IT 497: Graduation Project Report

Product Release-2

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First Semester 1445
Fall 2023

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NAQI

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Abstract (English)

Air pollution poses significant threats to health and the environment; thus, it is essential to monitor indoor and outdoor air quality to ensure a healthier future. High indoor carbon dioxide levels indicate poor ventilation, which increases the risk of virus transmission and respiratory health problems. Additionally, breathing in dust from the outdoors may aggravate respiratory diseases. To combat this problem, NAQI, an Arabic mobile application, has been proposed that uses the Internet of Things and LoRaWAN technology to collect and analyse air quality data that are collected by various sensors. This application allows real-time monitoring of CO2 levels, allowing users to ensure a healthy indoor environment. The application can automatically turn on the fan when CO2 levels exceed specific thresholds. The app also measures dust levels outside, providing a comprehensive view of the overall air pollution situation based on the health status level of the user. Evaluation and testing have proven the NAQI application's effectiveness in monitoring and controlling indoor air quality to reduce respiratory health issues. The results demonstrate the potential of this technology-based approach to significantly impact public health and its importance in alleviating the challenges posed by contemporary concerns about air quality.

Abstract (Arabic)

يشكل يشكل تلوث الهواء تهديدات كبيرة للصحة والبيئة؛ وبالتالي، من الضروري مراقبة جودة الهواء الداخلي والخارجي لضمان مستقبل أكثر صحة. يشير ارتفاع مستويات ثاني أكسيد الكربون في الأماكن المغلقة إلى سوء التهوية، مما يزيد من خطر انتقال الفيروسات ومشاكل صحية في الجهاز التنفسي. بالإضافة إلى ذلك، فإن استنشاق الغبار من الخارج قد يؤدي إلى تفاقم أمراض الجهاز التنفسي. ولمواجهة هذه المشكلة، تم اقتراح تطبيق نقي، وهو تطبيق عربي للهاتف المحمول، يستخدم تقنية إنترنت الأشياء وتقنية اللوراوان لجمع وتحليل بيانات جودة الهواء التي يتم جمعها بواسطة أجهزة استشعار مختلفة. يتيح هذا التطبيق مراقبة مستويات ثاني أكسيد الكربون في الوقت الفعلي، مما يسمح للمستخدمين بضمان بيئة داخلية صحية. يمكن للتطبيق تشغيل المروحة تلقائيًا عندما تتجاوز مستويات ثاني أكسيد الكربون حدًا معين. يقوم التطبيق أيضًا بقياس مستويات الغبار في الخارج، مما يوفر رؤية شاملة للحالة العامة لتلوث الهواء بناءً على مستوى الحالة الصحية للمستخدم. أثبت التقييم والاختبار فعالية تطبيق نقي في مراقبة جودة الهواء الداخلي والتحكم فيها للحد من مشاكل صحة الجهاز التنفسي. توضح النتائج إمكانية هذا النهج القائم على التكنولوجيا في التأثير بشكل كبير على الصحة العامة وأهميته في التخفيف من التحديات التي تفرضها المخاوف المعاصرة بشأن جودة الهواء.

Keywords: LoRaWAN ; Sensor; Indoor; outdoor; gateway; controller.

INTRODUCTION

1 Introduction

One of the most important elements for the survival of living organisms is air. Individuals require not only air, but also clean, pollution-free air to survive. Human, animal, and plant health can all be harmed by air pollution. Crowded areas may have a lower level of oxygen, necessitating certain ventilation requirements to ensure the safety of individuals. In 2019, it is estimated that ambient (outdoor) air pollution contributed to 4.2 million premature deaths globally [1], and over 237 000 deaths of children under the age of five were caused by household air pollution in 2020, which is estimated to be the cause of 3.2 million deaths annually [2].

Air pollution is one of the increasing concerns these days. Several diseases, including lung conditions, allergies to the chest, and even death, can be brought on by air pollution. In addition, higher levels of CO2 in the building are an indication of poor ventilation, which increases the risk of virus spreading and causes a variety of health issues. For example, the health of humans working in factories may be at risk, as the most important air pollutants are emitted during industrial activity. In terms of the outdoors, anybody who is exposed to excessive quantities of dust may be impacted; the longer that they breathe in the dust, the more likely it will cause illness. The department of health advises individuals to consider dust control and personal protection equipment anytime they engage in dusty activities. For a better future and a healthier living, it is essential to monitor and control the indoor and outdoor air quality [3]. Monitoring air quality technologies provide an easy and effective way to detect an above-acceptable level of chemicals such as CO2 and take the necessary steps to ensure that people breathe the cleanest air possible [4].

To overcome these challenges, a mobile application has been developed in order to minimize the effect of these problems. It receives data from a LoRaWAN indoor air quality monitoring system that can detect insufficient ventilation in real time and maintain good air quality. The system makes a fan start to operate if the CO2 level rises above a specific threshold. Additionally, the application empowers users to remotely control the fan. The system could measure the level of dust and pollution of the air outdoors; this is seen as a solution that will help cities transform into smart cities. The system could send alert notifications to the user when the air quality is poor. The user can enter his health status in order to customize the appropriate notification for him. The application enables users to view real data for indoor and outdoor air quality. Moreover, it creates periodic reports that have statistical information in the mobile application. This system

helps users who have breathing issues or are aware of the importance of air quality in monitoring air quality and take the necessary steps as soon as there is an undesirable air quality situation.

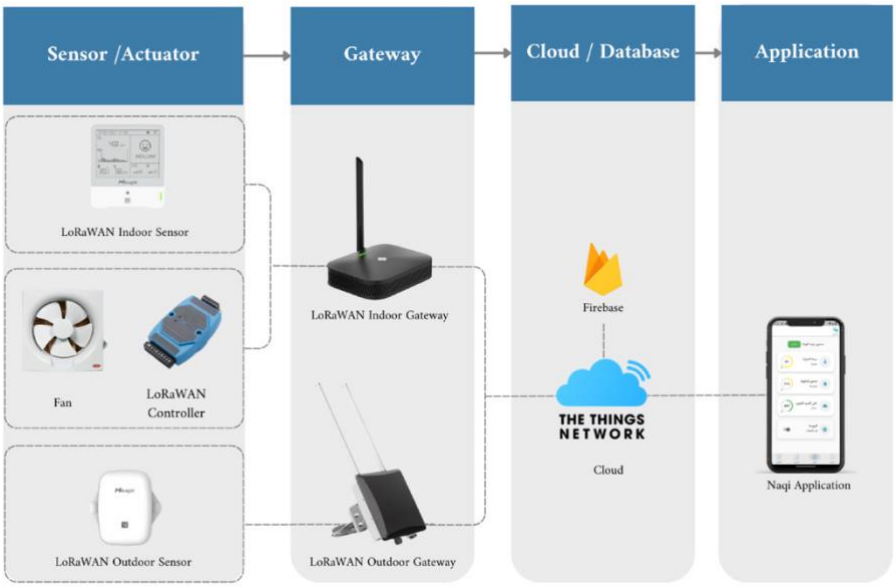


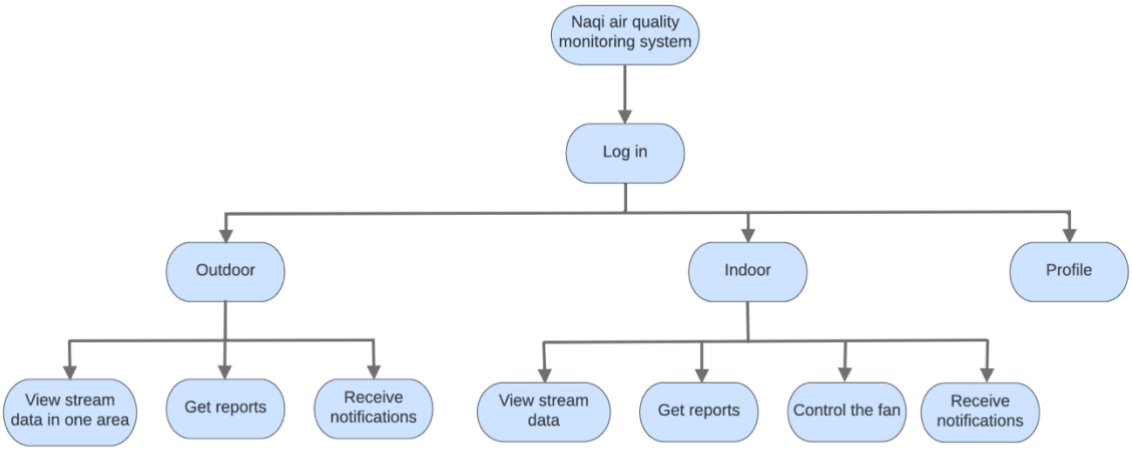
Figure 1 - 1 IoT devices

Figure (1-1) shows how the devices are connected. The sensors will monitor the air quality and send the data to LoRaWan gateways, which are connected to the cloud. Also, there is a LoRaWan controller to control the fan based on the data retrieved from the cloud.

NAQI is an Arabic Mobile Application and IoT hardware, for monitoring air quality that measures key indicators such as carbon dioxide (CO2), and dust (PM2.5). However, measuring volatile organic compound (VOCs) and nitrogen dioxide (NO2) are not included. It can be used in houses to make sure the air quality is good. Also, it helps people who have breathing difficulties. In the outdoor air quality monitoring system, it will cover one area. While indoor, it is only available in one room and the user is able to add more rooms later. The user can create a profile and customize health status, view streaming live data and receive alert notifications about air quality based on their health status. The system create daily, weekly, and monthly reports that have statistical information. An exhaust fan is operating automatically if the level of air pollution has risen and can be remotely controlled by the user. Sharing air quality air information via social media,

and creating a website is out of the scope. The application was developed for the Android platform using Flutter (Dart language). Figure (2 -1) shows the structure of NQAI application.

Figure 2 – 1 NAQI air quality monitoring system



Product Vision:

For people

Who want to know the indoor and outdoor air quality quickly and easily

NAQI is a smart IoT system that is connected to a mobile application

That keeps track of air quality measurements

Unlike other air quality monitoring systems that only shows the sensor's reading using the embedded screen

Our product has a mobile application that informs the users about the indoor/outdoor air quality anytime

The development of the NAQI application followed an Agile approach, which emphasizes iterative and incremental progress and provides flexibility in responding to changing requirements. The first step was gathering requirements, understanding user needs through meetings with stakeholders, and formulating user stories. Then created the interfaces design for the application and integrated the LoRaWAN devices with The Thing Network cloud and a web hook to connect them with the application to view indoor and outdoor real-

time data of indicators. Additionally, Google Cloud functions are used to store readings that come to The Thing Network cloud in Firebase to be used in display reports of indicators in the application, such as the temperature of the last week. To make sure the NAQI application is in line with user expectations and effectively addresses air quality issues, an iterative evaluation of the application was carried out.

NAQI application has a positive impact on public health and aims to improve the lives of individuals by monitoring and improving air quality. It has an impact both locally and globally by empowering individuals with respiratory diseases to monitor and manage their exposure to air pollution. As a result, they will live better and be less vulnerable to the negative effects of bad air quality. Main features that set NAQI apart from existing solutions on the market: users can define their health status within the application, which then provides them with personalized alert notifications based on their specific health status. This feature helps individuals manage their daily activities more efficiently and effectively. Also, the application supports the smart home by turning on and off the fan automatically inside the house to ensure proper ventilation. This feature helps individuals create a safe and healthy living environment, especially for those who spend a significant amount of time indoors.

This report covers the information needed to develop the NAQI application, which is organized as follows: Chapter 2 covers the background, providing an overview of the Internet of Things (IoT), IoT in air quality monitoring, and LoRaWAN. This chapter aims to simplify the understanding of the suggested solution. Chapter 3 presents the literature review, offering an overview of research-based and mobile application-based air quality monitoring technologies. Chapter 4 covers system design and development, encompassing methodology, system requirements, system design, data design, interface design, and implementation. Chapter 5 focuses on system evaluation, including user acceptance testing, quality attributes, and discussion. Chapter 6 comprises the conclusions and future work.

BACKGROUND

2 Background

This chapter focuses on giving a quick overview of the Internet of Things, IoT in monitoring the air quality, and LoRaWAN, which are the topics covered by the solution domain. This information should make it easier to understand the suggested solution.

2.1 Internet of Things

The Internet of Things (IoT) is a network of connected devices and technology used to connect and exchange data with other devices and systems via the internet [5]. It enables continuous communication between people, processes, and things. Low-cost computers, the cloud, big data, analytics, and mobile technologies enable the sharing and collection of data by physical objects with a minimum of human intervention. Digital systems can capture, monitor, and adjust every interaction between connected entities [5]. IoT can be applied in many aspects of life, such as agriculture, transportation, hospitality, smart homes and smart cities. The concept of smart cities includes traffic monitoring, which makes use of mobile phones as sensors to gather and exchange data from moving automobiles via applications like Google Maps. Traffic pattern analysis assists commuters to avoid traffic by being aware of possible alternatives [6].

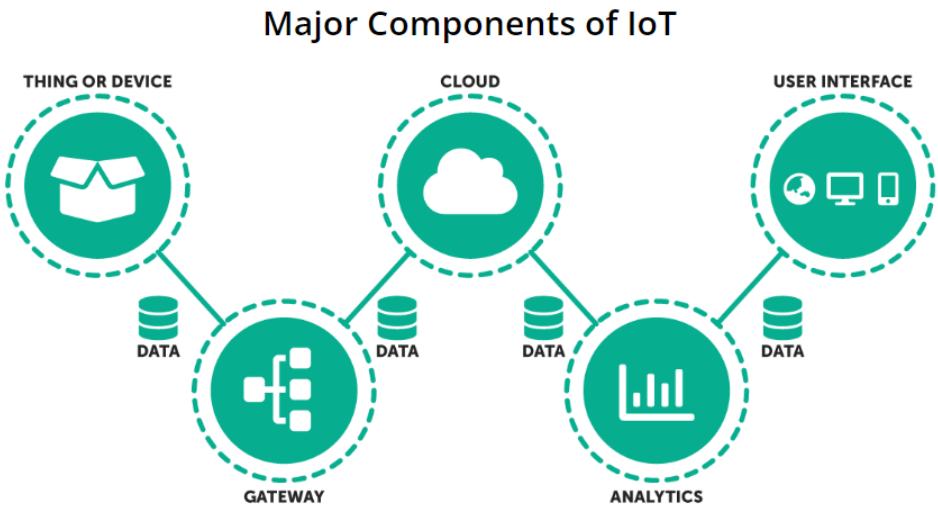


Figure 3 – 2.1 Major components of IoT *[7]*

IoT is made up of 5 primary components as shown in Figure (3 - 2.1) including: Sensors/Devices, Gateways, Cloud, Analytics and User Interface.

- Devices, which are the physical items being tracked. Smart sensors are attached to devices to gather data from the device and transmit it to the portal, also known as the gateway, at the next layer. New developments in microelectronics have made it possible to create small smart sensors for a number of uses, such as temperature sensors, pressure sensors, humidity detectors, and light intensity detectors. Actuators are a type of IoT devices. It is an element of a machine that moves the system's mechanism. The device's sensors gather information about its surroundings, and control signals are then created for the actuators in accordance with the actions that must be taken. As seen in Figure (4 – 2.1) the controller instructs the actuator to execute the action based on the sensor data. The sensors/devices can be connected to the cloud via various methods such as cellular, satellite, WiFi, Bluetooth, low-power wide-area networks (LPWAN) [8].

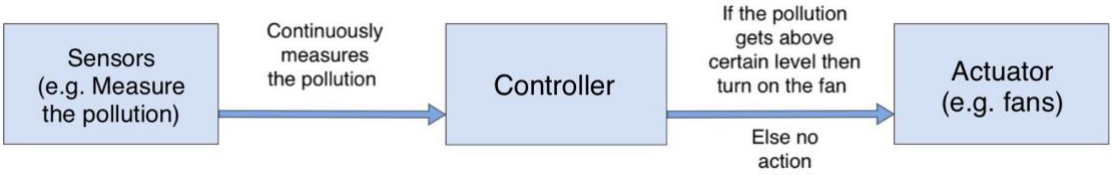


Figure 4 – 2.1 Working of IoT devices and use of Actuators *[8]*

- Gateway, which controls data flow in both directions between various networks and protocols, assures interoperability of connected devices and sensors, and offers security for transmitted data by encrypting it. It serves as a middle layer between the cloud and the devices to defend against malicious intrusion and unauthorized access [9].
- Data collected from various devices or things is stored in the cloud. IoT clouds are a network of connected servers that manage data collection, processing, management, and archiving over the Internet in real time. Industries and services can access the data remotely, allowing them to make critical decisions at any time [9].
- Analytics is the process of turning raw data from lots of smart devices and sensors into interpretable, actionable insights. IoT systems require intelligent analytics solutions in order to manage and enhance the system as a whole [9]. Checking whether the temperature is within the permissible range could be one of the tasks. It could be as complicated as identifying items in the video [10].

- User interfaces are the visible part of the IoT system that users can access. The information has a number of advantages for the end user. To accomplish this, an email, text message, or notification alert may be sent to the user. For example, a notification when the temperature rises too high, or an interface that enables the user to proactively check on the system. The user may also be able to act and influence the system, for example, by remotely changing the temperature via an app or a website. Also, the system may take various activities automatically based on pre-established rules, such as adjusting the cooling system when the temperature is high [10].

2.2 Internet of Things in monitoring the air quality

As technology develops, smart cities will be able to use devices to collect high-quality data on air pollution levels. A city must first collect data from carefully selected places before acting to address these problems. In general, air quality sensors are now more automated, less expensive, and smaller than they once were. IoT sensors are widely employed across a number of sectors, including manufacturing, transportation, aviation, and logistics. IoT sensors are an investment that smart cities should undertake because they can be affixed to existing structures and infrastructure and interact with one another without any trouble. Also, they can share information on the pollutant concentrations in a certain area, enabling city officials to make inferences and locate polluted hotspots. Technologies for the smart house are also being created. Even the typical customer can keep an eye on the air quality in their immediate vicinity to determine whether they want to stay there and assume the dangers or move elsewhere [11].

In the past, detecting pollution was a challenging task, but today, with the use of Internet of Things-based technology, it has become simple to find solutions to the rising pollution, allowing people to take safety precautions. There are a lot of IoT-based sensors on the market that are intended for environmental monitoring, including measuring gas concentrations and air quality. The combination of these sensors and IoT applications makes for an excellent atmosphere for better environments. The Internet of Things-based air monitoring systems monitor the air quality and will sound an alarm if the quality goes below a predetermined threshold, indicating the presence of harmful gasses like CO2 or dust [12]. The following are some of the most popular types of air quality sensors: Ozone (O3) sensors: they are used to measure the amount of ozone in the air. Chest pain, throat irritation, coughing, and other health problems can all be brought on by breathing ozone. PM Sensors: These sensors are able to detect tiny particles that are 2.5–10

µm in size. PM10 refers to particles with a diameter of less than 10 µm and PM2.5 refers to particles with a diameter of less than 2.5 µm. Dust is an example of them. Sulfur Dioxide (SO2) Sensor: SO2 causes soil and surface water to become more acidic. Vegetation is harmed by it. Levels of SO2 are monitored via a SO2 sensor. CO sensor: It keeps track of the level of CO. Human organs and tissues receive less oxygen when there is CO present. Nitrogen Dioxide (NO2) sensor: It monitors NO2 level. Volatile Organic Compounds Sensor: these sensors aid in the surveillance of dangerous air pollutants that may lead to cancer and/or other major health problems [13].

2.3 LoRaWAN

Recent years have seen a surge in scientific, research, and commercial interest in long-range wide area networks (LoRaWANs). LoRaWANs are essential for Internet of Things (IoT) applications especially since it is characterized by long-range connectivity, Low power consumption, GPS-free locating and integrated security by encryption and authentication mechanisms. The LoRaWAN protocol is the LPWAN communication protocol that uses LoRa modulation technology. It is cloud-based and consists of a Carrier-grade Macro Gateway located in a star topology. The LoRaWAN protocol is open-source and bi-directional communication, which means that anyone can use it to develop their own IoT solutions [14].

