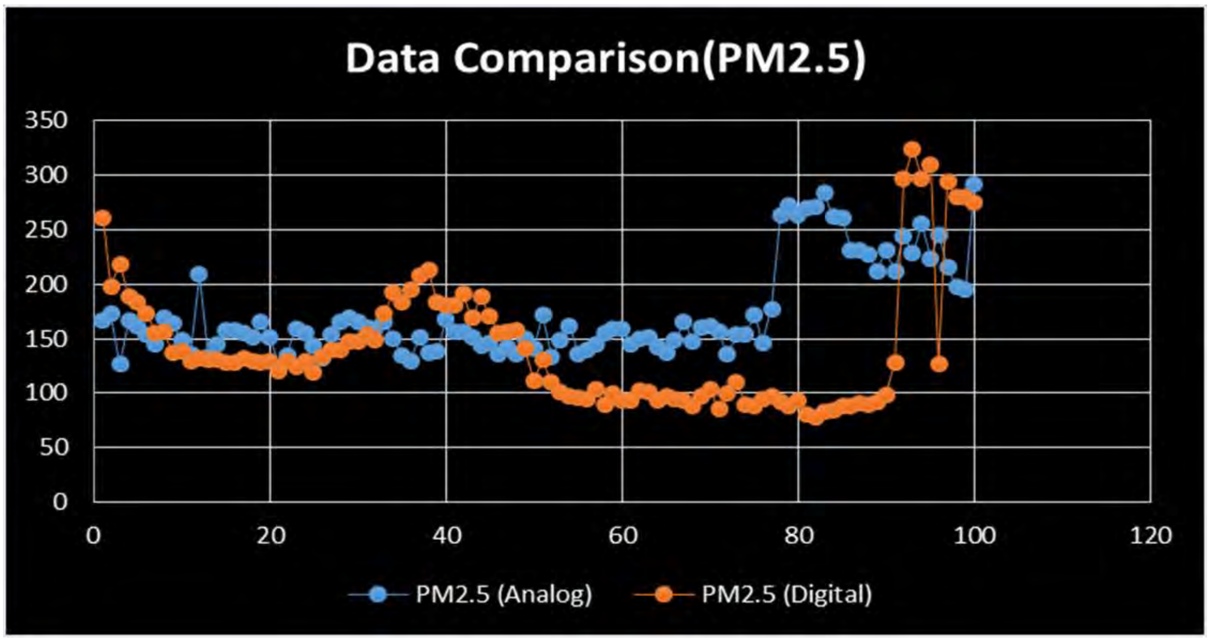


Figure 35: Data comparison with graphically (PM2.5)

Here we compare between two different types of sensor data. One is Analog PM2.5 Sensors and another is Digital PM2.5 sensor. This figure shows the comparison between analog data and digital we get from our sensors. As we know analog sensors are low cost and it takes time to get heated to give accurate value. On the contrary, digital PM2.5 sensors are more efficacious. It gives us more accurate data than analog sensors. For data validation, we use analog sensors reading as well as digital sensors reading at the same time and a similar indoor environment. As a result, we can observe that there are few times both sensors give the same reading of PM2.5. Also, there are few peaks where reading is not matched.

5.4 Conclusion

In this part of our project we follow some steps to complete the final design. Firstly, we calibrated all the sensors individually and matched the datasheet we collected by our research. Then we completed the whole system and connected the system with an app and cloud server, from where users can observe the air quality even if they are far away from the particular place. We tried to design the user interface of the app to make the system user friendly. Also, it will show the average Pm2.5 of a day which is the most important AQI measurement.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

Impact analysis and project sustainability plays an important role for any type of complex engineering project. Impact analysis basically refers to the impact that will be created after the main product is implemented. The changes of impact will indicate what type of role our project can play to improve the environment and public health. Project sustainability means the longevity criteria of the project or the maintenance process to keep the product technically accurate and function to get the desired results for indoor air quality index.

6.2 Assess the impact of solution

Health impact: Our projects aim to notify the real-time air index of indoor places and purify the air. This will keep the users away from harmful gasses. We did not find any negative health impacts from our project.

Societal impact: Our project will be constructed to monitor air quality at indoor locations and purify the air. This project's objective is to notify clients about the air quality. If the quality is bad then it will help to purify the air at that particular place. So, this process will definitely help to improve the indoor air quality and this will encourage people to implement this system in their offices, schools, labs, and hospital cabins to find a better solution for air quality in the context of Bangladesh. So, this project can have a large range of societal impacts.

Economical-impact: In fact, the economic benefits of good air quality alone often outweigh the costs of climate change reduction strategies. Investing in low-cost sensor networks empowers developing countries and their citizens with direct, transparent access to pollution data. Data is the basis of understanding air pollution and the first step to mitigating it. Having an extensive air quality monitoring network of properly-calibrated low-cost sensors enables data-driven and educated decision-making.

Environmental impact: Our project is basically about Indoor location-based so it will obviously help the indoor places to get the results for indoor and purify the air of that particular area. But this monitoring system can help overall improve the air quality index if we can make sure it has big demands in certain places like- chemical industries, labs, hospital cabins, indoor sports venues. As its working manual will be designed in a manner which will monitor air quality and will help to purify the air. So, this process in large numbers can definitely help the environment to get the expected air quality index which is sustainable for human beings.

6.3 Evaluate the sustainability

For this design system, we will expect to have a longevity of 5-8 years if we use appropriate design methodology and proper operating guidelines. Also, we will like to ensure that we can get the near accurate values of the air quality index and will try to make sure of minimum system errors.

Societal: Our project will try to measure indoor air quality and at the same time it will improve the air quality of indoor places. So, this system can play a significant role in indoor places to make sure the air quality is good for the health system. Also, this system can be a very unique system to showcase the importance of air quality in our country.

Economically: Normally, the air quality index measurement processes are covering big areas and a limited number of organizations monitor this system to get the real scenery of air quality of that particular area in Bangladesh. Also, this process would give the overall air quality index but not any specific location air quality index as it is expensive and not designed for indoor use. Our project can solve this problem as it will be designed for the indoor location and will help to improve the air quality of those places at a very minimal cost.

Environmental: By the name of this project, it might look like it doesn't have any environmental impacts as it is all about Indoor location. But the air quality index for indoor locations is extremely important for the environment. If we can make sure this project will be used in large numbers in chemical industries, laboratories, hospital cabins, and pharmacy labs then it will certainly help to improve the air quality of these places which can gradually improve the air quality of the environment even if it is for limited areas. Also, we will purify the air so this can help to make sure toxic gas doesn't have large impacts on the environment.

SWOT Analysis

Table 8: SWOT Analysis

	Beneficial	Harmful
Internal	**Strength-** • Advanced features. • Reliable and sustainable. • Affordable price. • Ideal measurement procedures. • Low power consumption.	**Weakness –** • Not tried and tested method. • Equipment covers a large amount of space at an indoor location.
External	**Opportunity-** • New feature on air quality index measurement in Bangladesh. • Provide large-scale public health benefits. • Can play a vital role in Bangladesh improving air quality at different locations.	**Threats-** • Not giving importance to the air quality index at indoor locations. • Expecting low market value in the context of Bangladesh.