As mentioned LoRaWAN topology uses a star-of-stars architecture as shown in Figure (5 -2.3) which facilitates one hop communication between end devices (sensors and actuators) that operate in various industries and gateways. Also, it permits packet receipt by all network gateways within the end device's range. This improves the dependability and reliability of LoRaWAN [15].

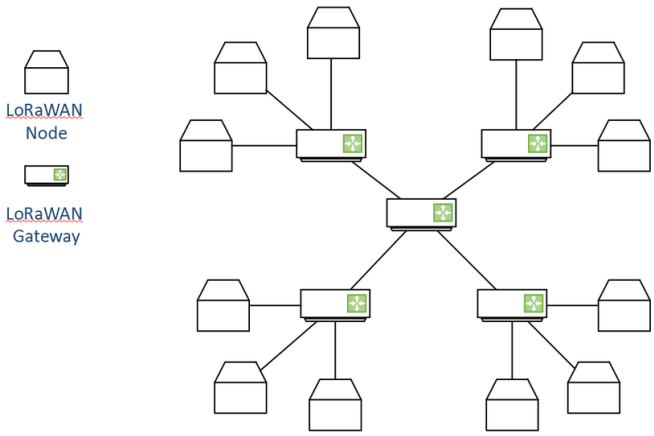


Figure 5 – 2.3 Star-of-stars LoRaWAN topology *[16]*

2.3.1 Elements of LoRaWAN protocol

LoRaWAN protocol consists of the following elements as shown in Figure (6 – 2.3.1):

1. First level continues the IoT end-devices, such as sensors or actuators, and the communication between end-devices is not supported.
2. The second level is made up of gateways, which reserves and forwards data packets between end devices and the network servers. The communication between end-devices -such as sensors- and gateway is through LoRaWAN protocol and the communication between gateway and network servers can be any communication protocol such as wifi or ethernet.
3. The third level, there are the network servers (NSs) which is responsible for decoding uplink (from sensors to gateway and from gateway to the LoRaWAN network servers) messages, as well as routing of downlink (from LoRaWAN network servers to gateway and from gateway to the sensors) messages. The Fourth level is application servers (ASs) which oversees the safe handling, management, and interpretation of the data, while encrypting and decrypting downlinks and uplinks, respectively [17].

Overall LoRaWAN is a powerful and flexible communication protocol that is well-suited for a wide range of IoT applications.

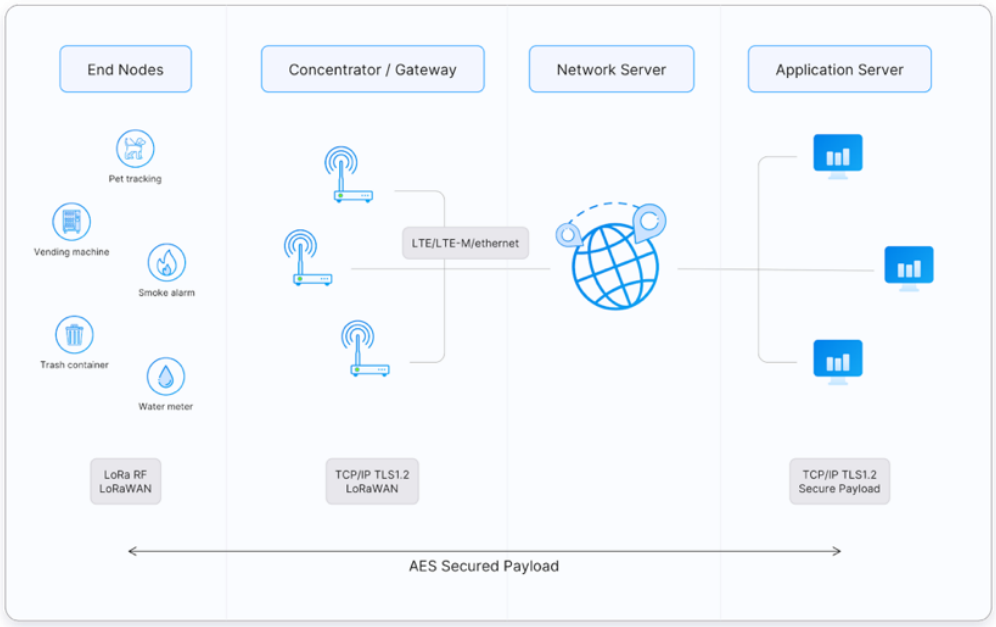


Figure 6 - 2.3.1 LoRaWAN Architecture *[18]*

LITERATURE REVIEW

3 Literature Review

This chapter provides an overview of the research-based and mobile application-based air quality monitoring technologies to aid with project needs.

RESEARCH-BASED

The proposed IOT-based air pollution monitoring system in [19] used an Arduino microcontroller to monitor the indoor air quality via a web server on the Internet. When the air quality drops below a predetermined threshold level, which occurs when there are enough harmful gasses like CO2, smoke, alcohol, benzene, NH3, LPG, and NOx present in the air, an alarm will be set off. Also, it will display the air quality in PPM on the LCD and on the website so that it can be easily monitored. The sensors used are an MQ135 sensor to monitor NH3, NOx, alcohol, benzene, smoke, CO2, and some other gasses, and an MQ6 sensor to sense liquefied petroleum gas. And the ESP8266, which is a low-cost Wi-Fi chip with a full TCP/IP stack to give the system access to Wi-Fi or the internet.

Moreover, Messan *et al.* [20] demonstrated the design, functionality, and outcomes of their Air-MIT device, a monitoring tool for air quality that securely populates and transmits data to a cloud server using the Internet of Things (IoT). They have developed a low-cost IoT-based air monitoring system that can detect carbon dioxide (CO2), carbon monoxide (CO), methane gas (CH4), and ammonium (NH4), with the provision of adding extra sensors that can also detect other dangerous gases and harmful particles. The system is intended to continuously monitor interior air quality and to sound an alert if any one of the readings goes above a set threshold. The device also has a feature that operates the exhaust fan in the kitchen or house to ventilate the area and clear the air, reducing the exposure of dangerous gasses and preventing any mishaps or fires. On the LCD and website, the system will show the air quality in parts per million, making it simple to monitor. The system uses NodeMCU as a microcontroller, which gives it the ability to openly perform editing, modification, and rebuilding of project programs and functions through different programming environments. MQ series gas sensors include MQ-7 to detect carbon monoxide, MQ-4 to detect methane, MQ-2 to detect smoke and LPG, MQ-137 to detect ammonia gas, and MQ-135 to detect overall pollutants. A MG-811 gas sensor is used to detect carbon dioxide. The Arduino IDE is used to program NodeMCU to run the system. It is a platform used for compiling and uploading programs to the microcontrollers. Also, ThingSpeak to show the graphical results, and PushBullet for notification.

In addition, the work in [21] developed an IoT-based air quality monitoring system to evaluate the local air quality. The system will use sensors to monitor the concentrations of various airborne contaminants, including particulates, O3, SO2, and CO. To read sensor data, an Arduino microcontroller is used. Four different types of sensors were employed, namely MQ-7 to monitor CO compound levels, MQ1-131 to measure ozone levels, MQ-135 to test SO2 levels, and Pm10 to assess airborne particle levels. Lastly, data is sent to the ThingSpeak cloud system using an Arduino WIFI module and the API made available by the ThingSpeak cloud service. The ThingSpeak cloud service provides a webpage where the monitoring results can be seen.

Also, in [22], an IOT-based air pollution monitoring system was developed to monitor the air quality online while using the internet. The system will sound an alarm when the air quality drops below a certain point, which is when there are enough dangerous gases like CO2, smoke, alcohol, benzene, and NH3 in the atmosphere. On the LCD and on the website, the air quality will be displayed in PPM for easy monitoring. With this IOT project, you may use a PC or a mobile device to check the pollution level from anywhere. The microcontroller Arduino Uno, it is the most adaptable hardware platform now in use since it is based on the Almerassor, which can be programmed to perform certain tasks. The MO13S Sensor to monitor the Gas. M0135 can monitor several harmful gasses, including hydrogen sulfide, ammonia, and benzene series steam. With the WI-FI Module ESP8266 A self-contained SOC integrated IP protocol stack called the ESP8266 Wi-Fi Module can grant a microcontroller access to Wi-Fi network. In order to offload Wi-Fi networking tasks from one application processor to another, the Wi-Fi module can either host an application. Every Torozoo module already has a command software installed. Our ability to connect to the Arduino board is limited. The ESP8266 module is a very affordable electronic board.

All previous researches used Arduino. However, some research used LoRaWAN for developing IoT system. For instance, the smart long-range (LoRa) sensing node suggested in this study [23] would collect and update air quality data in real time on the cloud. The developed LoRaWAN-based Internet of Things (IoT) air quality monitoring system, also known as LoRaWAN-IoT-AQMS, was implemented outdoors. Multiple sensors (NO2, SO2, CO2, CO, PM2.5, temperature, and humidity), an Arduino microcontroller, a LoRa shield, a LoRaWAN gateway, and an Internet of Things (IoT) platform called The Thing Network (TTN) make up the system. The system collects data on air quality while using the smart sensing unit and sending it to the TTN platform, which is linked to the ThingSpeak IoT server via the gateway. This action updates the data that has been gathered and shows it on a web-based dashboard as well as a Graphical User Interface (GUI) that makes use of the Virtuino mobile application. Users can therefore quickly access the displayed

information on their smartphones. In addition, Camarillo-Escobedo *et al.* demonstrated in this study [24] a remote sensing system that is intended to monitor the air quality at specific zones, with a focus on larger cities and densely populated industrial zones as an alternative to fixed air quality monitoring stations. The LoRa WAN protocol and an Unmanned Aerial Vehicle (UAV), which collects data in real-time, enable the system to be operated as a fixed or mobile station for remote sensing applications. The system can identify the geographical and temporal patterns of NO2, SO2, NH3, CO, PM10, and PM2.5. Also, the multi-sensor system collects measurements of ambient factors like temperature, humidity, pressure, and wind speed. The outcome measurement values they came up with were nearly identical with official information and global databases.

Discussion for the Research-Based

After completing the search about the air quality monitoring researches-based system as shown in table 1, we found that the developing of an air quality monitoring system can be implemented indoor or outdoor. [19], [20], [21] and [22] implement air quality monitoring indoors. While [23] and [24] implements air quality monitoring outdoors. When the air quality falls below a certain threshold, some action can be taken, for example, [19] and [22] utilize an alarm, and [20] turn on a fan. Whereas [21], [23] and [24] do not take any action. These systems represent the data in different ways: [19], [20] and [22] display data on the LCD and on the website, [21] display data on a webpage, and [23] display data on a website and mobile application. Most of them use an IoT server in order to store and analyze the data.

Table 1 – 3 comparison between 6 air quality monitoring researches and the proposed system.

Research	Mobile application	Indoor implementation	Outdoor implementation	IoT Server	Using an actuator
[19]		✓		✓	
[20]		✓		✓	Fan
[21]		✓		✓	

[22]		✓		✓	
[23]	✓		✓	✓	
[24]			✓		
NAQI	✓	✓	✓	✓	Fan

MOBILE APPLICATION-BASED

IQAir AirVisual

Figure 7 - 3 IOAir AirVisual application logo

IQAir AirVisual is designed to monitor air quality in real-time. The app provides users with information on air quality indexes for various pollutants, such as PM2.5, PM10, and ozone, as well as an overview of the weather and temperature. AirVisual works by using data from over 10,000 air quality monitoring stations around the world and provides personalized health recommendations based on the current air quality conditions. The app also allows users to track air quality trends over time and compare air quality conditions across different regions. Overall, AirVisual is an app aimed at promoting awareness and understanding of air quality and its impact on health. Also, the app has the ability to sync with the IQAir AirVisual Pro air monitor to monitor indoor air quality and receive readings, recommendations, and control over monitor settings [25]. and the app can sync with the AirVisual Outdoor sensor to monitor outdoor air quality. This sensor is perfect for keeping an eye on the local air quality around your house, place of business, or school. excellent for estimating the amount of environmental pollution caused by wildfires or agricultural burning, as well as exposure to air pollution from traffic and industry [26].

Air Matters

Figure 8 – 3 Air Matters application logo

An app called Air Matters was developed to assist individuals track the quality of the air hourly, monthly, and daily. Also, this app provides pollution alerts and keeps users informed of a wide range of other data, including temperature, moisture content, wind speed, etc. It gives real-time updates from more than 11,000 air monitoring agencies worldwide. This app is available on both Android and iOS. This app also captures indoor air quality by connecting to air purifiers (only if you have an intelligent air purifier). The app also offers advice to manage air quality and save self from health risks. The app uses color-indicating methods to make them easy and convenient to understand [27].

AirCare

Figure 9 –3 AirCare application logo

You can connect the iOS and Android versions of the AirCare app to your apple watch. This software keeps users informed of the UV index, fire alarms, pollution data, and air quality without a doubt. A few more features in this app allow you to share information and updates with friends online. You may take pictures using the camera with this feature of the app, and it also includes an air quality index at the bottom. Also, there are kid-friendly facts, graphs, maps, etc. in the app. The data can be shared on other networks, including Twitter, Instagram, and Snapchat. There are areas for community and education. They are visually appealing and enticing because they contain heat maps, graphs, and other visual content [27].

Airthings Wave Mini

Figure 10 – 3 Airthings application logo

The Airthings Wave Mini sensor monitors three aspects of indoor air quality: airborne chemicals (VOCs), humidity and temperature [28]. The Airthings Wave Mini comes with an app that connects via Bluetooth to your smartphone and provides readings when you are within Bluetooth range, so it does not provide you with up-to-date information when you are away from home. It offers you access to the web dashboard, which has in-depth graphs that let you track and examine how readings change over time [29].

uHoo

Figure 11 – 3 uHoo application logo

uHoo is an application designed to help monitor indoor air quality. The app works with the uHoo sensor, which measures various indoor air quality factors, such as temperature, humidity, air pressure, carbon dioxide, volatile organic compounds, air-purifying agents, and particulate matter. The app provides real-time data and analysis of indoor air quality, helping users to adjust their environment for optimal health and productivity. The app also sends alerts for potential air quality threats, such as high levels of pollutants, and suggests lifestyle changes and air purifying solutions to improve the air quality. Overall, uHoo is an app that aims to enhance awareness and understanding of indoor air quality to help people live a healthier life indoors [30].

Breezometer

Figure 12 – 3 Breezometer application Logo

Breezometer designed to help users monitor and understand outdoor air quality. It uses data from thousands of air quality monitoring stations to provide real-time air quality information based on the user's location. The app provides information on various pollutants, such as PM2.5, PM10, ozone, and nitrogen oxide, and graphical representations of the air quality data over time. Users can also receive notifications for air quality alerts. Overall, Breezometer is an app aimed at improving awareness and understanding of outdoor air quality and its impact on health [31].

Discussion for the Mobile Application-Based

After completing the analysis of the air quality monitoring applications currently available as shown in table 2, we found there are no air quality monitoring applications that support the Arabic language. Thus, the proposed system will support the Arabic language. Almost all of the applications agreed with most of the monitoring factors; most of the applications provide temperature, humidity, CO2, PM10 and PM2.5 detection. also have an indoor implementation, and some have an outdoor implementation in addition to the indoor implementation. The proposed system will be distinguished from other applications by the ability to operate the fan automatically as well as the ability to operate the fan remotely. All applications provide general notifications about air quality; some of the applications provide the ability to enter a certain AQI (air quality index) to personalize the notifications. Nevertheless, no one offers personalized notifications based on the user's health status. All applications contain air quality reports.

Table 2 – 3 Comparison between 6 air quality monitoring applications and the proposed system.

	IQAir AirVisual	Air Matters	AirCare	Airthings Wave Mini	uHoo	Breezometer	NAQI
Support Arabic language		✓					✓
sensor measurements	PM 2.5, PM 10, CO2, Humidity, Pressure Temperature.	PM 2.5, PM 10, O3, NO2	PM 2.5, PM 10, CO2,	Humidity, airborne chemicals (VOCs), and temperature	Temperature, humidity, pressure, CO2, TVOC, PM2.5, CO, NO2, O3, and virus index	PM 2.5, PM 10, NO2 SO2, O3, CO, Humidity, Temperature.	Temperature, humidity, motion, light, TVOC, barometric pressure, CO2, PM10,PM2.5
Indoor implementation	✓	✓	✓	✓	✓		✓
Outdoor implementation	✓					✓	✓
Use actuators							✓
General Notification	✓	✓	✓	✓	✓	✓	✓
Customized							✓

notification based on the user health status							
Air quality reports	✓	✓	✓	✓	✓	✓	✓

SYSTEM DESCRIPTION

4. System Design and Development

4.1 Methodology

This section gives a broad overview of the methodology we followed (Agile), including how we implemented the Scrum Framework and the tools we used to improve our workflow.

Our software development process followed the **Agile Approach.** Agile is a project management methodology that emphasizes small, iterative steps with the goals of rapid delivery, flexibility in the face of change, and teamwork. It places a significant value on feedback loops, which enable stakeholders to communicate consistently and team members to adapt to difficulties. [32]

We specifically implemented the **Scrum framework** [33] within the agile approach. It is a common agile methodology that gives the development process structure. It is made up of defined roles, events, and artifacts as follows:

Scrum Roles:

In our team, we had three key roles:

1. Scrum Master: This role is responsible for coaching the team and ensuring the team follows Scrum principles by providing feedback, helping with writing stories, and organizing meetings.
2. Product Owner: represented the link between the customer and the development team. Responsible for writing user stories with their acceptance criteria and prioritizing them in the product backlog.
3. Development Team: This team has the knowledge to create and develop software increments and is capable of delivering them with the required quality. They consist of developers, designers, and testers.

Scrum Events:

1. Sprint: Is an iteration over a fixed period to complete items from the product backlog.
2. Sprint Planning: To determine the sprint goal by defining the high-priority work items from the product backlog and how to accomplish them.
3. Daily Scrum: is a daily standup to discuss progress between the development team and plan for the coming day.
4. Sprint Review: At the end of each sprint, all the scrum team members meet to check product increment and adapt the product backlog.

5. Sprint Retrospective: At the end of each sprint, all the scrum team members meet to discuss the success of the previous sprint, identify any challenges or issues, and decide how to enhance their performance in future sprints.

Scrum Artifacts:

1. Product Backlog: prioritized list of all the requirements, features, and technical work that represents the work that needs to be done in the future.
2. Sprint Backlog: Is a subset of the product backlog that includes work items that the development team intends to complete during a specific sprint.
3. Product increments: Is a tangible outcome that sums up all the completed product backlog items during a sprint.

Tools:

- **Jira** helps to keep track of the development process of software projects by creating and managing a product backlog of user stories and documenting meetings.
Jira link: https://github.com/Abeer-Aljabri/2023-GP1-04
- **GitHub** is a cloud-based code hosting platform that helps the development team by allowing them to upload and synchronize the finished project's codes with every team member.
GitHub link: 2023-3rd-gp04.atlassian.net

As mentioned above, our team uses Agile, especially the Scrum framework, to manage our project and achieve substantial outcomes and continuous improvement. We were able to track productivity and accomplishment, assign tasks and prioritize them to meet customer needs, hold evaluation meetings to gather feedback to improve the work, and all of this. It happens at times that are close together as a sprint, which enabled us to connect ideas together and produce a useful and sustainable product. With the aid of programs like Jira, which offers features like product backlog, among others, we completed all of the tasks mentioned. We were able to empower everyone on the team and improve communication by adhering to Scrum's primary roles. This made it easier to pinpoint problem areas and find quick fixes.

4.2 System Requirements

4.2.1 System Users

NAQI is designed to be used by anyone who can read Arabic and whose age is 16 and above, regardless of educational background, and who wants to know the air quality before leaving the house or wants to keep healthy indoor air quality in their homes. Also, the user can be anyone who wants a system to alert and ventilate air when air quality is unsuitable. For the application to work, the user's mobile device must support the Android operating system, and there aren't many technical requirements for the user to set up the system.

4.2.2 Requirements Elicitation and Analysis

Understanding user needs and behavior is essential for developing solutions that satisfy those needs and improve user behavior. As our two methods for discovering requirements, we used questionnaires and interviews. In addition to being a quick, efficient, and flexible way to gather user needs and requirements, questionnaires' low cost makes it possible for us to quickly reach a wide range of audiences. Interviews also minimize the possibility of misunderstandings because any uncertainties can be cleared up right away by asking more questions. allows the interviewer to elicit a more in-depth response. This helped us collect more information on the abilities and needs of our users.

Questionnaire:

Here, we provide a summary of the survey's findings (see Appendix A). To learn more about the users and obtain their opinions, a survey was created using Google Forms and circulated over social media, it was answered by 43 people. The age group between 21 and 29 received the biggest percentage of responses (17 people), followed by those between 40 to 49 (4 people), 30 and 39 (2 people), 40 to 49 (4 people), and 50 to 59 (1 people). 37 of users are female, while 6 are male.

When asked if they are concerned about the levels of air pollution in their area, the majority of respondents (25 people) said "sometimes," 8 said "often," 7 said "little," and only 3 said
"never." Additionally, when asked if they care about the air quality before leaving the house, 19 stated "sometimes," 15 said "yes," and 9 said "no". Following that, in order to determine whether they require an air quality monitoring system, we discovered that the majority of them spend their time in crowded enclosed areas or places with high levels of pollution. We also asked them how satisfied they are with the current ways to measuring air quality, and only a few responded were very satisfied. We asked them if they defend

themselves against pollution to see if they were aware of the pollution effect, and we discovered that the majority of them do. Furthermore, the majority of people are concerned about the effects of pollution on the respiratory system. In the following question, 26 people have respiratory difficulties caused by poor air quality, whereas 17 do not. Furthermore, the majority of people believe that air monitoring systems are very effective at decreasing or mitigating air pollution.

In order to create a solution with real-world usefulness for people, we asked them how important it was to have an air quality monitoring app that could be adjusted based on their health state, and 19 said "very important". Likewise, when asked how important it is to have an app that offers periodic information and reports on air quality, 19 said "very important." In enclosed spaces, 33 desire an automated ventilation system. 39 would like an app that notifies them when the air quality is poor. We also added in the survey a section for suggestions and notes; several people recommended developing a mobile application that alerts users when air quality is poor. Offer recommendations for reducing pollution, a ventilation system when the quality is poor, and a controlled external device for ventilation via the application.

Interviews:

We give an overview of the interview's results (see Appendix B). Social media and weather apps about the weather outside are the main information sources for people to learn about air quality; however, these sources are not very dependable or useful for use inside or at home, suggesting that people need an app that notifies them of changes in air quality conditions. The majority of people who have chest allergies struggle to determine the air quality conditions, such as dust levels and whether it is safe to go outside, because they have no way of understanding if it is safe to go outside or not. Also, the people use traditional methods to improve air quality by opening windows when the weather is nice, but if it's not ideal, it's better to close the windows. If they're outside, most people prefer to wear a mask. From this, it is evident that there are no new or effective ways to improve air quality inside or outside the home. Some of them have never used an air quality monitoring app or other technologies, but others use weather apps to check the air quality. They would prefer if there were more features like increased sports suggestions and warnings if the weather outside is dry and needs moisturizing for the skin, etc., yet one of its merits is that it shows the proportion of dust and humidity. They all concurred that air quality monitoring systems are crucial and helpful since they will assist mitigate hazards and implement the required safety measures for those with chest ailments. They also concur that the application will be very helpful and influential because it will aid them in taking the necessary

precautions. They want it to have alerts that they set so that they can know the danger they are concerned about, receive an alert about it, and take appropriate action. They also want it to have a warning if the air quality in the area is poor, measurements of the oxygen level and dust rate, the majority of these features will be accessible through our app. When it comes to alarms, they want to warn customers about dust, moisture, lack of oxygen, increased carbon dioxide or air pollution. They also want to customize a specific level of dust to get alerts for allergy sufferers, this shows that because people are constantly busy and uninterested in these things, they must be constantly alerted and guided.

4.2.3 User Interactions

The use case diagram shown in Figure (13 – 4.2.3) shows the main actors of the NAQI application and the main functions.

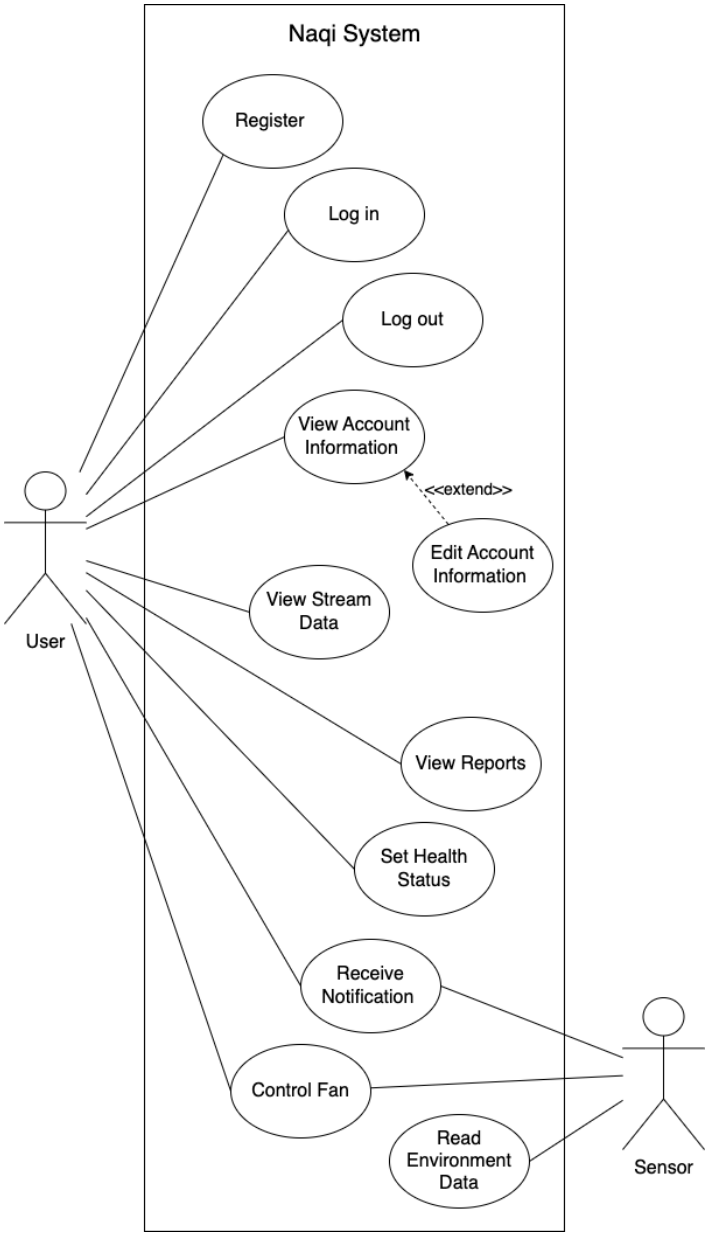


Figure 13 – 4.2.3 Use case diagram

4.2.4 Roadmap and Product Backlog

4.2.4.1 Product Roadmap

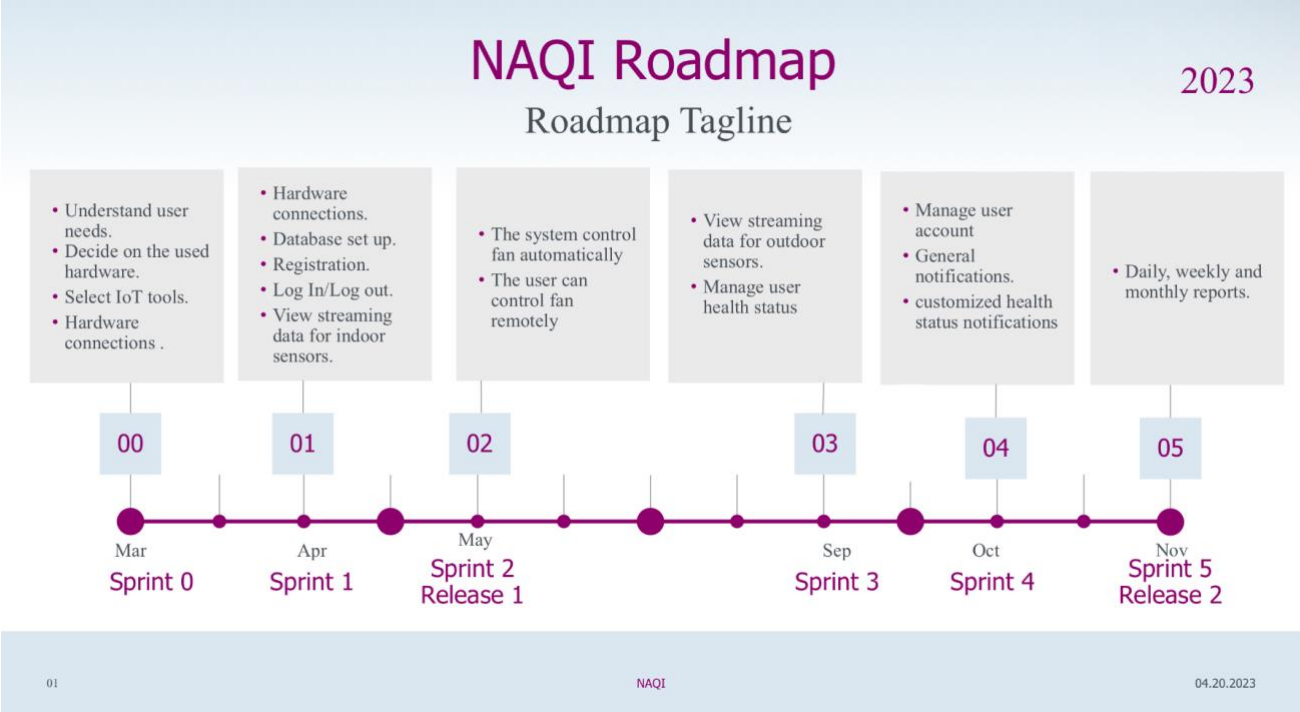


Figure 14 – 4.2.4.1 NAQI Product Roadmap

As shown in Figure (14 – 4.2.4.1) , release 1 begins with a project overview and decision-making process, followed by database setup, registration process development, completion of all indoor tasks, and finally, the fan tasks. Following that, for Release 2, we develop all outdoor-related and user-information tasks and reports

4.2.4.2 Product Backlog

Table 3 – 4.4 Product backlog table

PBI **(User Stories)**	Size	Type	Status	Acceptance Criteria
	2	Feature	Done	- As a user, if I visit the sign-up page, enter my first and last names, email address, password, and phone number, then click on sign up, I should have an

As a user, I want to be able to sign up, so that I can have an account in the application that gives me access to all the features.				account in the app with access to all functions. - As a user, if I visit the sign-up page and omit any information or enter it incorrectly, the sign-up process will fail and an error message will be displayed to let me know what went wrong.
As a user, I want to be able to log in to the application, so that I can access my own account.	2	Feature	Done	- As a user, If I already registered, then I should be able to log in using my user name and password. - As a user, if I go to the log in page and enter my username and password and click on log in, then I should be able to access my own account. - As a user, if I visit the login page and input the erroneous username or password, my attempt to log in is unsuccessful and I receive an error message.
As a user, I want to be able to log out, so that I can exit my account.	2	Feature	Done	- As a user, if I click on log out, then I can exit my account.
As a user, I want to be able to view the indoor air quality data, so that I can monitor the air quality inside my home.	5	Feature	Done	-As a user, if I choose the indoor air quality, then I should view the indoor air quality data.
As user, I want a system that starts a fan when the CO2 level rises above a specific threshold,	13	Feature	Done	-As a user, if the CO2 level rises above a specific threshold, then a fan should to start operate automatically.

so that the air quality can be improved automatically.				
As a user, I want to be able to control a fan, so that I can control it by myself.	8	Feature	Done	-As a user, If I click on/off fan, then I should control a fan.
As a user, I want a notification system that alerts me when the indoor air quality is above the threshold, so that I can stay informed that the fan has started.	5	Feature	Done	-As a user, if the indoor air quality is above the threshold, then I should informed that the fan has started by receiving a notification.
As a user, I want to be able to reset my password, so that I can retrieve my account when I forget my password.	5	Feature	Done	- As a user, if I forget my password and I click on the "Did you forget your password?" link on the login page and enter a new password, then this password should be my new password and allow me to access my account. - As a user, if I enter my new password on the new password page, I should enter it again, so I can ensure that I did not write it incorrectly.
As a user, I want to set my health status, so that I can receive personalized notifications based on my health condition.	5	Feature	Done	- As a user if I set my health status, then my health status should be displayed in my profile. -As a user, if the air quality above threshold, then I should receive personalized notifications based on my health status.

As a user, I want to set the level of my health status, so that I can customize my health status.	3	Feature	Done	- As a user, if I want to set the level of my health status, then it should be an existing health status. -As a user, if I go to my health status and click ' set level' and select the level, then my health status level should be displayed.
As a user, I want to view my account information, so that I can access and review my account information at any time.	3	Feature	Done	-As a user, if I click on my account information icon, then I should be able to be able to view my account information.
As a user, I want to be able to edit my account information, so that I can manage my account setting.	3	Feature	Done	-As a user, if I want to edit my account information, then it should be an existing account information. -As a user, if I go to my account information and click 'edit' and enter my updated information and confirm, then my updated account information should be displayed.
As a user, I want to be able to enter the indoor sensor ID, so that I can connect to the desired sensor.	3	Feature	Done	- As a user, if I visit the View Indoor Air Quality page for the first time, I should find an input area where users can enter the indoor sensor ID. - As a user, if I enter an indoor sensor ID, I expect a validation mechanism to check the ID's validity. - As a user, if the entered ID passes the validation, I expect to receive a confirmation message indicating the successful add. - As a user, after receiving a confirmation message, I expect the

				system to direct me to the View Indoor Air Quality page. - As a user, if the entered ID fails the validation, I expect to receive an error message.
As a user, I want to be able to enter the outdoor sensor ID, so that I can connect to the desired sensor.	3	Feature	Done	- As a user, if I visit the View Outdoor Air Quality page for the first time, I should find an input area where users can enter the outdoor sensor ID. - As a user, if I enter an outdoor sensor ID, I expect a validation mechanism to check the ID's validity. - As a user, if the entered ID passes the validation, I expect to receive a confirmation message indicating the successful add. - As a user, after receiving a confirmation message, I expect the system to direct me to the View Outdoor Air Quality page. - As a user, if the entered ID fails the validation, I expect to receive an error message.
As a user, I want a notification system that alerts me when the outdoor air quality is bad, so that I can take necessary precautions.	5	Feature	Done	-As a user, when I turn on alerts, then I should be able to get alerts when the outside air quality is bad.
As a user, I want a customized notification system based on my health status that alerts me when the outdoor air quality is bad, so that I can take necessary precautions.	5	Feature	Done	-As a user, if I want to receive a customized notification, then it should be an existing health status. -As a user, when I turn on customized notification, then I should be able to get

				alerts when the outside air quality is bad based on my health status.
As a user I want to be able to choose the period and sensor data, so that I can view report that displays statistical information about air quality based on chosen information.	5	Feature	Done	- As a user, if I click on a report, then I should be able to choose period and sensor data. -As a user, if I choose period and sensor data, then I should be able to see statistical information based on chosen information.
As a user, I want to be able to view the outdoor air quality, so that I can monitor the air quality outside my home.	5	Feature	Done	- As a user, if I choose the outdoor air quality, then I should view the outdoor air quality data.
As a user, I want to be able to edit sensor ID, so that I can manage my sensors.	3	Feature	Done	- As a user, if I navigate to the Devices page, I should see both indoor and outdoor sensor IDs. - As a user, if I click the field to edit a sensor's ID, I should be presented with an input field where I can modify the ID. - As a user, if I submit the edited ID, I expect the system to validate the new ID. - As a user, if the edited ID passes the validation, I expect to receive a confirmation message indicating the successful update. - As a user, if the edited ID fails the validation, I expect to receive an error message. - As a user, after successfully editing a sensor's ID, I should see the updated ID displayed in the sensor ID field.

As a user, I want the system to notify me if the sensor is disconnected so that I can be aware that the readings are not up to date.	3	Feature	Done	- As a user, I want the notification to clearly state that the sensor is disconnected and that the readings may not be up to date. - As a user, I should have the option to acknowledge or dismiss the notification once I have read it. - As a user, if a sensor is disconnected, I expect to see a note from the system indicating the date and time of the last reading.
Non-functional user story (performance) As a user, I want to receive a response to any input in less than or equals 3 seconds, so that I will not have to wait long for the app to response.	NA	Feature	Done	-As a user I want the time between clicking a button and to the response being displayed does not exceed 3 seconds. [34]
Non-functional user story (usability) As a user, I want the system to be usable, so that I can use the system easily.	NA	Feature	Done	- As a user, if I want to use the system, it should be easy to use, and I shouldn't need any instructions to use it.
Non-functional user story (security) As a user, I want my login information to the system like passwords to be hashed, so that they can be secure.	NA	Feature	Done	- As a user, if I enter my password in the application, then the system should be able to hash my password before storing it in the database.

5 System Design

5.1 Architecture Diagram

The architecture of an IoT application refers to the way in which the different parts of an IoT system are organized to perform a specific task or set of tasks, and the architecture type is Client- Server. As shown in Figure (15 – 5.1), an IoT application typically comprises four layers: the sensing layer, the communication layer, storage layer and the application layer.

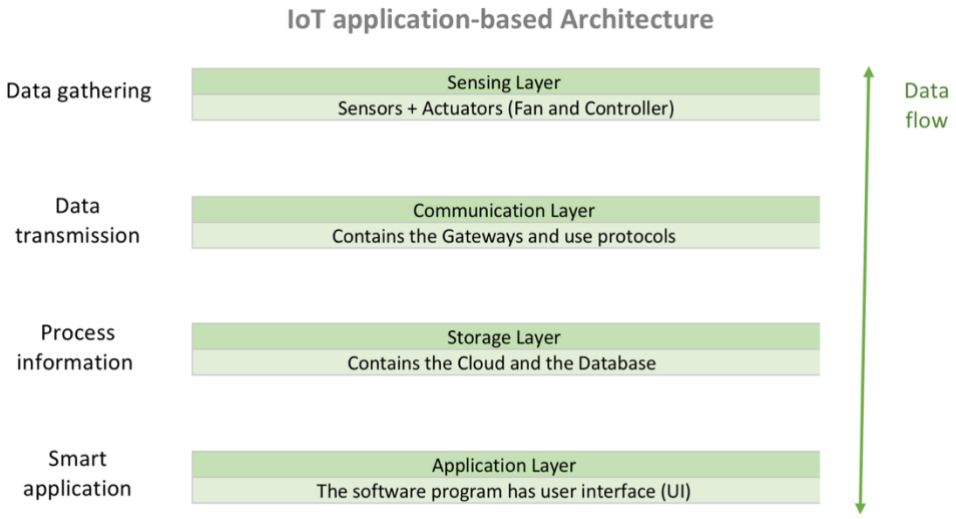


Figure 15 – 5.1 IoT-based application architecture

- **The sensing layer**, also known as the perception layer, is the first architectural component of IoT [35]. It collects data using sensors and devices that are connected to the internet [35]. This layer is responsible for gathering information from the physical world and providing it to other layers for processing and analysis. Data from the physical world must be collected by this layer and sent to higher layers for processing and analysis. Because it provides the data needed for insights that guide decision-making, the sensing layer is a crucial part of IoT. The sensing layer uses many different types of sensors and devices, such as temperature sensors, motion sensors, light sensors, gas sensors, and many more. Homes, companies, hospitals, and other places all employ these sensors in a variety of applications. The actuator, a component of the sensing layer, is in charge of acting in response to the information gathered by the layer. It is made up of elements that can communicate with the outside world, including motors, valves,

and relays. Actuators are used to control a variety of systems, including security, lighting, and air conditioning. In the sensor layer, controllers are essential because they are in charge of processing the information obtained from the sensing layer and directing commands to the actuators. These instructions are based on various algorithms and pieces of logic that lead to the desired result [36].