A weighted average of SWOT Analysis:

Table 9: A weighted average of SWOT Analysis

	Activity	Rating	Weight scores	Short terms	Intermediate terms	Long term
	Advanced features	5	1.2			✓
	Reliable and sustainable	5	1.5		✓	
	Affordable price	4	0.8		✓	
	measurements	3	0.3		✓	
	Low power consumption	3	0.9	✓		
O1	New feature in air quality index	4	0.7		✓	
O2	Improve public health	5	3.1		✓	
O3	Improve indoor air quality	5	2.8			✓
	Not tried and tested	3	1.09			

	Covers a large space	3	0.4	✓		
	Ignorance of indoor air quality	4	1.1			✓
	Expected low market value	5	2.1		✓	

Here, we calculated the ratings of each of the parameters out of 5 and weight ratings by the whole analysis table on a scale of 15.

6.4 Conclusion

Our device is made with everyone in mind. This aspect is ensured first so that everyone can buy it. And it is priced as such. It is less expensive on the one hand and more durable on the other. Each and every component inside the device is as firmly placed as necessary steps have been taken to keep them secure. Moreover, there is a way to easily replace the parts if there is any problem. While trialing this device, we tested it in very harsh weather conditions. And there it has been successful. So, we can say that it has ensured a cheap price on one hand as well as durability.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

Engineering project management is a vital part of implementation of a project prototype within time limit or within boundaries to evaluate the main project progress. Here, in this chapter we will discuss the different project managing plans, management processes throughout the year to complete this project.

7.2 Define, plan and manage engineering project

Project management for engineers involves proper planning and communication of that strategy to an engineering group. It consists of identifying the project's objectives and goals as well as creating various scenarios and contingency solutions. Any engineering team that skips this step risks having the efforts of a large number of people interrupted by the unexpected.

Engineering is a complicated and constantly changing field, thus project management in this field must be flexible and aware about all of the latest modern quality management systems. This comprises general management abilities as well as engineering procedures relevant to the particular project.

Project plan for three phases for FYDP-

Work flow chart for FYDP_P:

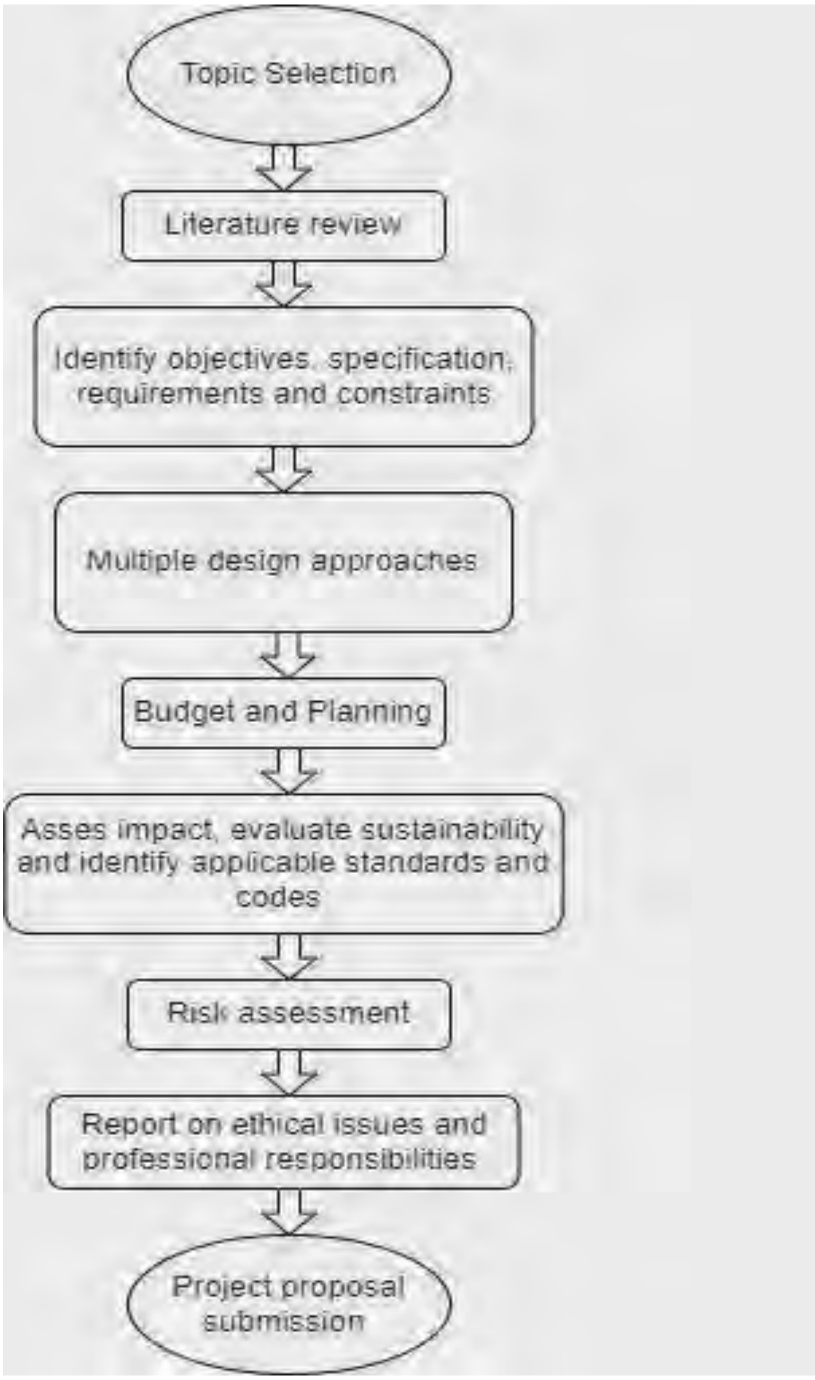


Figure 36: 400P flow chart

The mentioned flow chart represents the process we follow to select our topic initially, then how we conducted our literature review to support the topics. After the topic approval from our Advising panel we started working on the objectives and requirements of the project. Then, we identified multiple design approaches to justify our objectives as well as to conduct hardware implementation in future. We had to come up with a budget to reflect specific components requirements for this project. Also, we identified impact, sustainability and applicable standard code for this project. Last, before the proposal submission we needed to modify our design approach and the name of the project to evaluate the project progression.

Working procedure for FYDP_D

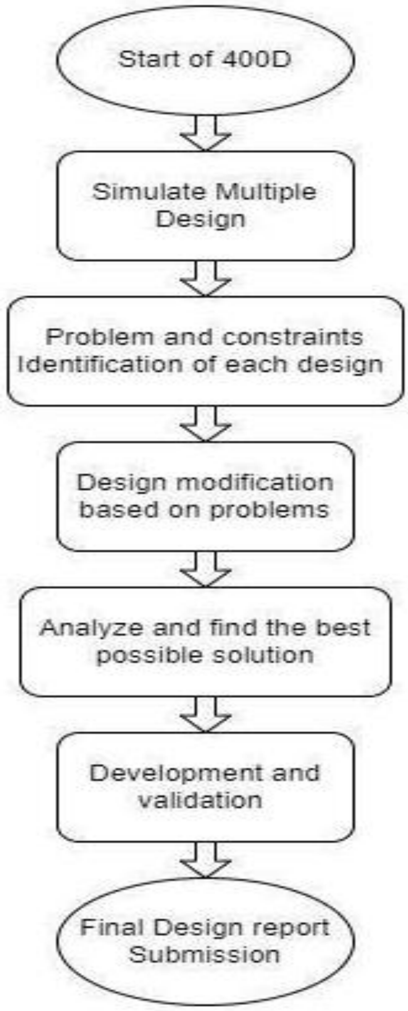


Figure 37: 400D flowchart

During this time of the project, we represented the selected design approach in the simulation process to visualize the hardware prototype setup and also designed 3D visuals to represent the idea of how the project would look like or how it should be worked at an indoor location. We had to modify our multiple design approaches to support the idea of our project as well as we researched a lot about the simulation tools which would support complex engineering problems. After completing the simulation process for both the design approach then we had to comment about the optimal design approach of our project. With that we also had to validate our results to justify the project object or the outputs we are getting from the simulation processes to support our project aims or not.