- **The communication layer** in IoT is responsible for ensuring that devices can communicate with each other and transmit data. This layer consists of the protocols and gateways that allow data to be transferred between systems and networks using both wired and wireless connections. By allowing devices to connect to various networks and protocols, gateways play a crucial part in IoT connectivity. The protocols provide for established methods of communication between devices and guarantee efficient and safe data transmission. The LoRaWAN protocol will be used for this project [37].

- **The storage layer** in IoT is responsible for storing the large amounts of data generated by devices in a secure and scalable manner. The cloud is a popular storage solution for IoT data, as it provides on-demand availability, scalability, and reliability. Cloud providers such as Microsoft Azure and Amazon Web Services offer a range of storage solutions for IoT data. In addition to the cloud, databases are also an important component of the storage layer in IoT. Databases enable efficient data access and retrieval and provide features like data integrity and transaction support. IoT data can be stored in both relational and non-relational databases, depending on the nature of the data [38].

- **Applications** are computer programs that operate on hardware to offer particular functionality or services. Applications may be created for a variety of use cases, including environmental monitoring, home automation, healthcare monitoring, industrial automation, and home automation. These applications are built on top of the IoT architecture layers, making use of the data and services provided by the lower layers [39].

5.2 Class Diagram /DFD

Figure (16 – 5.2) shows the class diagram of Naqi system which is consists of sensor, air quality, user, health status, fan, controller, and report classes.

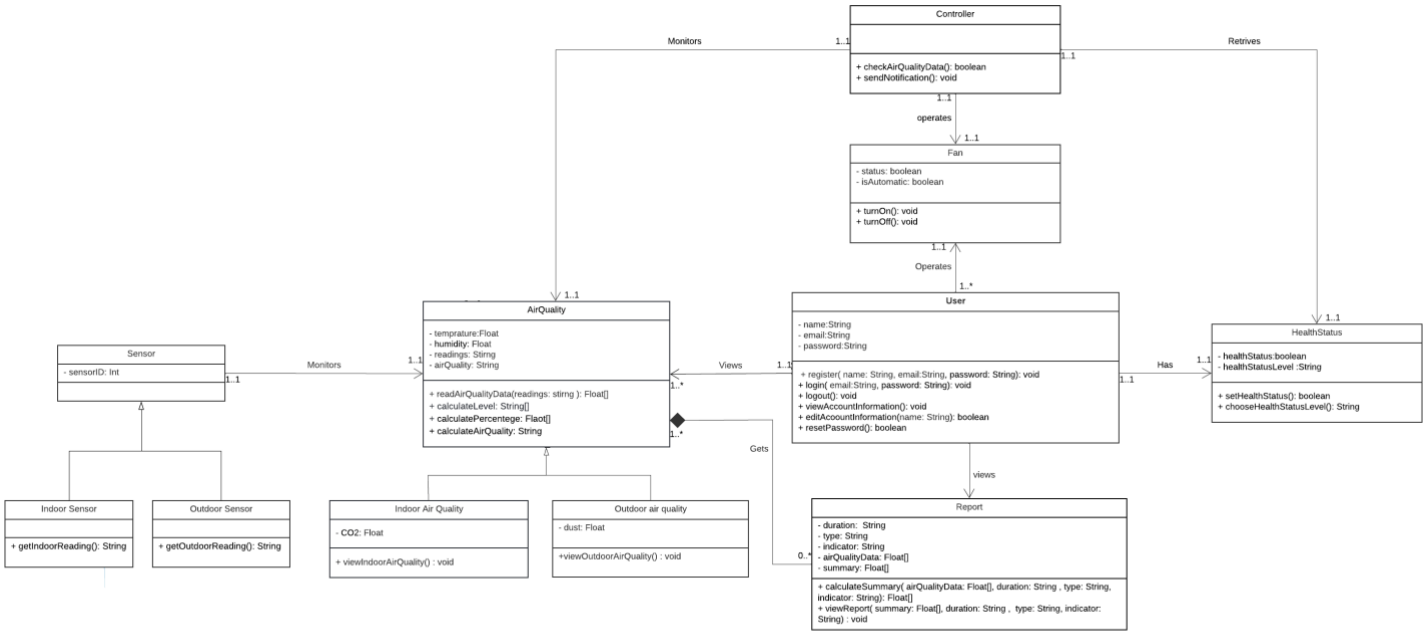


Figure 16 - 5.2 Class diagram

5.3 Component Level Design

- **View indoor air quality**

1. **BEGIN**
2. **DECLARE** readings [], levels [], percentages [], Air quality
3. **DECLARE** i , j
4. **GET** indoor air quality data (CO2, Temperature, Humidity) collected from sensor
5. **SET** readings [] = CO2, Temperature, Humidity
6. **WHILE** readings list didn’t finish DO
7. **READ** reading

8. **CALCULATE** reading level
9. **CALCULATE** reading percentage
10. **SET** levels[i] = reading level
11. **SET** percentages [i] = reading percentage
12. **SET** i = i +1
13. **END** WHILE
14. **CALCULATE** Air quality
15. **DISPLAY** Air quality
16. **WHILE** readings list didn't finish DO
17. **DISPLAY** readings [j], levels [j], percentages [j]
18. **SET** j = j +1
19. **END** WHILE
20. **END**

- **Control the fan automatically**

1. **BEGIN**
2. **GET** CO2, fan status, switch status, automatic
3. **IF** CO2 > 1000 **AND** fan status == 0 **THEN**
4. **TURN ON** the fan
5. **ENDIF**
6. **ELSE IF** CO2 < = 1000 **AND** automatic == 1 **AND**
7. **TURN OFF** the fan
8. **ENDIF**

9. **END**

- **Send outdoor air quality notification to the user based on the health status**

1. **BEGIN**
2. **GET** outdoor air quality data collected from sensor (dust)
3. **GET** user health status
4. **GET** user health status level
5. **GET** threshold values
6. **IF** the dust value exceeds the threshold values **THEN**
7. **SEND** notification to the user
8. **END IF**
9. **END**

- **Add outdoor sensor ID**

1. **BEGIN**
2. **Read** sensor ID from user
3. **If** sensor ID is not empty **and** sensor ID exists in the database **Then**
4. **Retrieve** sensor type from the database for the given sensor ID
5. **If** sensor type is 'outdoor' **Then**
6. **Add** the sensor ID to the user's outdoor sensor ID
7. **ELSE**
8. The user re-enter the sensor ID
9. **END IF**
10. **ELSE**
11. The user re-enter the sensor ID
12. **END IF**
13. **END**

- **View reports about air quality based on chosen information (period, sensor type, measure type)**

1. **DECLARE** summary []
2. **GET** period, sensor type, measure type
3. **RETRIVE** sensor data from firebase based on the period, sensor type, measure type
4. **CALCULATE** averages
5. **SET** summary [] = average**s**
6. **VISUALIZE** summary using bar char**t**

5.4 Data Design

5.4.1 Data Models

Figure (17 – 5.4.1) shows the ER diagram of Naqi system which is consists of user, air quality,sensor, fan.

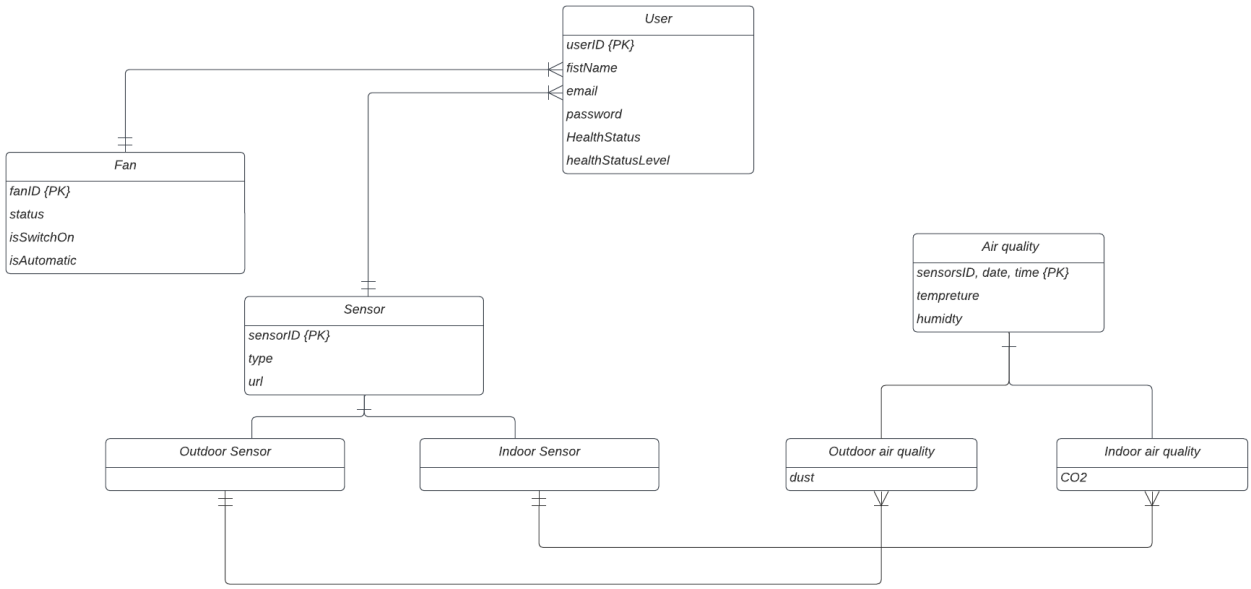


Figure 17 - 5.4.1 ER diagram

- The non-relational data model

Figure (18 – 5.4.1) shows non-relational data model of Naqi system, we employ fanID and sensorID referencing in user documents since user, fan, and sensor are freestanding entities that will be accessed separately at some point. Air quality, on the other hand, are totally dependent on the sensor; hence, they must

be maintained together by embedding it in the sensor document. With this approach we can quickly search for all the air quality values connected to a certain sensor.

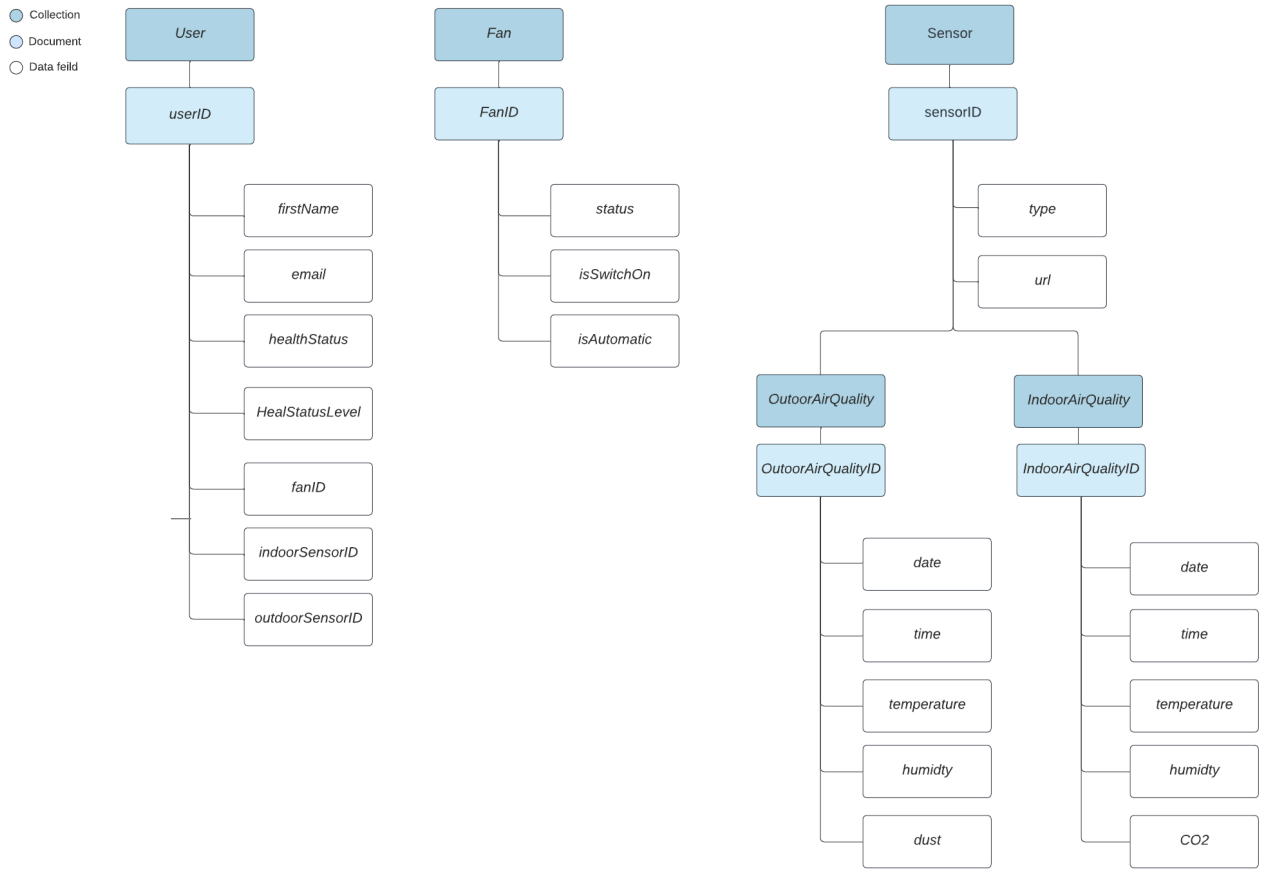


Figure 18 - 5.4.1 Non-relational data model

5.4.1 Data Collection and Preparation

NAQI system relies on sensors to carry out its primary functions. The sensors are a specialized devices, the first sensor is an indoor sensor (Milesight AM307 ambient sensor), which is designed to detect various environmental factors. This sensor is capable of detecting and keeping an eye on parameters including temperature, humidity, light, noise, CO2, and TVOC [40]. The sensor has three levels of measurements: good, polluted, and bad [41]. We just keep track of the temperature, humidity, and CO2. The second sensor is an

outdoor sensor (Milesight EM300-TH sensor), detects outdoor environmental factors such as temperature and humidity.

The sensors can communicate with a LoRaWAN gateway without any difficulties, and the gateway can then send the measured data to cloud servers via the internet. Due to this connection, environmental factors may be remotely monitored and data-driven choices can be made using both historical and current data [40]. The sensor data are all numerical values. Webhook is integrated with The Things network cloud to obtain the data for viewing stream data, and it is stored using Firebase in order to maintain historical records.

Due to the limited budget, we use the DSM501A sensor, which is a low-cost particle density sensor used to detect dust. This sensor is compatible with the Arduino IDE, providing a cost-effective solution for our project. It communicates using WiFi, which allows for remote monitoring and data transmission. The data is stored using Firebase.

5.5 Interface Design

User Navigation hierarchy:

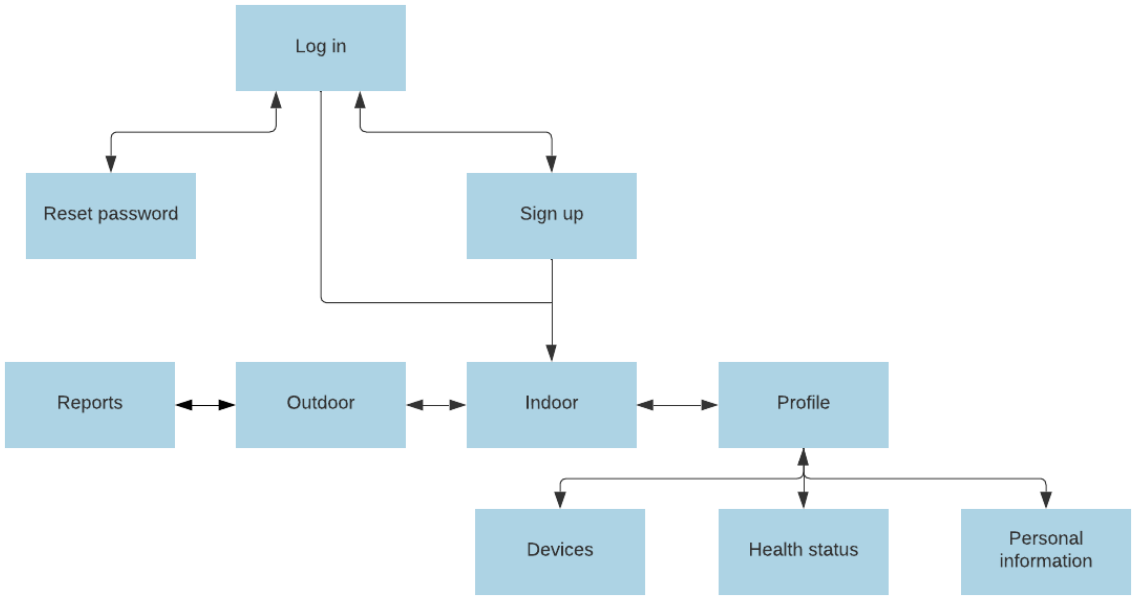


Figure 19 - 5.5 User navigation hierarchy

UX guidelines:

In order to provide an appealing product for our project, the following UX rules were adhered to.

- **Providing feedback:**

One of Norman's design tenets states that the user must receive feedback following each action they take to know whether it was successful [42]. As we applied by informing our users when they sign up successfully and confirming they have logged out.

- **Simplicity:**

We've created an app with straightforward, user-friendly designs that lower mistakes, and support requests. Additionally, users can quickly and effectively find what they need.

- **Preventing errors :**

One of the ten usability principles put forth by Jakob Nielsen [43] is the prevention of errors.

To get that, we added additional requirements to the sign-up and log-in sites and provided real-time alerts indicating whether or not the user had met each password requirement as they typed it. Additionally, we looked for conditions that were prone to errors, alerted users, and required confirmation from them before they committed to an action using a confirmation message.

- **Consistency:**

We used the same color scheme and user-friendly language throughout all pages. Additionally, people anticipate that applications will function similarly to other programs they frequently use, therefore we made sure that every part of our application behaved as the majority of users would anticipate [44].

- **Familiarity:**

As analogies, we also used symbols that are well-known, such as the icon indoor, outdoor, the reports page, and the profile, back arrows icon, and other well-known icons to the user.

User Interface:

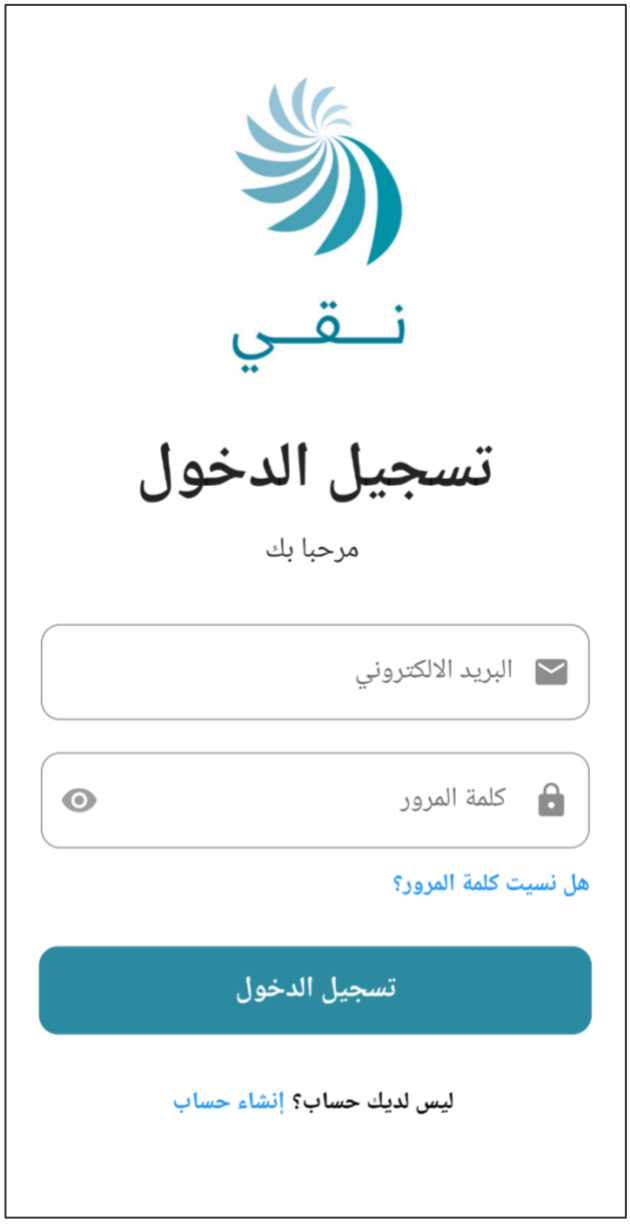


Figure 20 - 5.5 Log in page

Figure 21 - 5.5 Sign up page

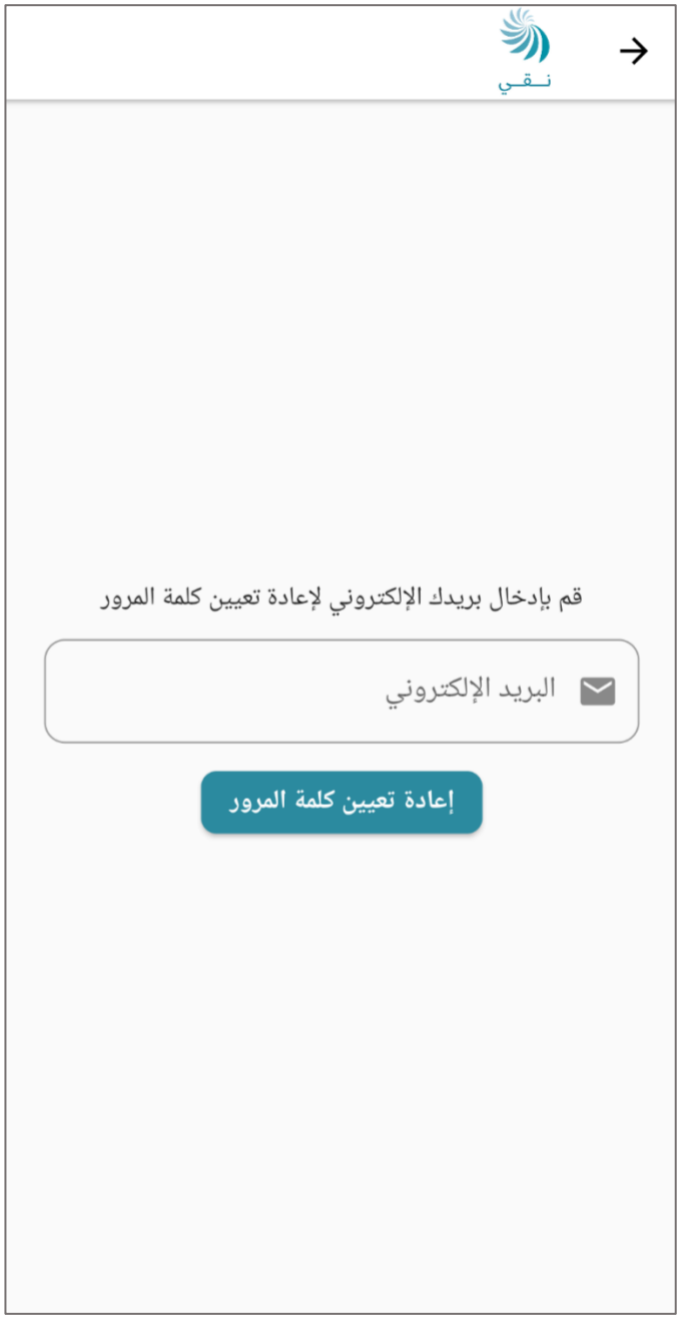


Figure 22 - 5.5 Reset password page

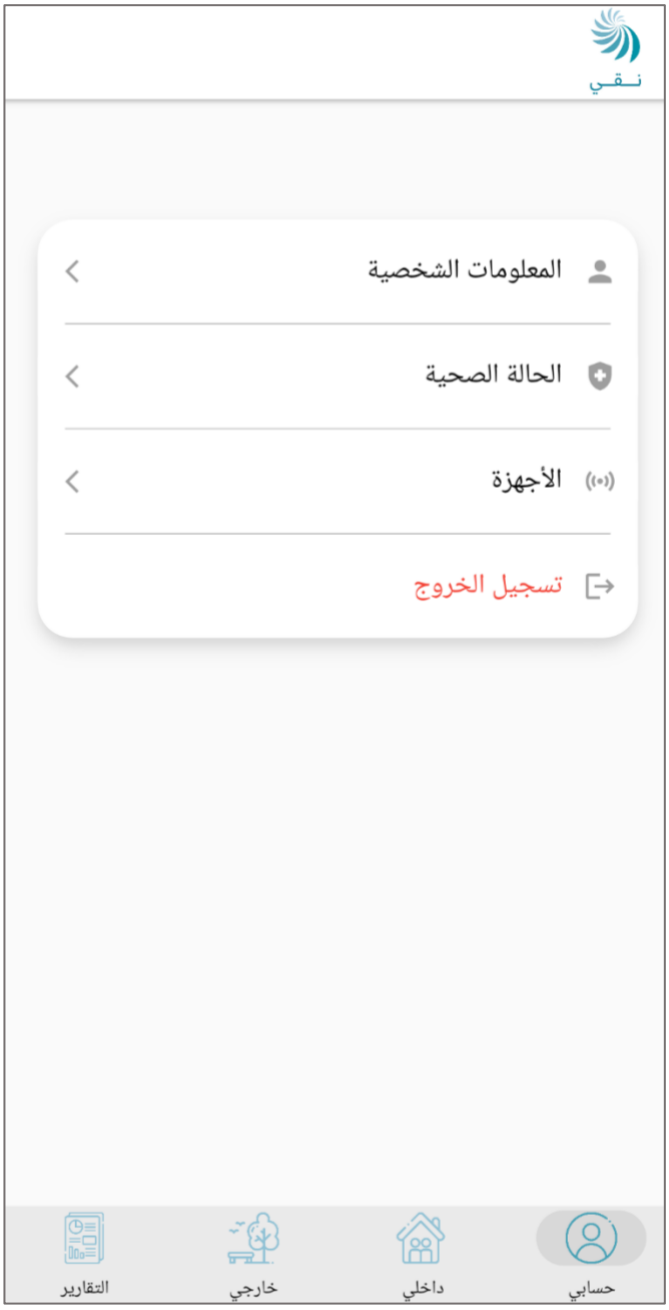


Figure 23 - 5.5 Profile page

Figure 24 - 5.5 Personal information page

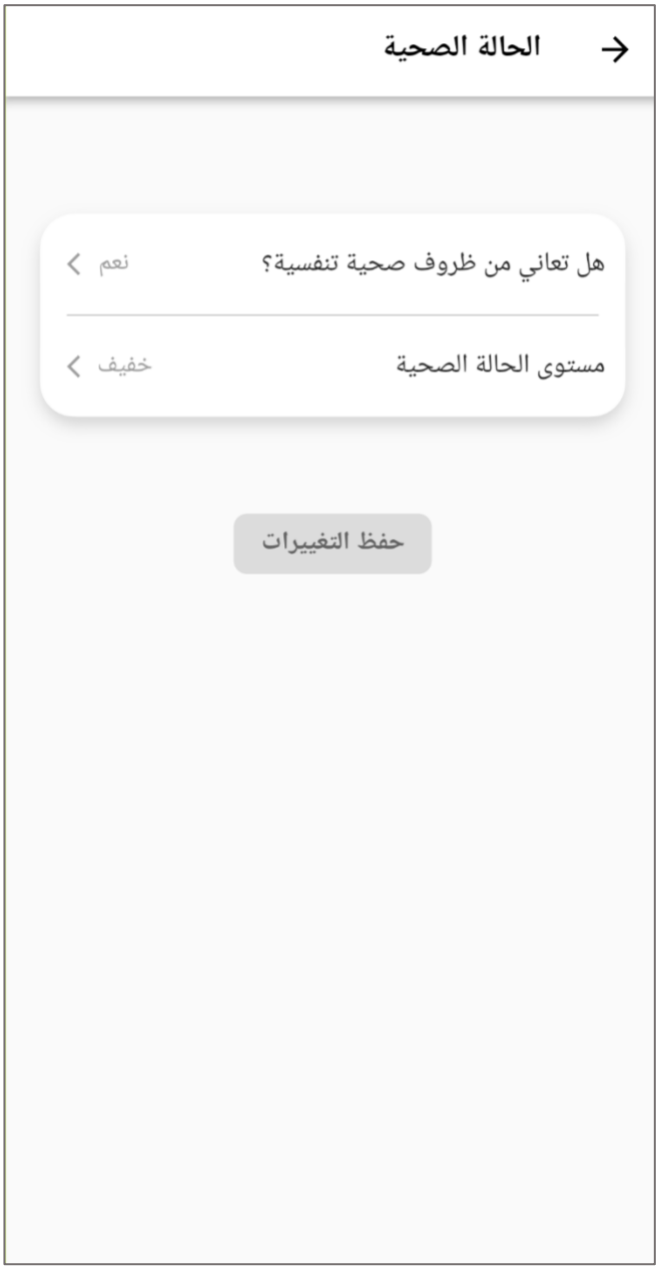


Figure 25 - 5.5 Health status page

Figure 26 - 5.5 Devices page

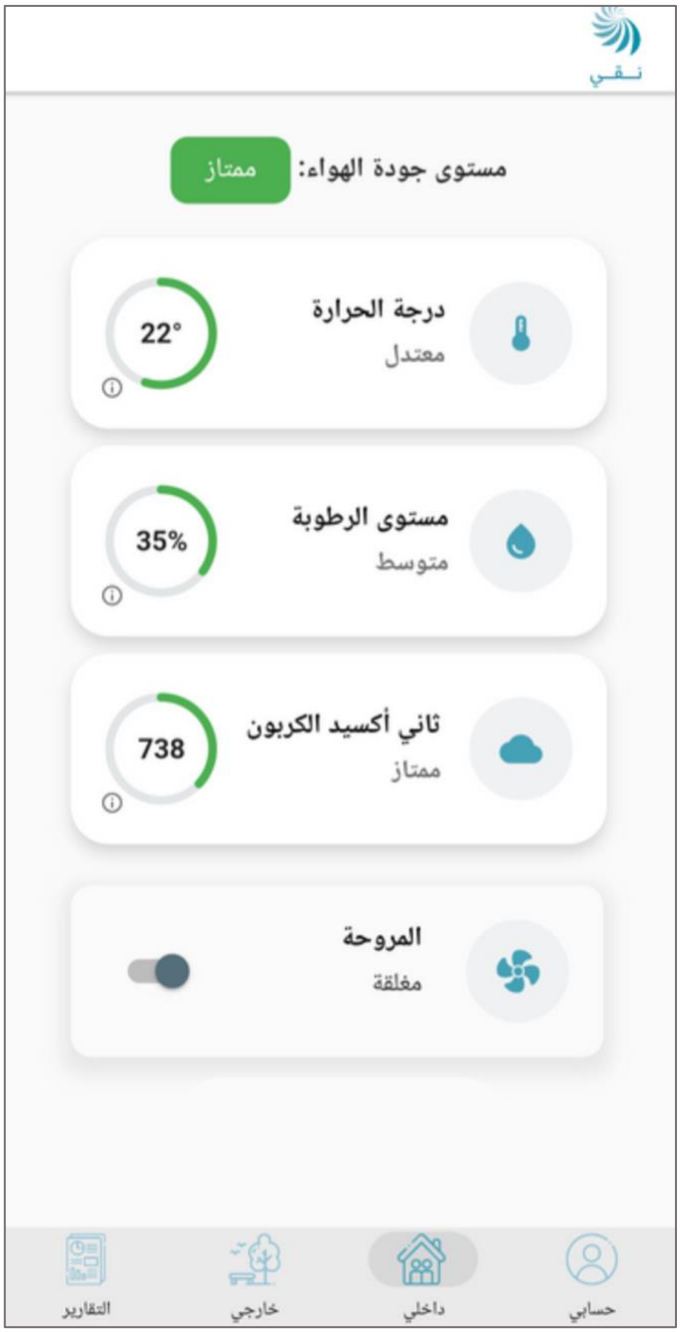


Figure 27 - 5.5 Indoor page

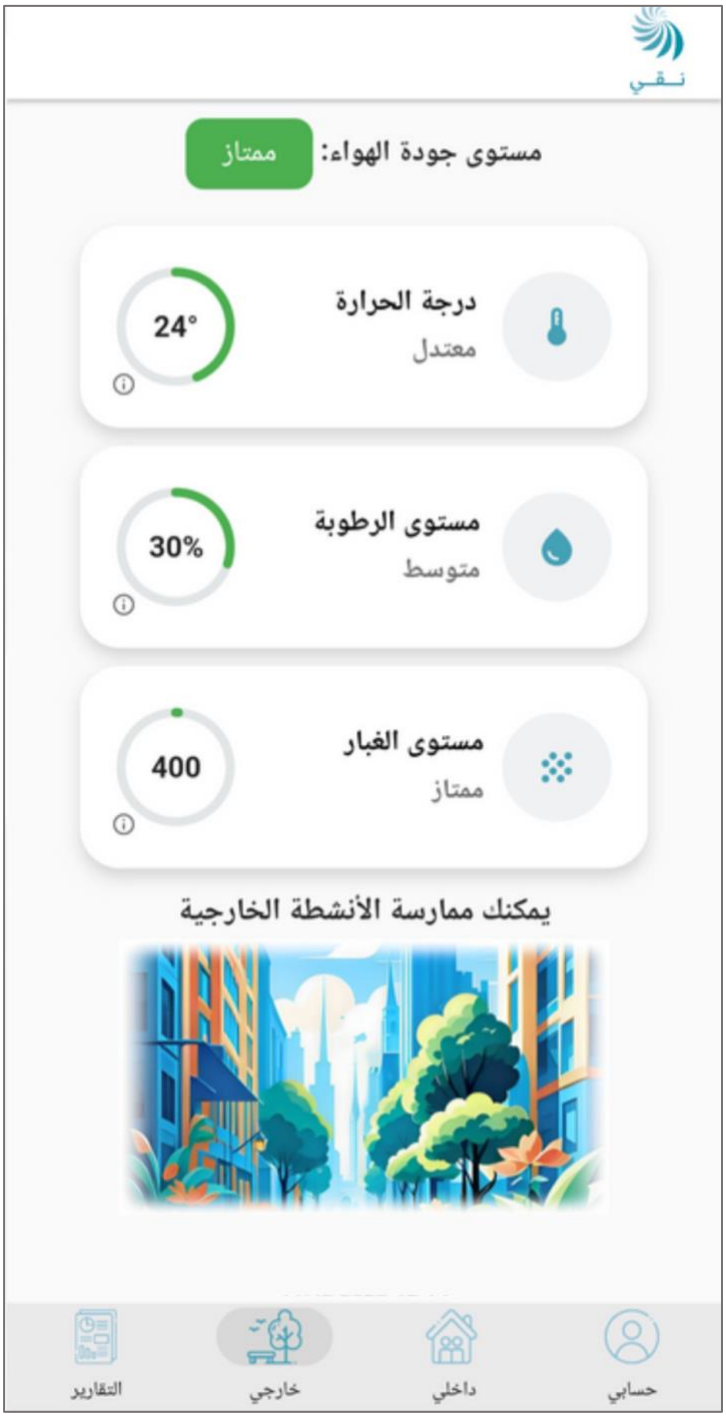


Figure 28 - 5.5 Outdoor page

Figure 29 - 5.5 Reports page

6 System Implementation

This chapter goes through system implementation and integration in great depth. It details the hardware and software tools used to construct the application, as well as the system implementation components, and code segments.

6.1 Software and Hardware Tools

6.1.1 Software Tools

Table 4 – 6.1.1 Software Tools

System Name	Software Version	Description
Flutter	3.10.4	It is Google's free and open-source mobile UI framework that uses a single codebase and the Dart programming language.
Dart	3.10.2	Dart is a programming language designed by Google to be simple, easy to learn, and efficient for developing client-side applications with high-performance.
Visual Studio	17.6	It is an IDE developed by Microsoft that provides developers with tools and services to build applications across multiple platforms.
Android Studio emulator	2022.2.1	It enables developers to test their Android applications in a virtual environment that simulates the look and behavior of a real Android device, allowing them to test, debug, and refine applications in real-time.
Firebase FireStore	-	It is a scalable, flexible serverless NoSQL database that enables real-time data synchronization and provides real-time data synchronization, reporting, cloud communications, and authentication.
The Things Network Cloud	-	It is a cloud-based platform for building and running LoRaWAN-based Internet of Things (IoT) networks. It offers capabilities like data storage, security, network connectivity, and more.

GitHub	-	It is a web-based platform for version control, code management, and collaboration for software development projects.
Webhook.site	-	Webhook.site is a platform for developers that allows them to test, process, and modify HTTP requests and emails. It generates a unique URL and email address for inspecting and automating incoming HTTP requests.
Google Cloud Functions	-	It is a serverless execution environment for developing and connecting cloud services. It enables users to create single-purpose functions that are attached to events emitted by their cloud infrastructure. The function is triggered when an event occurs, eliminating the need for infrastructure provision or server management.
Milesight Toolbox	1.5.10	It is a user-friendly device configuration app for Milesight sensors, offering functions like on/off status, serial number, model, device EUI, firmware and hardware version, battery power, and LoRaWAN frequency configuration.
Arduino IDE	2.2.1	It is a software environment designed for programming and developing applications with Arduino microcontrollers. It simplifies the process of writing, compiling, and uploading code to Arduino boards.

6.1.2 Hardware Tools

Table 5 - 6.1.2 Hardware Tools

Name	Description	Usage	Figure
WisGate Edge Lite 2 Indoor LoRaWAN Gateway	Indoor LoRaWAN gateway that supports up to 8 channels and is suitable for small to medium-sized industrial applications.	Used to connect LoRaWAN sensors and devices to the cloud in indoor environment.	 Figure 30 – 6.1.2 Indoor LoRaWAN Gateway *[45]*

Milesight AM307 Sensor	LoRaWan indoor ambience monitoring sensor.	Used to measures indoor temperature, humidity, and CO2.	 Figure 31 - 6.1.2 Milesight AM307 sensor *[40]*
Dragino LoRaWan I/O Controller	LoRaWAN I/O controller that provides an easy and low-cost installation by using LoRa wireless technology.	Used to connects sensors and devices in various applications to a LoRaWAN network, and enables remote control.	 Figure 32 - 6.1.2 Dragino Controller *[46]*
Fan	Exhaust fan	Used to provide ventilation and remove unwanted air from an indoor space.	 Figure 33 - 6.1.2 Exhaust fan *[47]*
RAK7289CV2 Outdoor LoRaWAN Gateway	Outdoor LoRaWAN gateway, featuring improved sensitivity and performance. Available in 8 or 16-channel versions, it supports Ethernet, Wi-Fi, and Cellular connectivity.	Used to connect LoRaWAN sensors and devices to the cloud in outdoor environment.	 Figure 34 - 6.1.2 Outdoor LoRaWAN Gateway *[48]*

Milesight EM300-TH Sensor	LoRaWan outdoor monitoring sensor.	Used to measures outdoor temperature, and humidity.	 Figure 35 - 6.1.2 Milesight EM300-TH Sensor *[49]*
ESP8266 NodeMCU	It is a compact, low-cost, Wi-Fi enabled microcontroller board.	Used for connecting projects to local WiFi networks, and to send sensor data to the cloud.	 Figure 36 - 6.1.2 ESP8266 NodeMCU *[50]*
DSM501A Dust Sensor	The DSM501A dust sensor module is a low-cost particle density sensor used in air cleaners and purifiers.	Used to measure the dust concentration level.	 Figure 37 - 6.1.2 DSM501A Sensor *[51]*

6.2 System Implementation

This section outlines the processes involved in implementing NAQI system, as well as the primary components and code fragments. It is divided into two parts: software implementation and hardware implementation.