Flowchart for FYDP_C:

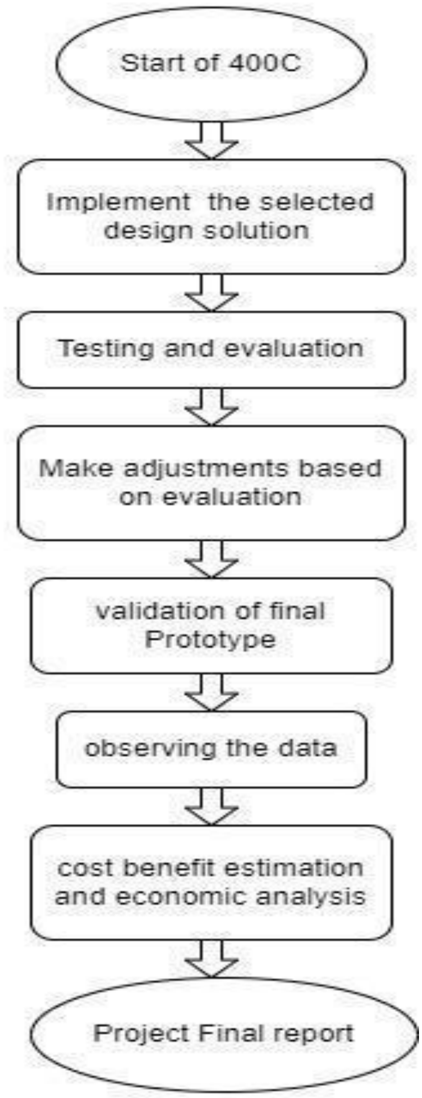
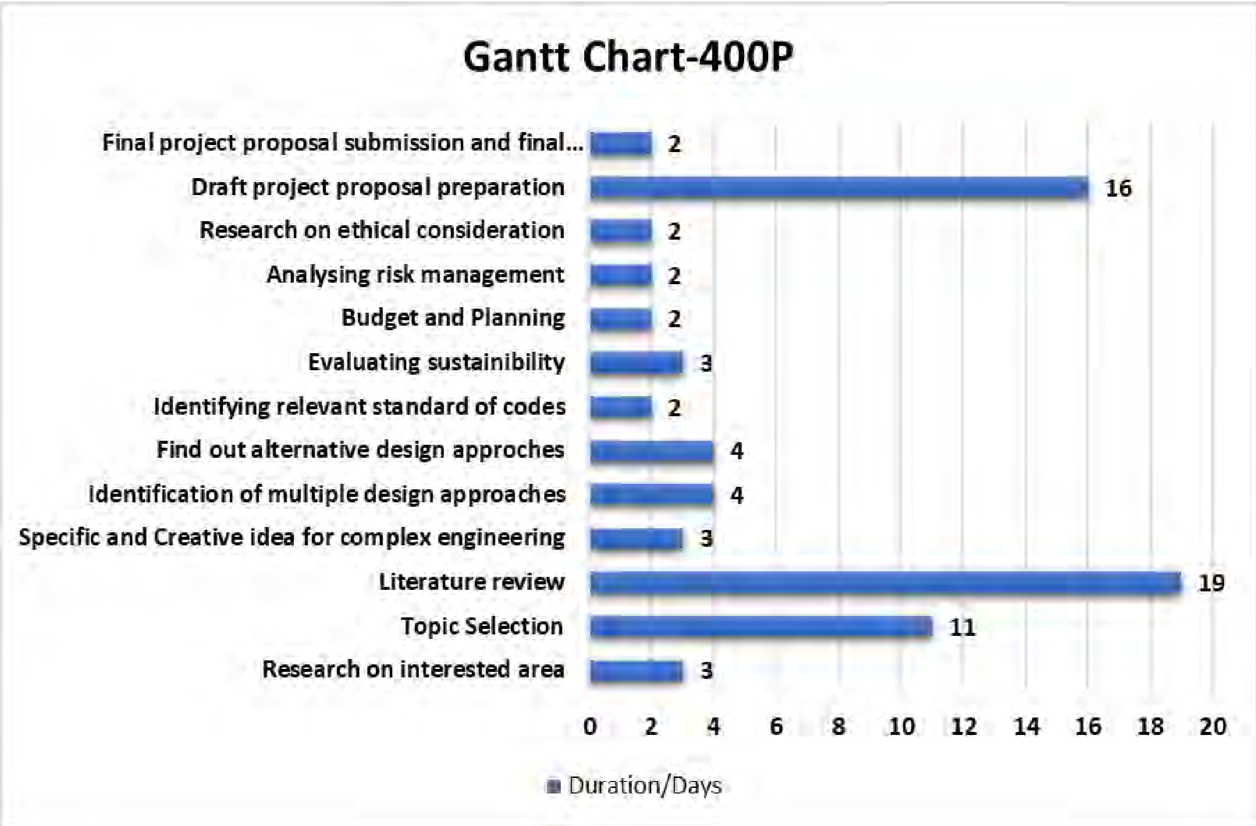


Figure 38: 400C flowchart

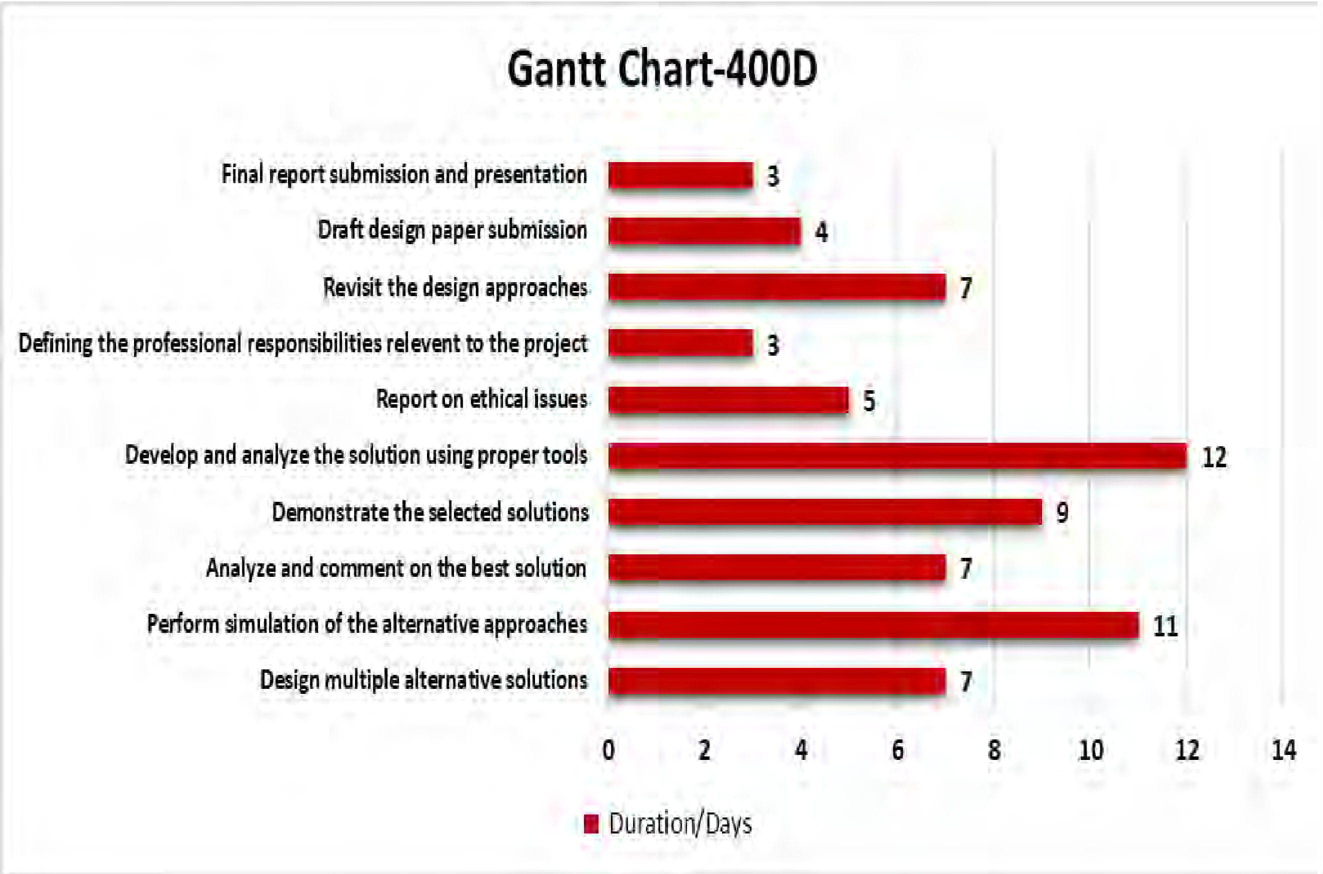
During this timeframe, firstly we selected our final design solution keeping in mind; our optimal solution. We researched again for the hardware implementation as well as the selected design to overcome the lacks. Then components were collected then we started testing the devices and tried to start building up our final prototype. We needed lot of adjustments to organize our plans so that we can start collecting data to evaluate and cross check with standard range. We needed to modify our system to collect real time data and lastly, we validated our results with project final objectives.

Plan for 400P:



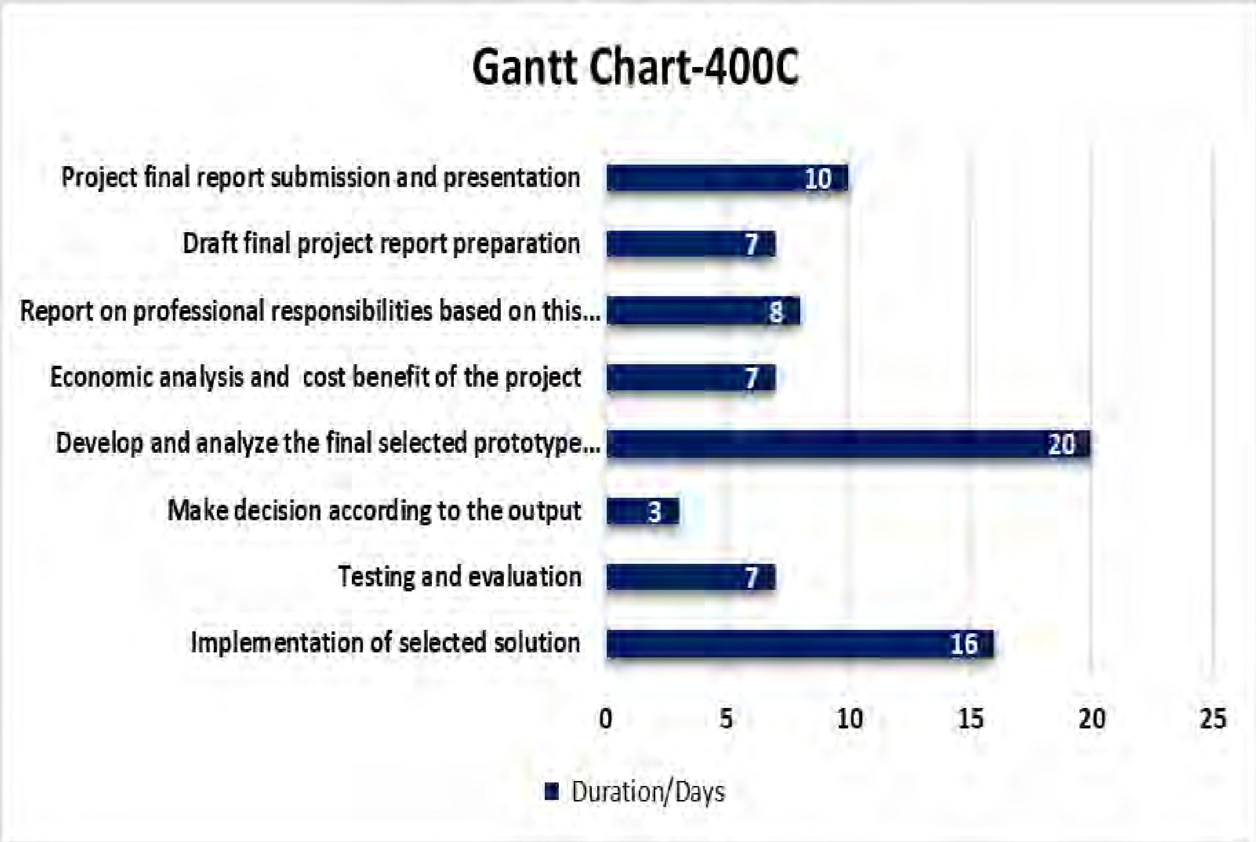
Initially, we divided up our works among the group members. Multiple planning and scheduling changes were required. We got started on our assignment in the second week of the month. Discussions in our group and suggestions from our ATC helped us choose our topic. Tonmoy, Prashanta and Imtiaz worked on the part on the tentative problem statement and objective. The multiple-design approaches were overseen by Tonmoy, Prashanta and Imtiaz. The specification, requirements, and limitations were also worked on by Tonmoy, Prashanta and Imtiaz was ready to choose the appropriate code components. Additionally, Tonmoy was in charge of the technique and methodology, Imtiaz was in charge of the project planning, and Imtiaz was in charge of the budget. And the risk management part is finished by Hasan.