6.2.1 Software Implementation

The "Naqi" application was created in the "Visual Studio Code" environment utilizing the Dart programming language and the Flutter Ul framework. Because the majority of Flutter applications utilize Dart, we choose it. In addition, it resembles the Java programming language in several ways, which makes it simpler for us to learn. Additionally, it has a lot of resources that support the implementation of the necessary features. We used a real Samsung mobile device together with an Android virtual device created by Android Studio to run the program and verify that all of its features operate as intended and correctly. We used the Firebase platform for the "Naqi" application because of the capabilities and facilitation it offers, which are ideally suited for agile development. Additionally, we used Firebase Cloud to store all of them. A user's registration and login also serve to aid in identifying and authenticating. Google Cloud Functions are utilized to implement serverless functions that run in response to events or triggers. This serverless computing service allows us to deploy individual functions without the need to manage the underlying infrastructure.

Table 6 - 6.2.1 View indoor air quality data description and code segment

Function	View indoor air quality data
Description	Allowing user to monitor the indoor air quality data.
Functions' Flow	Two functions are used to view indoor air quality data: The getReading function sends an HTTP request to the cloud-integrated webhook URL. It gets the most recent reading and returns the response body. Then it is converted into a JSON object, which will be sent to the readData function. readData extracts the CO2, temperature, humidity, and received time and returns these values as a list.
Code	

```
Future<String> getIndoorReading() async {
   indoorURL = FirebaseService.indoorSensorURL;

   final response = await http.get(Uri.parse(indoorURL));
   if (response.statusCode == 200) {
     return response.body.toString();
   } else {
     print("Connection Error");
```

```
      throw Exception("faild");
    }
  }
dynamic readData(dynamic data) {
    if (data.containsKey('uplink_message')) {
      var paylaod = (data as Map)['uplink_message'];
      if (paylaod.containsKey('decoded_payload')) {
        var paylaod1 = (paylaod as Map)['decoded_payload'];
        if (paylaod1.containsKey('co2')) {
          co2 = ((data as Map)['uplink_message']['decoded_payload']['co2'])
              .round();
          temp = (data as Map)['uplink_message']['decoded_payload']
                  ['temperature']
              .round();
          hum = (data as Map)['uplink_message']['decoded_payload']['humidity']
              .round();
        }
      }
    }
    time = DateTime.parse((data as Map)['received_at']);
    List<dynamic> readings = [temp, hum, co2, time];
    return readings;
  }
```

Table 7 - 6.2.1 Send notification for indoor air quality description and code segment

Function	Send notification for indoor air quality
Description	This function informs the user that the fan has turned on by receiving a notification when the CO2 level exceeds the threshold and the fan is turned on.
Functions' Flow	The checkIndoorAirQualityData function is called whenever receiving a CO2 value. It retrieves the fan status and isAutomatic from the database, then compares the CO2 value to the threshold; if the CO2 value exceeds the threshold and the fan is closed, it will turn on the fan, update isAutomatic and switch status on firebase , and call the sendNotification function. The sendNotification function specifies the title and body of the message.

Code

```
void checkIndoorAirQualityData(var co2) {
    // Get fan status and switch status from databse
    Future<String> fanStatus = firebase.getStatus();
    Future<String> isAutomatic = firebase.isAutomatic();
    fanStatus.then((value) {
      status = value;

      isAutomatic.then((value) {
        atomatic = value;
        // check CO2 and fan status
        if ((co2 > 1000) & (status == '0')) {
          fan.turnOn();
          fan.updateisAutomatic('1');
          fan.updateSwitch('1');
          // FirebaseService.switchStatus = '1';
          sendNotification(
              "مستوى ثاني أكسيد الكربون مرتفع! سيتم تشغيل المروحة");
        } // check CO2 and fan status and switch status
        else if ((co2 <= 1000) & (atomatic == '1')) {
          fan.turnOff();
          fan.updateisAutomatic('0');
          fan.updateSwitch('0');
          sendNotification("مستوى ثاني أكسيد الكربون جيد! سيتم ايقاف المروحة");
        }
      });
    });
  }


 void sendNotification(String text) {
    AwesomeNotifications().createNotification(
      content: NotificationContent(
          id: 10, channelKey: "default_channel", title: "تنبيه!", body: text),
    );
  }
```

Table 8 - 6.2.1 Control the fan description and code segment

Function	Control the fan
Description	This feature makes the ability to turn the fan on and off.

Functions' Flow	To control the fan, a downlink must be sent to the cloud with a specific payload to regulate the controller's relay output. According to the controller specification [46], we found that '030111' payload turns on the fan, while '030000' turns it off. These payloads are Base64-encoded and sent to the sendDownlink function. The fan status in the firebase is then modified.

Code

```
void turnOn() {
    sendDownlink('AwER');

    try {
      FirebaseFirestore.instance
          .collection('Fan')
          .where('fanID', isEqualTo: FirebaseService.fanID)
          .get()
          .then((QuerySnapshot querySnapshot) {
        if (querySnapshot.size > 0) {
          String documentID = querySnapshot.docs.first.id;

          // Update the document with the new value for 'Status'
          FirebaseFirestore.instance.collection('Fan').doc(documentID).update({
            "Status": '1',
          }).then((value) {
            print('Status updated successfully!');
          }).catchError((error) {
            print('Error updating Status: $error');
          });
        } else {
          print('No document found with fanID: $FirebaseService.fanID');
        }
      }).catchError((error) {
        print('Error querying documents: $error');
      });
    } catch (e) {
      print('Error: $e');
    }
  }
  }


  void turnOff() {
```

```
  sendDownlink('AwAA');
  try {
    FirebaseFirestore.instance
        .collection('Fan')
        .where('fanID', isEqualTo: FirebaseService.fanID)
        .get()
        .then((QuerySnapshot querySnapshot) {
      if (querySnapshot.size > 0) {
        String documentID = querySnapshot.docs.first.id;

        // Update the document with the new value for 'Status'
        FirebaseFirestore.instance.collection('Fan').doc(documentID).update({
          "Status": '0',
        }).then((value) {
          print('Status updated successfully!');
        }).catchError((error) {
          print('Error updating Status: $error');
        });
      } else {
        print('No document found with fanID: $FirebaseService.fanID');
      }
    }).catchError((error) {
      print('Error querying documents: $error');
    });
  } catch (e) {
    print('Error: $e');
  }
}
```

Table 9 - 6.2.1 Send notification for outdoor air quality description and code segment

Function	Send notification for outdoor air quality
Description	This function notifies the user when the dust level exceeds the threshold set for the user's health status.
Functions' Flow	First, the function retrieves healthStatus and healthStatusLevel from firebase, then it checks if a notification has already been sent and checks the value of dust. If the dust value is greater than 30,000, it sends a notification indicating polluted air, setting notificationSent to true and setting flag (general). If the healthStatus is true, it checks the healthStatusLevel and sends notifications based on the dust level for the specific health status. If the dust level returns to normal, it resets the notificationSent flag. The function also handles edge cases, where the dust level is still high even after

	a custom notification has been sent or if the dust level is within an acceptable range after a general notification has been sent.

Code

```
void checkOutdoorAirQuality(var dust) {
 // Get user health status information
 bool healthStaus = FirebaseService.healthStatus;
 String healthStatusLevel = FirebaseService.healthStatusLevel;

 // check to see if a notification has already been sent
 if (!notificationSent) {
   if (dust > 30000) {
     sendNotification('جودة الهواء الخارجي: ملوث');
     notificationSent = true;
     general = true;
   }
   // check dust value based on user health status
   else {
     if (healthStaus == true) {
       if ((healthStatusLevel == 'شديد') && (dust >= 15000)) {
         sendNotification('جودة الهواء الخارجي: ملوث بالنسبة لحالتك الصحية');
         notificationSent = true;
         custom = true;
         general = false;
       }
       if ((healthStatusLevel == 'متوسط') && (dust >= 20000)) {
         sendNotification('جودة الهواء الخارجي: ملوث بالنسبة لحالتك الصحية');
         notificationSent = true;
         custom = true;
         general = false;
       }
       if ((healthStatusLevel == 'خفيف') && (dust >= 25000)) {
         sendNotification('جودة الهواء الخارجي: ملوث بالنسبة لحالتك الصحية');
         notificationSent = true;
         custom = true;
         general = false;
       }
     }
   }
 }
 // If a notification has already been sent
 // check to see if the dust value returns to its normal value
 if (notificationSent) {
   if (healthStaus == true) {
     if ((healthStatusLevel == 'شديد') && (dust < 15000)) {
       notificationSent = false;
```

```
      }
      if ((healthStatusLevel == 'متوسط') && (dust < 20000)) {
        notificationSent = false;
      }
      if ((healthStatusLevel == 'خفيف') && (dust < 25000)) {
        notificationSent = false;
      }
      if ((dust > 30000) && (custom == true)) {
        sendNotification('جودة الهواء الخارجي: ملوث');
        custom = false;
        general = true;
      }
      if ((dust <= 30000) && (general == true)) {
        notificationSent = false;
      }
    } else {
      if (dust <= 30000) {
        notificationSent = false;
      }
    }
  } }
```

6.2.2 Hardware Implementation

To implement the hardware element of Naqi system, each hardware device configure as follows:

- Gateway: The gateway configured through Wi-Fi connectivity.
- Sensor: The sensor is set up with NFC technology and the Milesight Toolbox app. The reading intervals have been reduced from 10 minutes (the default) to 1 minute.
- Controller: The period between delivering uplinks is modified from the default 10 minutes to 10 seconds. To adjust the controller's uplink interval, a downlink must be sent to the cloud with a specified payload indicating the desired interval. First, we define the sendDownlink() function. In the url, the webhook is defined, and the cloud name and device ID are given. The header is also specified, which includes the API key. And then the body is defined, and we pass it the payload. The request is made using http.post(). Then, to adjust the interval, the setUpController() function calls sendDownlink() and passes a specified payload. According to the controller specification [52], the payload for changing the interval should be '01000001'; however, because the cloud converts the payload to hex, we modify it to Base64 and send 'AQAAAQ==' instead of '01000001'. and

when the cloud got it, it changed to '01000001'. The gateway will send a downlink to the controller with that payload after it has been received by the cloud so that the controller setting can be changed.

```
 Future<void> sendDownlink(String payload) async {
    final String url =
                  'https://eu1.cloud.thethings.network/api/v3/as/applications/naqi-indoor-
controller/webhooks/controller-webhook/devices/controller/down/replace';

    // Define header content
    Map<String, String> headers = {
      'Authorization':
                                                                    'Bearer
NNSXS.S5AHBXSHVE6LDQBI5SI7WTDZKZTVE7WLYAGY6BY.GGB427AY2WJVBMZHZVLXZ3GGSDAJDRAHTGVDZBYQZPJ
DTPHB457A',
      'Content-Type': 'application/json',
      'User-Agent': 'my-integration/my-integration-version',
    };

    //Define body content
    Map<String, dynamic> body = {
      'downlinks': [
        {
          'frm_payload': payload,
          'f_port': 2,
          'priority': 'NORMAL',
        }
      ],
    };
    //Send http request
    String jsonBody = json.encode(body);
    http.Response response = await http.post(
      Uri.parse(url),
      headers: headers,
      body: jsonBody,
    );
    print(response.body);
  }

   void setUpController() {
    sendDownlink('AQAAAQ==');
  }
```

Figure 38 - 6.2.2 Controller configuration code segment

Once configured, the gateway, sensor, and controller are then connected to the things network cloud, allowing them to communicate with one another as well as see sensor data and send commands to the controller to operate the fan.

- Arduino: The arduino is configured in three steps: connect the microcontroller to Wi-Fi, collect data from the sensor, and send data to a real-time database.

  Connecting a microcontroller to Wi-Fi is critical for communication with the internet and cloud services. To connect, we include the ESP8266WiFi Wi-Fi library, set Wi-Fi network credentials (SSID and password), initialize the Wi-Fi connection using the provided credentials, and check the connection status using functions such as WiFi.begin(). This ensures that the microcontroller connects to the local Wi-Fi network. Figure (39 – 6.2.2) shows the implementation steps.

```
#include <ESP8266WiFi.h>
#define WIFI_SSID "stc_wifi_4720"
#define WIFI_PASSWORD "LiNhTG2DdaM"
void setup() {
  Serial.begin(115200);
 // connect to wifi.
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
  Serial.print("connecting to Wi-Fi ");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    delay(500);
  }
  Serial.print("connected with IP: ");
  Serial.println(WiFi.localIP());
```

Figure 39 - 6.2.2 WiFi connection

To collect data from the sensor, the sensor pin is defined to establish a connection with the microcontroller. Following this, the sensor is set up using the `pinMode()` function, configuring the microcontroller for effective communication with the sensor. Subsequently, sensor data is collected by reading and recording its output. To ensure efficient storage and processing of this data, it is then sent to a real-time database. This

involves incorporating the necessary library for database interaction, providing essential credentials and configuration information for connection establishment, and utilizing the library's functions to send the collected sensor data to the firebase. Figure (40 – 6.2.2) shows the implementation steps.

```
#include <Firebase_ESP_Client.h>
#define API_KEY "AIzaSyAGL08HmIE1Rdw8AXu9R3fo2WP2qJkQebE"
#define FIREBASE_PROJECT_ID "fairbase-naqi-app"
#define USER_EMAIL "test@gmail.com"
#define USER_PASSWORD "Test123@"
// Define Firebase Data object, Firebase authentication, and configuration
FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;
// Define sensor pin and its vaiables
#define DUST_SENSOR_DIGITAL_PIN_PM25 D5
unsigned long previousMillis = 0;
unsigned long previousPing = 0;
unsigned long lpoPM25 = 0;
unsigned long starttime;
unsigned long duration;
unsigned long sampletime_ms = 1000;
float ratio = 0;
float concentrationPM25 = 0;
void setup() {
  Serial.begin(115200);

 // sensor setup
  pinMode(DUST_SENSOR_DIGITAL_PIN_PM25,INPUT);
  starttime = millis();//get the current time;
// Firebase set up
  // Assign the API key
  config.api_key = API_KEY;
```

```
  // Assign the user sign-in credentials
  auth.user.email = USER_EMAIL;
  auth.user.password = USER_PASSWORD;;
  // Begin Firebase with configuration and authentication
  Firebase.begin(&config, &auth);
 }
void loop() {
  duration = pulseIn(DUST_SENSOR_DIGITAL_PIN_PM25, LOW);
  lpoPM25 = lpoPM25 + duration;
  if ((millis()-starttime) > sampletime_ms) {
   ratio = lpoPM25 / ( sampletime_ms * 10.0);
   concentrationPM25 = 1.1 * pow( ratio, 3 )-3.8 * pow( ratio, 2) + 520 * ratio + 0.62;
   lpoPM25 = 0;
  starttime = millis();
   delay(10000);
  // Define the path to the Firestore document
   String documentPath = "Sensor/eui-24e124136d416846/OutdoorAirQuality/";
// Create a FirebaseJson object for storing data
  FirebaseJson content;
   content.set("fields/dust/doubleValue", concentrationPM25);
   content.set("fields/date/stringValue", date);
    content.set("fields/time/stringValue", time);
  if (Firebase.Firestore.createDocument(&fbdo, FIREBASE_PROJECT_ID, "" ,
documentPath.c_str(), content.raw()))
         Serial.printf("ok\n%s\n\n", fbdo.payload().c_str());
        else
            Serial.println(fbdo.errorReason());
  // Delay before the next reading
  delay(60000);  }
}
```

Figure 40 – 6.2.2 Collect data and send it to firebase

6.3 Implementation Challenges and Difficulties

Learning dart as a new language has been quite difficult. We had trouble at first simply understanding the language, and we had no clue how or where to start. However, we were able to get around this problem by using YouTube. Additionally, in GitHub it was challenging for us to synchronize our work and comprehend the push and pull mechanisms of our project. Thankfully, we were able to get through these obstacles by watching YouTube tutorials several times. Even utilizing Firebase, which we had never used before, did not appear as difficult after a few attempts with the aid of YouTube videos. However, networking the devices was by far the most difficult part. In order to learn how to link the devices electrically and programmatically, we had to rely on materials from the cloud, user manuals, and YouTube. It took us a long time to properly understand and implement the necessary connections. But with perseverance and patience, we were able to complete the project.

The GitHub link: https://github.com/Abeer-Aljabri/2023-GP1-04

7 System Evaluation

7.1 User Acceptance Testing

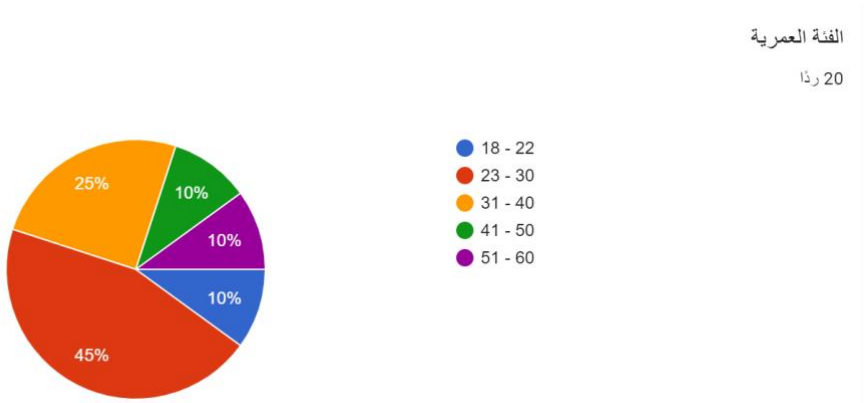
We will describe how our system was tested in this section. In order to determine whether the system satisfies business objectives and is usable by end users, we first conducted user acceptance testing. We recruited 20 participants adult end users, aged between 18 and 60, of both genders and suffer from respiratory diseases or diseases related to air quality. regardless of educational level, be able to read Arabic, possess fundamental technical know-how, and be able to utilize an Android mobile phone application.

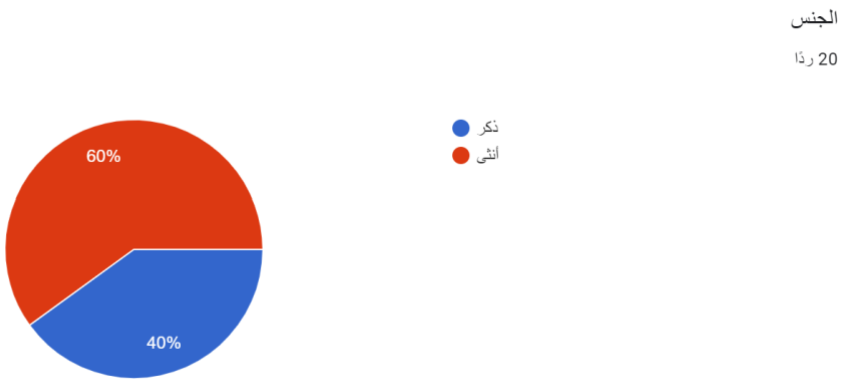
After the testing team had used the application, we evaluated its usability in terms of the user interface, technical aspects, key strengths, and key weaknesses by gathering data about it using a questionnaire that includes fifteen questions about the participants and their experience with the application. The respondent must select one of four answers for each question. (1) Strongly agree, (2) Agree, (3) Disagree, and (4) Strongly disagree.

Finally, we will offer the demographics, questionnaire results, and a discussion that interprets the results for more details on the participants and the questionnaire's conclusions.

7.1.1 Demographics of Participants

The participants in the application testing were asked about their age, gender, education level, and experience with mobile applications, The following Figure (41- 7.2.1) displays their answers.