Plan for 400D:



Beginning with the first week, we started our work. Background research was done by each group member. The CO analysis was then taken on by Tonmoy, Prashanta, and Imtiaz. The appropriate software to execute our proposal was then evaluated by Prashanta and Imtiaz. Additionally, Tonmoy, Hasan, Prashanta, and Imtiaz evaluated the design processes. Imtiaz and Tonmoy tried to troubleshoot the design. The process of comparing and identifying designs was under the supervision of Tonmoy, Prashanta, and Imtiaz. Tonmoy was responsible for discovering the ethical issues. We will also compare project progress to the project plan using a Gantt chart and a logbook. If necessary, the project will also experience rescheduling and plan adjustments.

Plan for 400C:



Beginning with the first week, we got to work. Each member of the group did background study to help them choose better alternatives for the components. The CO analysis was then taken on by Tonmoy, Prashanta, and Imtiaz. Tonmoy and Imtiaz then evaluated the necessary components for turning our project into motion. Additionally, Tonmoy, Prashanta, and Imtiaz analyzed the design processes used to create the prototype in order to conduct an actual experiment. The model design was completed by Tonmoy and Prashanta. Hasan and Imtiaz were in charge of calibrating the sensors. Datasets for different indoor locations were collected by Tonmoy, Prashanta, and Imtiaz. Additionally, each group member then contributes their best to validate the output.

7.3 Evaluate project progress

Progress of our project is divided into several parts to evaluate certain responsibilities and working management. Below we attached risk severity matrix and professional responsibilities;

Table 10: Risk severity matrix

	Risk Severity		
Possibility	**Low**	**Medium**	**High**
Almost Certain (This event is expected to occur .)	**Damage from water**	**Power cut**	**N/A**
Moderate (Given time likely to occur)	**N/A**	**Sensor failure, User disturbances**	**N/A**
Rare (This event may occur)	**N/A**	**Misinterpretation of data**	**System errors**

Responsibilities which are assigned individually to make sure the project fulfilling all the elements of complex engineering project;

Table 11: Individual responsibilities.

Problem	Analysis	Contingency plans	Assigned to
Sensor failures	For this air quality index-based management system we need to use different sets of sensors so these digital or analog sensors as these components might show problems in project conduction when we will use it.	Indoor location-based procedures will have much more effective digital sensors to make sure they can avoid frequent system errors.	Prashanta
Response to overall system errors	System will be designed to identify specific air pollutants which are affecting the locations so it is very much certain that there will be errors in results calculation systems in time to time as we use various components to measure results.	Sensors and purifiers which we are going to use need to be high quality so that pollutants which are in small numbers don't increase the pollution.	Tahsin

Misinterpretation of data	All the information about air quality is mainly based on the open space area and this information will not help to understand Indoor Air information along with the standard tools.	Design approaches of this project will ensure that project outcomes are going to be purely competitive for indoor location and tools are selected keeping in this matter.	Imtiaz

7.4 Conclusion

As a result of our analysis of the terminology and requirements for project management, we have included those aspects into our Final year Design project. Therefore, we have equally dispersed our project's work in order to finish it on time and within the budget by maintaining a logbook, a Gantt chart, and a peer assessment form.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

Engineering economic analysis refers to the many possibilities for an engineering project that are broken down based on their total costs. An engineering economic analysis examines a project from two fundamental angles: the time to finish the project and the physical expenses, such as materials and labor. Also, there is a term called intellectual capital that can be added in the economic analysis as people contribute their knowledge by building an engineering project.

8.2 Economic analysis

As we selected our final design approach during the simulation process, we needed to modify our budget structure during hardware implementation by looking at components effectiveness, longevity and efficiency. Here we analyze our budget after completing the main design solution.

Table 12: Budget Analysis of the hardware set up

Components	Quantity	Price (Tk.)
ESP32	1	800
GP2Y1010AU0F (PM2.5)	1	650
MQ135	2	240
MQ9	1	180
MQ2	1	100
DHT-22	1	250
LCD (20x4), I2C	1	550
Battery, Cooling fan, Veroboard	1:1:1	150
Miscellaneous Cost		1200
Total		**= 4120 Tk.**

8.3 Cost benefit analysis

Representation of cost benefit analysis after analyzing the hardware budget structure to observe the strength and weaknesses of the selected product.

Table 13: Cost benefit analysis

Components	Price	Strength	Weakness
ESP-32	800/-	1.Built-in wifi and Bluetooth services. 2.10 capacitive sensors. 3.High data storage capacity.	Frequency range of wifi connection for ESP-32 is only 2.4GHz.
PM 2.5	650/-	Lesser scattering working principle so dust particles of air can be measured easily.	Minimum 24 hours needed for evaluating the AQI values.
DHT-11	250/-	Efficiency of humidity measurement purposes is high.	Comparatively, costly than other humidity sensors.
MQ-135 [×2]	240/-	Can be used as both analog and digital sensors as both types of pin present at MQ-135.	Level of CO cannot be measured but can detect smoke, CO or CO2 in the atmosphere.
MQ-2	100/-	Detection level of any kind of flammable gas is between 300-10000 ppm.	Only detect some specific kinds of gasses concentration in the air.
MQ-9	180/-	Highly sensitive so give results faster than other gas sensors.	Heating issues of sensor coils.
Cooling Fan	50/-	Minimization of over-heating process of the products inside the box.	Not suitable for high temperatures.

8.4 Evaluate economic and financial aspects

Evaluating economic and financial aspects is one of the most important criteria we should follow in any engineering project. We evaluate the economic and financial aspects for our final year design project. In order to evaluate the economic and financial aspects of our project, we have studied research publications on engineering project economics and costs and have established a set of criteria.

8.4.1: Evaluate Economic aspects

There are several cost classifications that economic analyses might be based on:

- **Initial cost:** Initial cost refers to the Start-up costs for an activity, such as modifications to the premises, transportation, installation, and preliminary expenditures. Here if we evaluate the initial costs of our project, we can observe that the cost is not so high. which can help our project to be more available to the consumers.

- **Operation and Maintenance Cost:** They are experienced continually over the useful life of the activity. In our project operational and maintenance costs are low. Price of sensors is low.

- **Fixed cost:** Fixed costs are expenses incurred throughout an organization's operational lifetime that are related to current operations and result from planning for the future. Every engineering project contains some fixed cost throughout the life cycle of that project. In the Air Quality Monitoring System, there are some fixed costs. This system cannot continue without Wifi connection. So, we must ensure the system is always connected to Wifi.

8.5 Conclusion

In the conclusion, Recruiting the air quality index (AQI) as a measure of overall air quality in Bangladesh, we find that industrial production, financial development, and economic integration lead to higher overall air pollution. Nevertheless, efficiency in urban planning through public transportation and population density alleviates this environmental degradation. A closer look into the two main air pollutants in Bangladesh, sulphur dioxide and dust, further highlights the complexity of the issue. We tried to consider all the economic and financial aspects for the service providers and stakeholders. Additionally, as our final product can deliver the expected output, it has a positive influence on all the stakeholders out there.

Chapter 9: Ethics and Professional Responsibilities [CO13, CO2]

9.1 Introduction

Indoor air quality monitoring systems can play a big role both for the environment as well as for human health. To make this system impactful we need to maintain some ethical considerations to make it worthy of the solutions. This part of the report we analyze ethical point of view of this project as well as professional responsibilities to make it efficient and productive for both the environment and mankind.