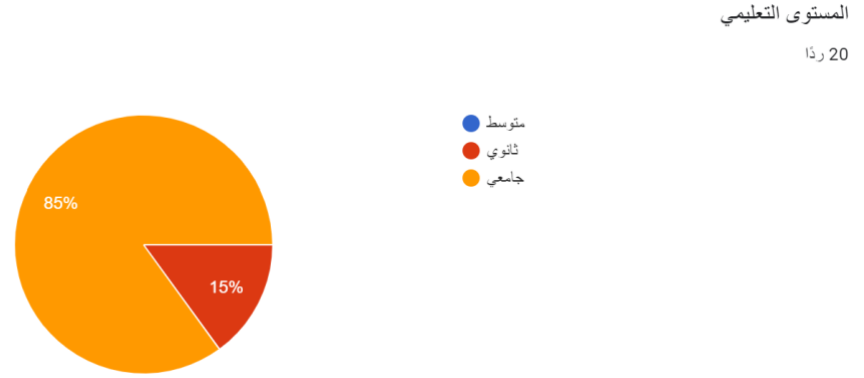
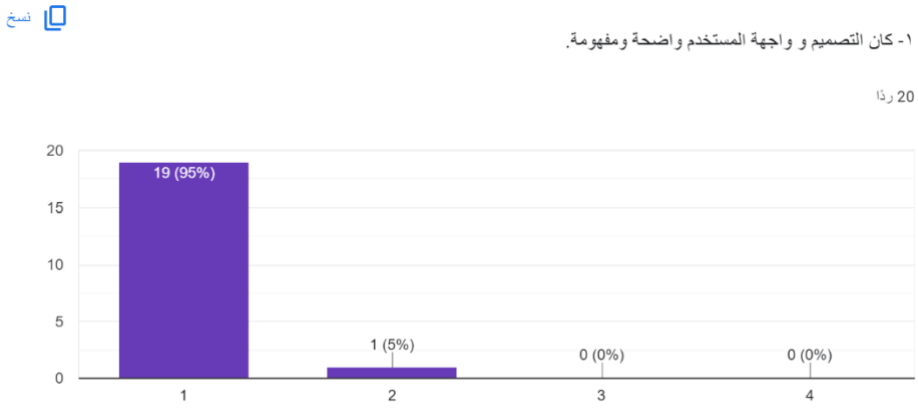


Figure 41 - 7.2.1 Demographics of Participants

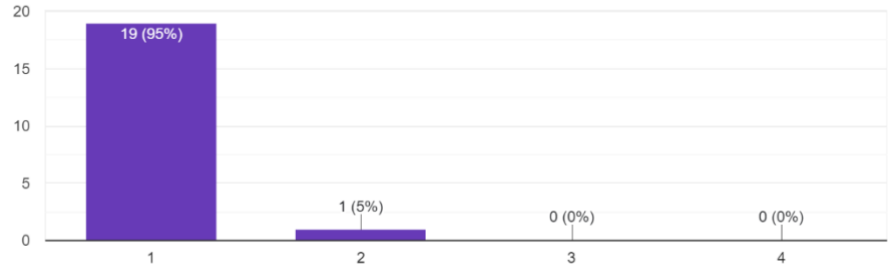
7.1.2 Questionnaire/Interview Results



نسخ

٢- كانت الألوان مريحة وواضحة.

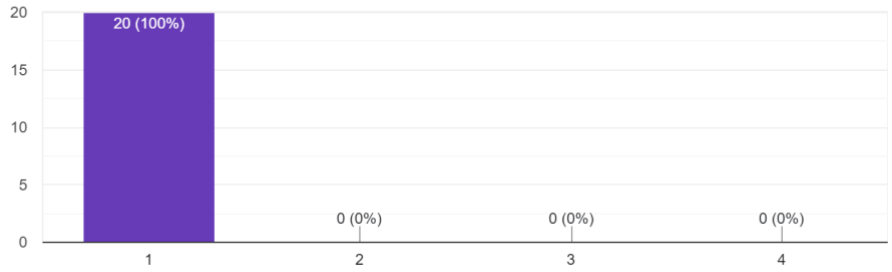
20 ردًا



نسخ

٣- وجدت أن الأيقونات المستخدمة سهلة الفهم.

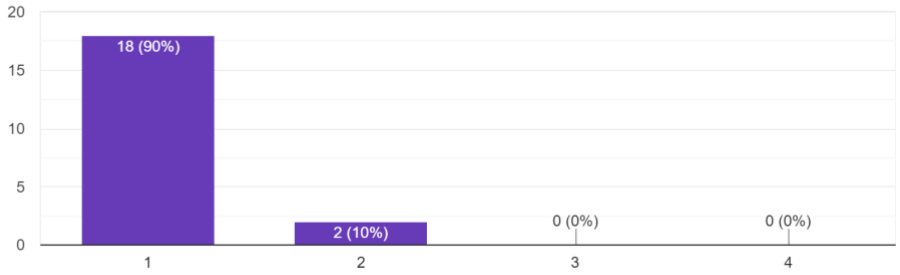
20 ردًا



نسخ

٤- في الخانات الإجبارية أو التي تتطلب مدخلات محددة، كانت واضحة لي واستطعت أن أفهمها.

20 ردًا

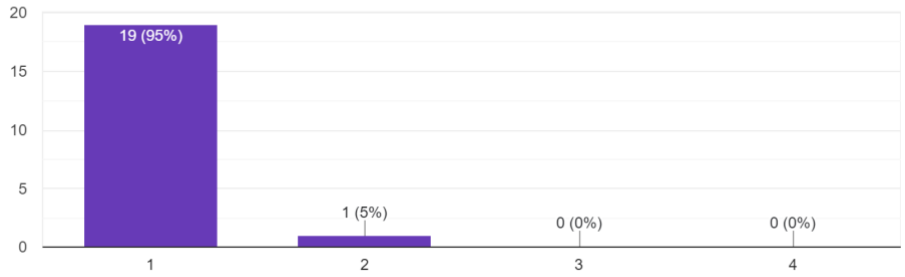


نسخ

نسخ الرسم البياني

٥- كان من السهل فهم بيانات قراءة المستشعر.

20 ردًا

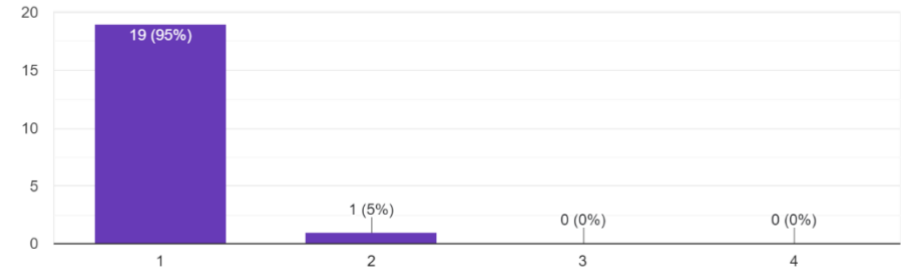


نسخ

٦- عرض التطبيق بدقة قراءات بيانات جودة الهواء.

20 ردًا

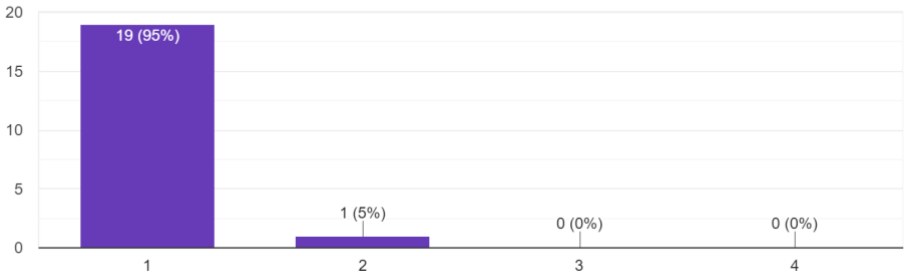
نسخ الرسم البياني



نسخ

٧- حقق التطبيق توقعاتي في مراقبة جودة الهواء الداخلي والخارجي.

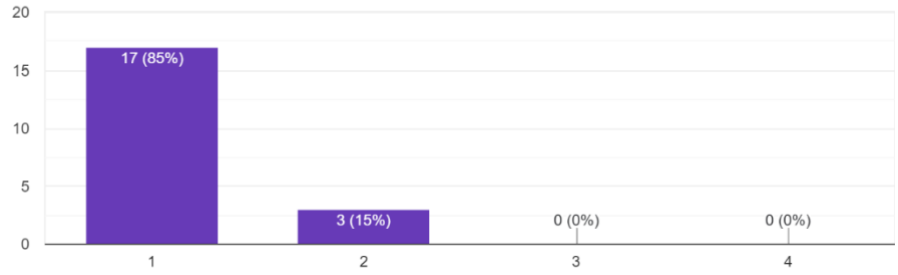
20 ردًا



نسخ

٨- وجدت أن استجابة التطبيق سريعة.

20 ردًا

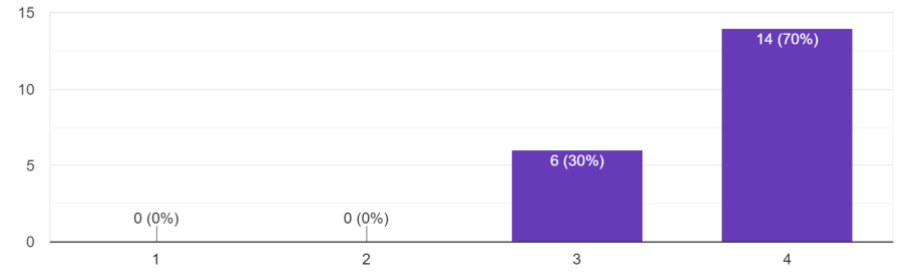


نسخ

نسخ الرسم البياني

٩- واجهت مشكلة أثناء استخدام النظام.

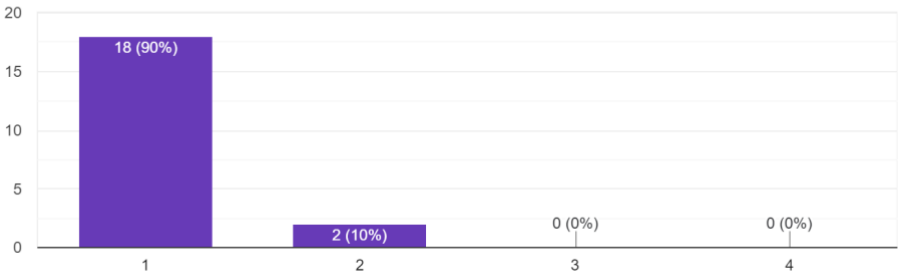
20 ردًا



نسخ

١٠- كانت الرسائل الإرشادية لاستخدام النظام واضحة وسهلة الفهم.

20 ردًا



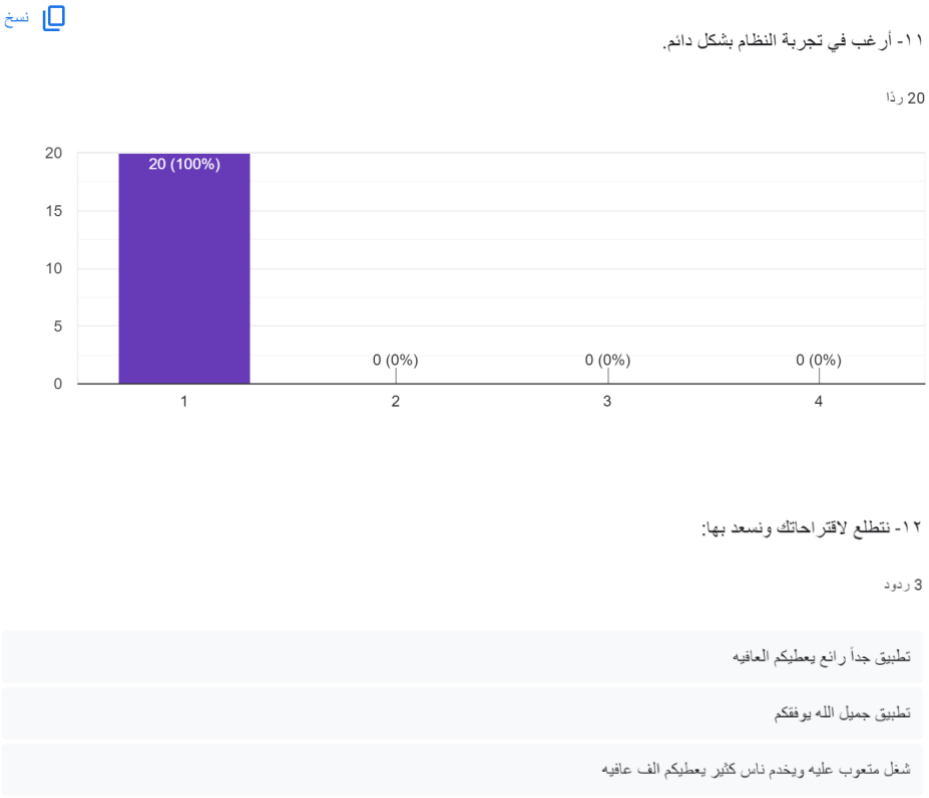


Figure 42 - 7.2.2 Questionnaire/Interview Results

7.2 Quality Attributes (NFR testing)

Table 10 - 7.2 NFR testing

User story	Quality Attribute	Measure	Results
As a user, I want to receive a response to any input in less than or equals 3 seconds, so that I will not have to wait long for the app to response.	Performance: The time it takes for a system to respond to a user's action or input.	Compute the response time: the desired response time is 3 seconds or less for navigation and update inputs from the user, launch the app time, and load readings time.	Test Scenario: - Launch the app and measure the time it takes for the system to respond. - Send various navigation or update inputs to the system and measure the time it takes for the system to respond.

			- Wait for readings to load and measure the time it takes for the system to respond. Number of Users: The test was performed with a sample of 1 user. Results: Minimum Response Time: 1.5 seconds Maximum Response Time: 2.9 seconds Average Response Time: 2.2 seconds
As a user, I want my login information to the system like passwords to be hashed, so that they can be secure.	Security: How authorized access to protected data is granted and unauthorized access is restricted in the application [53].	Only authenticated users are allowed to access the software.	Naqi depends on firebase authentication for authentication, and we found that Firebase Authentication uses an internally modified version of script to hash account passwords [54]. Also, the application prevents registering with a week password. The password must have both upper and lower cases also it should have numbers and at least 8 characters.
As a user, I want the system to be usable, so that I can use the system easily.	Usability: how the application is easy to learn and user-friendly [55].	The System Usability Scale (SUS) was used which is reliable and quick tool that measures the usability of a system [56]. SUS consists of	We tested our application with five users, and the average score was 88, which is higher than the average system usability scale (SUS) score of 68, indicating that our application is highly usable.

		10 questions (see appendix C for the questions) and the overall usability is calculated by finding the mean score for the responses of the participants	

7.3 Discussion

We can claim that the system evaluation was excellent and that we can now clearly identify the positive parts of the Naqi application once the users' acceptance test has been completed and the questionnaire data have been analyzed. Regarding the UX design, all users acknowledged that it was simple and didn't require any prior expertise to utilize. Additionally, all of them stated that the icons' meanings were clear and that they had no trouble comprehending them. 19 of the testers for the UI design concurred that the colors are soothing to them. Additionally, everyone could see that readings of the air quality data were accurate and exceeded their expectations for air quality monitoring. Finally, everyone favored the app and desired to use it continuously.

As for NFR testing, based on the results we can conclude that the performance of the application is great, as the response time for the desired response time is 3 seconds or less for navigation and update inputs from the user. And it has a high level of security, since it puts restrictions when choosing a password, and uses firebase authentications to hash the passwords. As for usability, Naqi scored 88 in the SUS, which exceeds the average score of 68, thus it can be concluded that it is highly usable.

Overall, the feedback was fantastic, indicating a very high level of acceptance. We can now see the positive aspects of the application. Most participants praised the user experience and interface of the application, as well as their ability to use it correctly and easily. Additionally, based on the results, we can see all of our key features, such as displaying temperature, humidity, carbon dioxide levels, indoor and outdoor dust levels, as well as daily, weekly, and monthly reports. However, there were some suggestions for improvements from the participants, which we have taken into consideration, such as clarifying certain readings that are difficult for the user to understand.

8 Conclusions and Future Work

This document details our experience working with Naqi, beginning with the introduction chapter that explains the issue and the proposed solution as well as providing a broad overview of Naqi. The background chapter follows the introduction and plays a crucial role in aiding the reader's comprehension of the specifics of the Naqi program by offering a brief description of the knowledge factors involved, such as the recommender systems and their various forms. To create an application that fills a market gap and outlines Naqi characteristics, we studied and debated mobile applications in the same field as Naqi during the document's literature review phase. Once we were clear on the features of Naqi, we next go on to a chapter on system analysis and design, which transforms Naqi characteristics into a form that makes it easier to implement Naqi and helps people understand how its parts interact. After analyzing our system, we began building the Naqi application using the Flutter framework and testing it to make sure there were no errors. And just like that, our application for measuring air quality has been completed and is functioning flawlessly, providing a safe and reliable tool for anyone concerned about their environmental well-being.

- **Global and local impact:**

The NAQI application plays a crucial role in enhancing public health, with a primary goal of elevating individuals' quality of life through continuous monitoring and improvement of air quality. Its impact is felt both locally and globally, especially for individuals managing respiratory conditions, empowering them to monitor and control their exposure to air pollutants. Consequently, they experience an improved quality of life and reduced susceptibility to the adverse effects of compromised air quality. Noteworthy features that distinguish NAQI from existing solutions include the ability for users to define their health status within the application, enabling personalized alert notifications tailored to their specific health conditions. This functionality supports individuals in efficiently managing their daily activities. Furthermore, the application contributes to smart home initiatives by automatically regulating indoor ventilation through the control of fans. This feature is instrumental in creating secure and health-conscious living spaces, particularly beneficial for those who spend extended periods indoors.

- **Problems and challenges encountered during the software development:**

Networking the devices was one of the biggest difficulties we encountered when developing the Naqi app. It was a huge challenge that took us a long time to overcome. To learn how to connect the devices both electrically and programmatically, we had to search a variety of sources, including cloud-based materials, user manuals, and instructional videos on YouTube. Our progress was significantly slowed down by our inability to fully understand how to apply the networking principles in particular. Despite these difficulties, we succeeded and completed the job.

- **Limitations of the system:**

The Naqi application's coverage and functionality are currently limited in several ways. Nitrogen dioxide (NO2) and volatile organic compounds (VOCs) are not measured. It will monitor one area in the outdoor air quality monitoring system. It is limited to one room when indoors, but the user can add more at a later time. Furthermore, the application is limited to Android cellphones at this time and only supports Arabic.

- **The main contribution of the project:**

By using our application, people with respiratory diseases can help as many people with the same discomfort as they will be able to access various information. Our application will contribute to improving air quality and people's health in general.

We have learned a lot over our difficult trip with Naqi; it has allowed us to put the knowledge we acquired during our university studies to use and has assisted us in honing our information-searching abilities. In terms of hard skills, we have discovered fresh programming ideas and methods. We have developed programs using the Dart programming language and the Flutter framework, integrated our system with the Firebase database, and overcome challenges that arose while developing the system.

- **Future work:**

The future work of the NAQI program will allow for further user customization, including the ability to establish custom criteria for metrics related to air quality. The goal of this feature is to provide a more personalized and user-focused experience. Furthermore, incorporating machine learning algorithms can make it easier to identify trends in air quality, giving the app the ability to proactively address possible problems and lower health risks. User contributions of anonymized air quality data are encouraged by community participation and data-sharing programs, which promote a group effort to combat air pollution. Integration of wearable technology provides users with real-time, portable air quality information for more

convenience, particularly when they are spending a lot of time outside. When air quality varies, improving the alerts and notifications system will give consumers useful information to act upon, enabling them to make well-informed decisions. A specialized team devoted to ongoing research and development guarantees that the NAQI application remains at the forefront of innovation in sensor technology, data analytics, and air quality management. This substantial contribution significantly enhances ongoing efforts towards a healthier future.