9.2 Identify ethical issues and professional responsibility

For our project, identification of ethical issues and professional responsibility play a big role in determining stakeholders or user requirements as there are lots of key aspects of the project that are related to this. At first, we need to consider the environmental aspects as we are measuring indoor air quality we have to ensure there are certain importance of these project for environment. Next, the safety for users as it is must for this type of product because it will only be located at indoor places so any kind of electrical failures or damages should be into consideration. Another part of that ethical issue should be privacy of stakeholders and users as we know it is wifi connection-based system so router connection to the programming channels need to be secured and safe. Also, for implementation we have to follow standard rules to select appropriate sensors, applicable codes, following the standard AQI index to ensure project is validating the need of users.

9.3 Apply ethical issues and professional responsibility

Ethical issues and professional responsibility are an important part of any kind of complex engineering project. Project success or failure depends heavily on these criteria. We can implement any kind of advanced and high efficiency-based system but if its procedure doesn't allow the proper safety protocol for the environment and humans then it has no real outcome. Our selected project will have various parts of ethical issues and analysis.

Assuring environment friendliness:

This project will be for the improvement of air quality in the indoor environment. So, the process we follow here will not only help the indoor places to identify the real sceneries of air quality but it will also help to improve the air of those places as we will introduce the purification system if we find the air is unsafe for human existence. The purification system will certainly help to make the environment safe and healthy at least for indoor places.

Figuring out human behavioral acts and social understanding:

This project is quite unique when it comes to using it. As it is totally for indoor location, it is probable that a large range of people may not consider it as an important feature that can have a significant impact on air quality index or this can help to improve the health conditions. For this reason, we need to make sure the project design can match the standard ideas to replicate the main objectives we want to achieve through this project. Apart from that, we need to try to implement in a way that works in the same way when it comes to covering large areas for air quality monitoring.

Understand the responsibility before the implementation:

As we are designing a system that will be only for indoor locations then so many ethical factors will be there. Firstly, we need to be honest and dedicated to our approaches for making sure our work ethics are appropriate and our design processes are going to achieve what we are looking for through this project. Next, as its functionality will be designed only for indoor locations for human benefits, we need to be extra careful when we are choosing the materials and the tools. We need to make sure that nothing can cause any damage to human life or even need to make alternative safety protocols for accidental circumstances. Choosing proper sensors, ideal battery sources, and adjacent modules to measure the values all are the responsibilities for doing safe and sustainable engineering projects.

Applicable Standards and Codes

- **National Ambient Air Quality Standards (NAAQS):** The United States' National Ambient Air Quality Standards (NAAQS) set limitations on the atmospheric concentration of six pollutants that are responsible for smog, acid rain, and other health risks, established by the United States Environmental Protection Agency (EPA) under authority of the Clean Air Act. Ozone (O3), atmospheric particulate matter, lead, carbon monoxide (CO), sulfur oxides (SOx), and nitrogen oxides are the six criteria air pollutants (CAP) or criteria pollutants for which limitations are specified in the NAAQS (NOx).

- **IEEE 2050-2018:** This standard is a real-time operating system (RTOS) specification for small-scale embedded systems like systems with a single chip microcomputer (single chip microcontroller), systems with 16-bit CPUs, systems with a limited quantity of ROM/RAM, and systems without a memory management unit (MMU). Data storage on the main chip requires ROM. This requirement also applies to managing reading.

Indoor AQI Monitoring Device Usability Test Consent Form

I ______________________ hereby granting **TAHSIN ABRAR TONMOY, IMTIAZ UDDIN AHMED, HASAN MOHAMMAD JAKARIA** and **PRASHANTA CHAKRABORTY** permission to use my feedback to a questionnaire and to site them in academic research works. I am aware that their work is intended for academic use.

I also accept that if the researchers ever publish this information in a scientific publication or online in electronic form, I renounce any claim to copyright to it.

I understand that the Research Title is **Air quality monitoring at an indoor location.**

I also understand that my responses to the questionnaire will remain anonymous to the researchers, who are hereby identified as **TAHSIN ABRAR TONMOY**, **IMTIAZ UDDIN AHMED, HASAN MOHAMMAD JAKARIA** and **PRASHANTA CHAKRABORTY.**
I hereby give my permission in the form of my signature below:

Signature ______________________ Date ____________________

9.4 Conclusion

After all, we can come up to the conclusion that this device made by us will not have any adverse effect on the environment. None of the components of this device are hazardous. Rather, it detects and quantifies the elements that are harmful to our body. And the sensors we used to measure it don't produce any byproducts. Moreover, no part of the device's core is out of the norm. So, we can say for sure that this device is made according to the proper rules.

Chapter 10: Conclusion and Future Work

10.1 Project summary/Conclusion

These kinds of projects aim are critical to interpret and properly share the massive volumes of data generated by air pollution monitoring. The suggested framework allows the environment to be studied from a distance using dedicated sensors at cheap costs, leveraging low-power, compact, and extremely precise technology. It will aid in the formation of large-scale agreements to combat rising levels of air pollution and preserve a healthy environment. Finally, it can detect long-term pollution patterns and ensure that clients are aware of them.

10.2 Future work

Our project has a vast range of scope for future work. As we are monitoring the indoor air quality and depending on the results we will take necessary steps to improve the indoor air quality. But this type of system can have various limitations to overcome-

- **Lack of specified sensor availability:** Sensors we used for this project all are analog and in the Bangladesh market some of analog gas sensors are unavailable so we have to adjust to look for different sensors which can detect similar kinds of results.

- **Budget issues:** Our project is designed basically for academic purposes so the budget was limited so even if we had desired to use digital sensors or arduino for better product efficiency but for budget limitations we could not afford.

- **Sensors quality:** Another major problem we faced during prototype setup was sensor measurements showing lots of garbage values or unrealistic values because in the market lots of copy versions of main sensors were available. As the budget is limited so we were not able to get all the real copies of air quality measurement sensors or the sensors we were not fully efficient to get accurate data continuously.

- **Heating issues of sensors:** When we run the product more often we found the temperature of the sensors were increasing so we need to keep it in mind from time to time to stop the running process to ensure its longevity. Other hand, when we start the product it takes lots of time to get the minimum coil heating to overcome garbage results or start giving the actual results of indoor places.

- **Lengthy time requirement to get the accurate results:** As we are using all analog sensors so it is obvious that it will take more time to start showing proper values based on the analog sensors quality that we mentioned above.

In addition, different systems implementation in our project can make it more technically correct and beneficial for human life and the environment. We discussed some of the future scopes of this project:

- **Alarming unit:**
  By integrating a Buzzer in our 'Air Quality Monitoring System' we can add an alarming unit feature that will deliver the message instantaneously to the people surrounding the indoor place. Also, there will be a notification unit which will send the consumers if the parameters cross the limit.

- **Purification system**:
  We can add a purification system with this setup. One way of purification process can be like if this system shows unhealthy results then we can purify the selected indoor location by installing a purifier at that location. Another way of purification is electrical mechanism based.

- **Digital sensors:**
  In our system the sensors, we are using are all analog sensors. By using digital sensors, we will get a more accurate output from our sensors.

- **Highly efficient sensor presence:**
  Sensors we used for our project are all cost effective but for this range of projects we need more highly efficient sensors to get faster and accurate results even if it is digital or analog sensors. It is obvious that there are no significant changes in indoor location monitoring sensors and outdoor monitoring sensors, just that we need high quality sensors for measuring air pollutants which we could not afford because of limited budget as well as limited sources.

Chapter 11: Identification of Complex Engineering Problems and Activities

11.1: Identify the attribute of complex engineering problem (EP)

Attributes of Complex Engineering Problems (EP)

	Attributes	Put a tick (√) as appropriate	Description
P1	Depth of knowledge required	✓	From research articles we came to know the requirements and specifications of this project. Also, learn about any drawbacks we may face by implementing the project. Moreover, we need to have knowledge about components that we will be using and sufficient coding skills.
P2	Range of conflicting requirements		
P3	Depth of analysis required	✓	By analyzing several research-papers we came up with three different design approaches.
P4	Familiarity of issues		
P5	Extent of applicable codes	✓	We use all required applicable codes and standards to build an Air Quality monitoring system.
P6	Extent of stakeholder involvement and needs	✓	There are some requirements from the side of stakeholders. During the manufacturing of this project, we maintain the requirements and needs.
P7	Interdependence	✓	The solution involves a combination of different subsystems

11.2: Provide reasoning how the project address selected attribute (EP)

P1: Depth of knowledge:
We gathered a few papers and journals and thoroughly reviewed them and learned about the requirements and specifications of our project. By analyzing such articles, we noticed there may be some scope of improvement that may feasible by implementing the project.

P3: Depth of analysis required:
We went through a number of research articles for this project to gain a thorough understanding of the analysis. Then we looked for reasonable components to incorporate in our system's design and came up with three different design approaches. Furthermore, after analyzing the research articles we found which gasses need to be detected by this project in indoor places.

P4: Familiarity of the issue:
Air is the most important element in the environment. But due to global warming and lack of responsibility for people, Air pollution is increasing day by day. Also, Dhaka city is one of the most polluted cities in the world. To live healthy, we must ensure that our residence and working place are safe. Without an appropriate air quality monitoring system, it will be hard for us to know the air quality index of particular places. So, this is the most familiar issue for everyone in the present time.

P5: Extent of applicable codes:
The project that we will be working on consists of several modules, components, and other features. Here, we are taking to account all applicable codes, regulations, and limitations established from the various organizations that are implicated in our project. Therefore, in order to prevent any potential conflicts with the applicable code, we shall employ the proper components.

P6: Extent of stakeholder involvement:
The main objective of our project is to notify the real time air quality index to the users and the working or living environment in that particular place. We will need some involvement from the side of the stakeholders to implement our project.

11.3 Identify the attribute of complex engineering activities (EA)

Attributes of Complex Engineering Activities (EA)

	Attributes	Put a tick (√) as appropriate	Description
A 1	Range of resources	✓	For this project's implementation, a number of resources are required, including funding, equipment, technology, supplies, and information from stakeholders. To adequately manage all of these resources, resource management skills are essential.
A 2	Level of interaction	✓	For information and feedback we need to interact with the stakeholders. We made some interaction with the Higher Authorities, collected some data through the survey and a consent form to conduct the project.
A 3	Innovation		
A 4	Consequences for society and the environment	✓	The project will significantly improve the quality of life.
A 5	Familiarity	✓	The problem we are dealing with is new to us and is not directly related to our curriculum. Therefore, we needed to do research and find out additional information that would help us.

11.4 Provide reasoning how the project address selected attribute (EA)

A1: Range of resources:
We studied a few research papers, publications, and journals to see how we could construct our project. These papers provided us with a wide range of options for how we may create our project, and we came up with three design approaches from which we would choose the optimal one to build it.

A2: Level of interaction:
The level of interactive participation in this project is considered important. In order to gather data and information from the project's stakeholders, we have created a Google form and personally met with some of the users.

A4: Consequences for society and the environment:
This project plays a significant role by giving the information about air index to the consumers to be sincere about the air quality of their surroundings. Moreover, warning consumers about the air quality might be an alarming message which can have an impact on people of the society about the perspective to reduce the air pollution.

A5: Familiarity:
This project is quite similar to the outdoor air index measurements process. Only things that is different from other projects is that here we will be measuring indoor air quality. So, for that range of our covering area will be different but the sensors which are used for air index purposes will be similar, even the system procedure will be similar.

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Appendix

Code:

```
//Libraries
#include <LiquidCrystal_I2C.h> // LCD display
#include <Wire.h> // For I2C communication
#include <WiFiManager.h>
#include <DHT.h>
#include <WiFi.h>
#include <HTTPClient.h>
#include <MQ2.h>
#include <MQ135.h>

//thinkspeak url
String serverName = "https://api.thingspeak.com/update?api_key=U14Y8AZPNTGCXLHN";
#define MQ2_sensor 39
#define MQ9_sensor 34
#define MQ1351_sensor 35
#define MQ1352_sensor 32
MQ2 mq2(MQ2_sensor);
MQ135 mq135_sensor(MQ1351_sensor);
MQ135 mq135_sensor_2(MQ1352_sensor);
//objects
LiquidCrystal_I2C lcd(0x27, 20, 4);
DHT sensor(13, DHT22);

// dust stuffs
int measurePin = 36;
```

```
int ledPower = 25;
float CO, SO2, NO2, O3, dust;
uint64_t current_time;

void setup() {
  Serial.begin(9600);
  lcd.begin();
  lcd.backlight();
  lcd.clear();
  mq2.begin();
  sensor.begin();
  pinMode(ledPower, OUTPUT);
  delay(1000); // delay sometimes
  printlcd("Hello & Welcome", 1, 0, 100);
  delay(2000);
  clearfrom(1, 0, 17);
  printlcd("Connecting to WIFI", 1, 0, 100);
  printlcd("If not Connect !", 0, 1, 50);
  printlcd("AP : AirQual", 0, 2, 100);
  printlcd("IP : 192.168.4.1", 0, 3, 200);
  // init wifi
  WiFi.mode(WIFI_STA);
  WiFiManager wm;
  bool response = wm.autoConnect("AirQual");
  if (!response) {
    lcd.clear();
    printlcd("Failed !!", 5, 1, 300);
    delay(2000);
    ESP.restart();
```

```
  } else {
    lcd.clear();
    printlcd("CONNECTED !!", 4, 1, 300);
    delay(2000);
  }
  lcd.clear();
  for (int index = 0; index < 5; index++) {
    sensor.readTemperature();
    sensor.readHumidity();
  }
  current_time = millis();
  GasFace();
}

void loop() {
  CO = mq2.readCO();
  SO2 = mq2.readSmoke();
  NO2 = mq2.readNO2();
  float rzero = mq135_sensor.getRZero();
  float correctedRZero = mq135_sensor.getCorrectedRZero(temperature, humidity);
  float resistance = mq135_sensor.getResistance();
  float ppm = mq135_sensor.getPPM();
  float correctedPPM = mq135_sensor.getCorrectedPPM(temperature, humidity);
  O3 = (correctedPPM / 100);
  dust = give_me_dust();
  //co
  lcd.setCursor(5, 0);
  lcd.print("           ");
  lcd.setCursor(5, 0);
```

```
lcd.print(CO);
//so2
lcd.setCursor(5, 1);
lcd.print("           ");
lcd.setCursor(5, 1);
lcd.print(SO2);
//no2
lcd.setCursor(5, 2);
lcd.print("         ");
lcd.setCursor(5, 2);
lcd.print(NO2);
//o3
lcd.setCursor(5, 3);
lcd.print("       ");
lcd.setCursor(5, 3);
lcd.print(O3);
//pm
lcd.setCursor(13, 3);
lcd.print("      ");
lcd.setCursor(13, 3);
lcd.print(int(dust));

handleSpeak();
delay(1000);
if (current_time + 25000 < millis()) {
  SensorFace();
  delay(4000);
  GasFace();
  current_time = millis();
```

```
  }
}

void printlcd(String msg, int col, int row, int interval) {
  int terget = 0;
  for (uint8_t index = col; index < col + msg.length(); index++) {
    lcd.setCursor(index, row);
    lcd.print(msg.charAt(terget));
    delay(interval);
    terget++;
  }
}

void clearfrom(int col, int row, int space) {
  for (uint8_t index = col; index < col + space; index++) {
    lcd.setCursor(index, row);
    lcd.print(" ");
  }
}

float give_me_dust() {
  int samplingTime = 280;
  int deltaTime = 40;
  int sleepTime = 9680;
  float voMeasured = 0;
  float calcVoltage = 0;
  float dustDensity = 0;
  digitalWrite(ledPower, LOW);
  delayMicroseconds(samplingTime);
```

```
  voMeasured = analogRead(measurePin);
  delayMicroseconds(deltaTime);
  digitalWrite(ledPower, HIGH);
  delayMicroseconds(sleepTime);
  calcVoltage = voMeasured * (3.3 / 4096.0);
  dustDensity = 170 * calcVoltage - 0.1;
  return dustDensity;
}

void SensorFace() {
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("TEMP:");
  lcd.setCursor(0, 2);
  lcd.print("HUMD:");
  lcd.setCursor(15, 1);
  lcd.print("C");
  lcd.setCursor(15, 2);
  lcd.print("%");

  lcd.setCursor(6, 1);
  lcd.print(sensor.readTemperature());
  lcd.setCursor(6, 2);
  lcd.print(sensor.readHumidity());
}

void GasFace() {
  lcd.clear();
  lcd.setCursor(0, 0);
```

```
  lcd.print("CO :");
  lcd.setCursor(0, 1);
  lcd.print("SO2:");
  lcd.setCursor(0, 2);
  lcd.print("NO2:");
  lcd.setCursor(0, 3);
  lcd.print("O3:");
  lcd.setCursor(16, 2);
  lcd.print("PM");
}

void handleSpeak() {
  HTTPClient http; // Initialize our HTTP client
  String url = serverName + "&field1=" + dust + "&field2=" + dust + "&field3=" + CO + "&field4=" + NO2 + "&field5=" + SO2 + "&field6=" + O3; // Define our entire url
  http.begin(url.c_str()); // Initialize our HTTP request
  int httpResponseCode = http.GET(); // Send HTTP request
  if (httpResponseCode > 0) { // Check for good HTTP status code
    Serial.print("HTTP Response code: ");
    Serial.println(httpResponseCode);
  } else {
    Serial.print("Error code: ");
    Serial.println(httpResponseCode);
  }
  http.end();
}
```

Logbook

Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
29-09-2022	1.Tahsin 2.Prashanta 3.Imtiaz 4.Hasan	1.Discussion on hardware tools selection based on the main design approach. 2.Need to understand the Fydp_C criteria. 3.Need to find the ways to select relevant programming criteria. **Meet platform:ATC meeting**/offline.	Task 1,2&3: Prashanta, Tahsin, Imtiaz.	It was an introductory meeting regarding Fydp -C procedure and course analysis.
08-10-2022	1.Tahsin 2.Prashanta 3.Imtiaz 4.Hasan	1.Discussion and research on the possible sensor selection and approach to build up hardware setup for the project. 2.Changes on design approach based on ATC fedback. **Meet platform:**offline	Task 1: Tahsin, Prashanta,Imtiaz, Hasan	
10-10-2022	1.Tahsin 2.Prashanta 3.Imtiaz 4.Hasan.	1.Selection on hardware tools depending on the main design approach. 2.Research on digital sensors for project validation. 3.Write up for the final report. **Meet platform:** Offline.	Task 1: Everyone Task 2: Tahsin,Prashanta Task 3: Imtiaz	
02-11-2022	1.Tahsin 2.Prashanta 3.Imtiaz 4.Hasan.	1.Sensors testing to identify project requirements. 2.Slide preparation for progress presentation. **Meet platform:** offline.	Task 1: Tahsin, Prashanta Task 2: Imtiaz,Hasan.	

05-11-2022	1.Imtiaz 2.Hasan 3.Tahsin 4.Prasha nta	1.Presentation preparation. 2.Discussion on presentation feedback. **Meet platform: ATC meeting**/ offline.	Task 1:all Task 2:all	1. Modification needed in sensor testing. 2.Technical aspects of this project needed to be clearly visible.
22-11-2022	1.Imtiaz 2.Hasan 3.Tahsin 4.Prasha nta	1.Discussion about implementation. **Meet platform:ATC meeting**/ offline	Task 1:all	1.Sensors calibration should be accurate to get proper data.
01-12-2022	1.Tahsin 2.Hasan 3.Prasha nta 4.Imtiaz	1.Discussion about how we properly set up our final project. . **Meet platform:ATC meeting**/ offline	1 Task 1: all	1. Data sheet should be compared with digital sensors results as well as outdoor datasheets to justify the outcomes.
07-12-2022	1.Tahsin 2.Hasan 3.Prasha nta 4.Imtiaz	1.Data sheets are modified. 2.Product run at different indoor locations. 3.Slide making and defense preparation. **Meet platform:ATC meeting**/ offline	1.Task 1:all 2.Task 2: all	1. Product was not showing appropriate values so the set up should be rechecked.

08-12-2022	1.Tahsin 2.Hasan 3.Prashanta 4.Imtiaz	1.Programming was rechecked. 2.Sensors were calibrated again. 3.Restart data collection in different locations. **Meet platform:ATC meeting/** offline	1.Task-1:Tahsin,Imtiaz. 2. Task-2:Hasan,Prashanta 3.ALL	1.Need to display different time zone output in reports as well as final presentation.
12-12-2022	1.Tahsin 2.Hasan 3.Prashanta 4.Imtiaz	1.Presentation preparation. 2.Discussion on presentation feedback. **Meet platform:ATC meeting/** offline	Task 1:all Task 2:all	
14-12-2022	1.Tahsin 2.Prashanta 3.Imtiaz 4.Hasan	1.Hardware set-up test. 2.Data validation. 3.Mock presentation. **Meet Platform: ATC meeting** /offline.	Task 1;all Task 2:all Task 3:all	1.Slides needed to be modified. 2.Limitations should be clearly mentioned in the slides. 3.Data validation should be specified.
18-12-2022	1.Tahsin 2.Prashata 3.Imtiaz 4.Hasan	1.The report has been overviewed. 2 Discussion on project.product limitation. **Meet platform:ATC meeting/** offline	Task 1: all Task 2: all	1.Report needed to be modified. 2.limitation should be specified and how to solve it.