9 Acknowledgements

We would like to express our heartfelt gratitude to all those who have contributed to the successful completion of this graduation project. This journey has been a significant chapter in our academic lives, and we are thankful for the support and encouragement we have received along the way.

First and foremost, we extend our sincere appreciation to our supervisor, Dr. Aljawharah Alnasser, for her unwavering guidance, invaluable insights, and continuous support throughout this project. Her expertise and encouragement have been instrumental in shaping the direction of our project and enhancing the overall quality of this work.

We would like to thank our family and parents for their unwavering support and sacrifices they made for us to reach where we are today, presenting our graduation project.

We are also indebted to the faculty members of the information technology department for their academic mentorship and constructive feedback. Their commitment to excellence has been a driving force behind my academic endeavors.

And to those who assisted us in connecting the fan, their support was crucial in successfully integrating the fan into our project. Additionally, we would like to extend our appreciation to those who made efforts to repair the malfunctioning sensor. The sensor issue was a manufacturing problem that couldn't be fixed, but they went above and beyond to help us. We are truly grateful for their assistance.

This project would not have been possible without the collective efforts of everyone mentioned above. Thank you for being an integral part of this academic endeavor and for helping us reach this significant milestone in our educational journey.

REFERENCES

10 References

[1] "https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health," [Online].

[2] "https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health," [Online].

[3] "https://www.healthywa.wa.gov.au/Articles/F_I/Health-effects-of-dust," [Online].

[4] "https://oxfordshire.air-quality.info/why-we-monitor-air-quality," [Online].

[5] "IoT," amazon, [Online]. Available: https://aws.amazon.com/what-is/iot/. [Accessed 1 Apr. 2023].

[6] J. Terra, "Real-World IoT Applications in 2023," Simple I learn, 14 Feb 2023. [Online]. Available: https://www.simplilearn.com/iot-applications-article. [Accessed 1 Apr. 2023].

[7] A. L. Monton, "Internet of Things in Singapore: A Future Landscape," globals sign, 1 Mach 2022. [Online]. Available: https://www.globalsign.com/en-sg/blog/internet-things-singapore-future-landscape. [Accessed 1 Apr. 2023].

[8] "Actuators in IoT," Geeks for geeks, [Online]. Available: https://www.geeksforgeeks.org/actuators-in-iot/. [Accessed 1 Apr. 2023].

[9] Rajiv, "What are the major components of Internet of Things," RF Page, [Online]. Available: https://www.rfpage.com/what-are-the-major-components-of-internet-of-things/. [Accessed 1 Apr. 2023].

[10] "How an IoT System Actually Works," Leverege, [Online]. Available: https://www.leverege.com/iot-ebook/how-iot-systems-work. [Accessed 1 Apr. 2023].

[11] smartcity, "How Smart Cities Can Improve Air Quality," 8 Apr 2022. [Online]. Available: https://smartcity.press/smart-cities-air-quality/. [Accessed 27 Mar 2023].

[12] P. Pal, R. Gupta, S. Tiwari and A. Sharma, "Air and Sound Pollution Monitoring System Using IOT," *International Research Journal of Engineering and Technology*, vol. 4, no. 10, pp. 1137-1140, 2017.

[13] "Air Pollution Sensor basics | Air Pollution Sensor types | Air Pollution Sensor Manufacturers," [Online]. Available: https://www.rfwireless-world.com/Terminology/Air-Pollution-Sensor-basics-and-Air-Pollution-Sensor-types.html. [Accessed 8 Apr 2023].

[14] AWS, "What is LoRaWAN?," AWS Amazon, 2023. [Online]. Available: https://docs.aws.amazon.com/iot/latest/developerguide/connect-iot-lorawan-what-is-lorawan.html.

[15] "What is LoRaWAN® Specification," LoRa Alliance, 2021. [Online]. Available: https://lora-alliance.org/about-lorawan/.

[16] A. Riegsecker, "Measuring Environmental Effects on LoRa Radios in Cold Weather Using 915 MHz," ResearchGate, Dec 2017. [Online]. Available: https://www.researchgate.net/figure/Star-of-Stars-topology_fig1_331583787.

[17] K. Banti, I. Karampelia, T. Dimakis, A.-A. A. Boulogeorgos, T. Kyriakidis and M. Louta, "LoRaWAN Communication Protocols: A Comprehensive Survey under an Energy Efficiency Perspective," MDPI, 25 May 2022. [Online]. Available: https://www.mdpi.com/2673-4001/3/2/18.

[18] "LoRaWAN Architecture," The Things Network, [Online]. Available: https://www.thethingsnetwork.org/docs/lorawan/architecture/.

[19] H. N. Shah, Z. Khan, A. Merchant, M. Moghal, A. Shaikh and P. Rane, "IOT based air pollution monitoring system," *nternational Journal of Scientific & Engineering Research,* vol. 9, no. 2, pp. 62-66, 2018.

[20] S. Messan, A. Shahud, A. Anis, R. Kalam, S. Ali and M. Aslam, "Air-MIT: Air Quality Monitoring Using Internet of Things," *Engineering Proceedings,* vol. 20, no. 1, p. 45, 2022.

[21] T. H. Nasution, M. Muchtar and A. Simon, "Designing an IoT-based air quality monitoring," *IOP Conference Series: Materials Science and Engineering,* vol. 648, 2019.

[22] R. G. S. T. A. S. Poonam Pal1, "IOT BASED AIR POLLUTION MONITORING SYSTEM USING ARDUINO," *www.irjet.net* , p. 4, 10 oct (2017).

[23] W. Jabbar, T. Subramaniam, A. Ong and M. Iqm, "LoRaWAN-Based IoT System Implementation for Long-Range Outdoor Air Quality Monitoring," *Internet of Things,* vol. 19, 2022.

[24] R. Camarillo-Escobed, J. L. Flores, P. Marin-Montoya, G. García-Torales and J. M. Camarillo-Escobedo, "Smart Multi-Sensor System for Remote Air Quality Monitoring Using Unmanned Aerial Vehicle and LoRaWAN," 2022 February 22. [Online]. Available: https://www.mdpi.com/1424-8220/22/5/1706.

[25] I. AG, "IQAir AirVisual | Air Quality," 2017. [Online]. Available: https://apps.apple.com/sa/app/iqair-airvisual-air-quality/id1048912974.

[26] IQAir, "Air Quality Monitors," IQAir, [Online]. Available: https://www.iqair.com/air-quality-monitors. [Accessed 8 Apr 2023].

[27] "https://geekflare.com/air-quality-apps/#geekflare-toc-aircare," [Online].

[28] "Wave Mini," Airthings, [Online]. Available: https://www.airthings.com/en/wave-mini. [Accessed Apr. 2 2023].

[29] "Airthings Wave," google Play, [Online]. Available: https://play.google.com/store/apps/details?id=com.airthings.airthings. [Accessed 2 Apr. 2023].

[30] "uHoo," [Online]. Available: https://play.google.com/store/apps/details?id=com.uhooair&hl=en_US. [Accessed 3 Apr. 2023].

[31] "Breezometer," [Online]. Available: https://play.google.com/store/apps/details?id=app.breezometer&hl=en_US. [Accessed 3 Apr. 2023].

[32] C. Staff, "What Is Agile? And When to Use It," 21 Nov 2023. [Online]. Available: https://www.coursera.org/articles/what-is-agile-a-beginners-guide.

[33] I. Sommerville, "Agile and Scrum Chapter 3 (Sommerville)," in *Software Engineering 9th Edition*.

[34] "https://techbeacon.com/app-dev-testing/understanding-front-end-vs-back-end-performance-metrics-mobile-apps," [Online].

[35] W. Wang, X. Xu, S. Luan and S. Chen, "A critical review of the perception layer in the internet of things," *journal of Network and Computer Applications,* pp. 103-114, 2019.

[36] M. Beigl, T. Schairer, H. Gellersen and D. Willemsen, "Energy-efficient air flow control using sensor networks and IoT technology," *Proceedings of the 1st ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings,* pp. 25-30, 2011.

[37] Y. Wu, X. Kong, H. Wang and F. Xia, "Edge Computing for Internet of Everything: A Survey," *EEE Internet of Things Journal,* vol. 9, no. 23, pp. 23472-23485, 2022.

[38] J. L. J. &. K. Y. Kim, "Distributed database system for managing IoT data," *IEIE Transactions on Smart Processing and Computing*, pp. 1-7, 2019.

[39] S. V. e. a. Lakshmi, "Role and applications of IoT in materials and manufacturing industries–Review.," pp. 2925-2928, (2021).

[40] "Ambience Monitoring Sensort," Milesight, [Online]. Available: https://www.milesight-iot.com/lorawan/sensor/am300/. [Accessed 5 Jun 2023].

[41] Delmation. [Online]. Available: https://delmation.nl/wp-content/uploads/manuals/UG_AM307-868M.pdf. [Accessed 13 Jun 2023].

[42] ""What are Norman's design principles?"," [Online]. Available: https://www.educative.io/answers/what-are-normans-design-principles.

[43] J. Nielsen, ""10 Usability Heuristics for User Interface Design"," [Online]. Available: https://www.nngroup.com/articles/ten-usability-heuristics/.

[44] A. Nikolov, ""Design principle: Consistency"," [Online]. Available: https://uxdesign.cc/design-principle-consistency-6b0cf7e7339f.

[45] "IoT Made Easy," RAK, [Online]. Available: https://store.rakwireless.com/products/rak7268-8-channel-indoor-lorawan-gateway?variant=41806937620678. [Accessed 5 Jun 2023].

[46] "LT-22222-L LoRa I/O Controller," Dragino, [Online]. Available: https://www.dragino.com/products/lora-lorawan-end-node/item/156-lt-22222-l.html. [Accessed 5 Jun 2023].

[47] "Ventilation Plastic Fan," Noon, [Online]. Available: https://www.noon.com/saudi-en/Z4ACBA7370D6F96DFA605Z/p/. [Accessed 5 Jun 2023].

[48] "IoT Made Easy," RAK , [Online]. Available: https://store.rakwireless.com/products/rak7289-8-16-channel-outdoor-lorawan-gateway. [Accessed 4 12 2023].

[49] "Temperature & Humidity Sensor," Milesight, [Online]. Available: https://www.milesight.com/iot/product/lorawan-sensor/em300-th. [Accessed 4 12 2023].

[50] electrony, "ESP8266 NodeMCU," [Online]. Available: https://ielectrony.com/product/nodemcu-lua-wifi-internet/.

[51] "DSM501A Dust Sensor Module," ielectront, [Online]. Available: https://ielectrony.com/en/product/%d9%85%d9%88%d8%af%d9%8a%d9%88%d9%84-%d8%ad%d8%b3%d8%a7%d8%b3-%d8%a7%d9%84%d8%ba%d8%a8%d8%a7%d8%b1-dsm501a-pm2-5/. [Accessed 4 12 2023].

[52] "End Device AT Commands and Downlink Command," Dragino, [Online]. Available: http://wiki.dragino.com/xwiki/bin/view/Main/End%20Device%20AT%20Commands%20and%20Downlink%20Command. [Accessed 9 Jun 2023].

[53] "Security testing (a complete guide)," [Online]. [Accessed 1 12 2023].

[54] "Firebase Authentication Password Hashing," Firebase, [Online]. Available: https://firebaseopensource.com/projects/firebase/scrypt. [Accessed 1 12 2023].

[55] "What is usability testing?," Guru99, [Online]. Available: https://www.guru99.com/usability-testing-tutorial.html. [Accessed 1 12 2023].

[56] "How to use the system usability scale (SUS) to evaluate the usability," [Online]. [Accessed 1 12 2023].

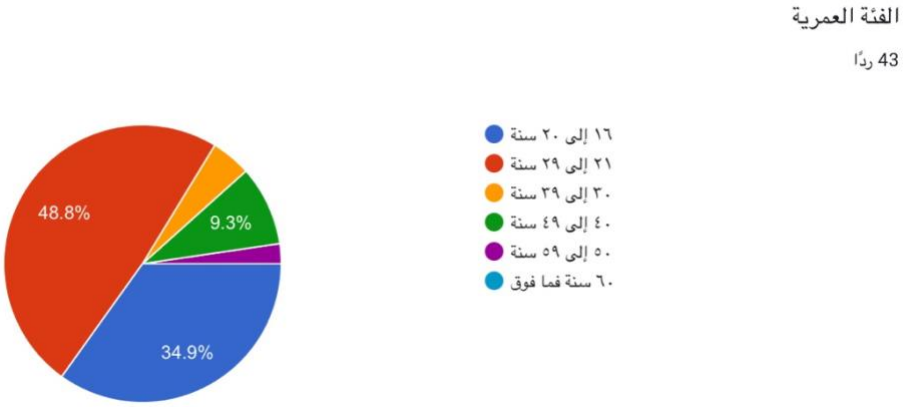
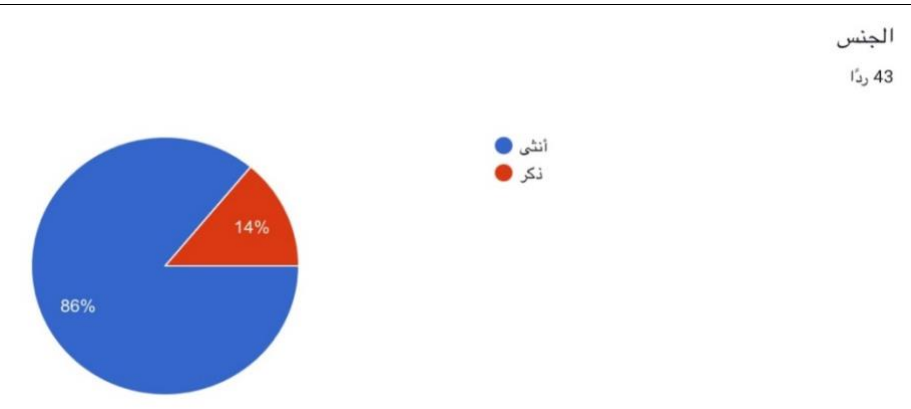
[57] "https://www.milesight-iot.com/success-stories/lorawan-jag-deployment-in-canadian-public-schools/," [Online].

[58] S. Hoober., ""What are Norman's design principles?"," [Online]. Available: https://www.uxmatters.com/mt/archives/2013/02/how-do-users-really-hold-mobile-devices.php.

APPENDIX

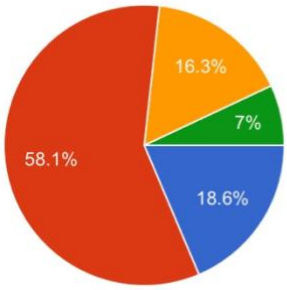
11 Appendix

Appendix A: Questionnaire

Q1

Q2

Q3

لدي مخاوف بشأن مستويات تلوث الهواء في منطقتي.
تنطبق هذه العبارة عليك:

43 ردًا

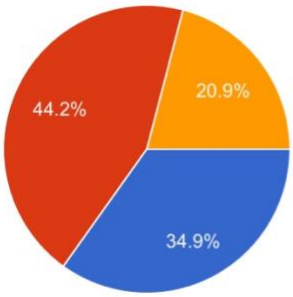


دائماً
أحياناً
قليلاً
أبداً

Q4

هل تهتم بمعرفة جودة الهواء قبل الخروج من المنزل؟

43 ردًا

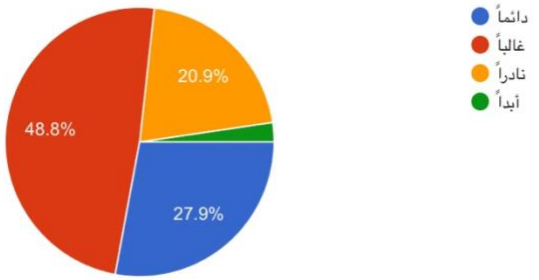


نعم
أحيانا
لا

Q5

أقضي وقتًا في مناطق مزدحمة (مثل الفصول الدراسية المكتظة) أو مناطق ذات مستويات عالية من تلوث الهواء.
تنطبق هذه العبارة عليك:

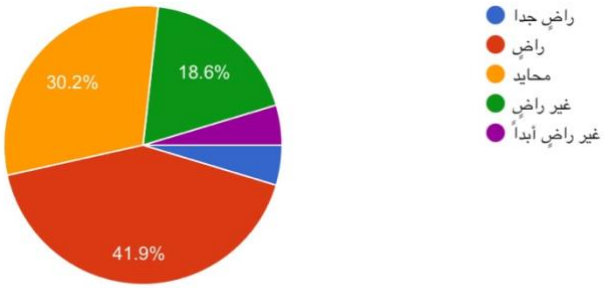
43 ردًا



Q6

إلى أي مدى أنت راض عن الطريقة المتبعة حاليا للاطلاع على جودة الهواء (مثل تطبيقات الطقس وغيرها)؟

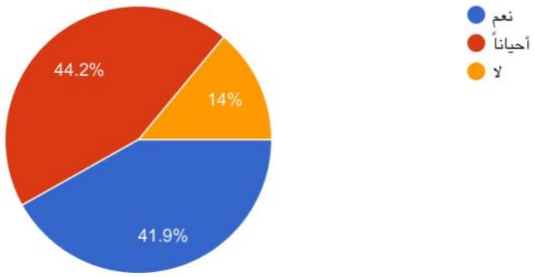
43 ردًا



Q7

هل تتخذ أي إجراءات لتقليل أو حماية نفسك من تلوث الهواء مثل تجنب الأنشطة الخارجية خلال ساعات ذروة التلوث أو ارتداء كمامة؟

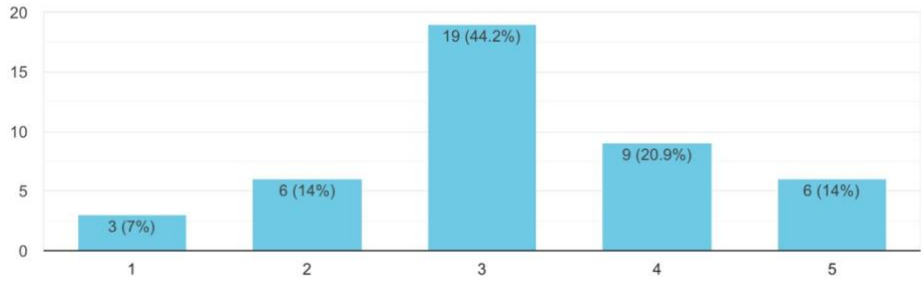
43 ردًا



Q8

ما مدى قلقك بشأن تأثير جودة الهواء على صحة الجهاز التنفسي؟

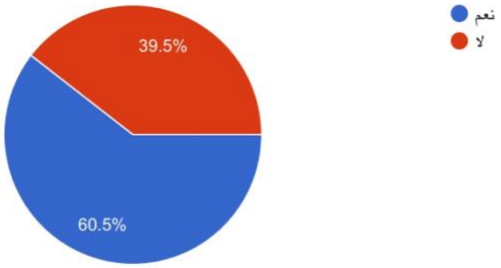
43 ردًا

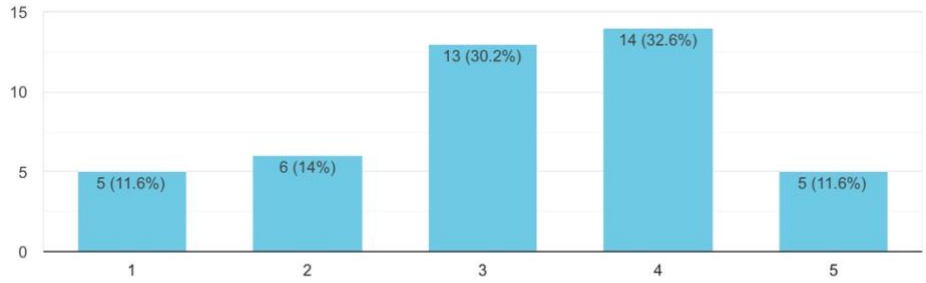


Q9

هل سبق لك أن عانيت من مشاكل تنفسية تتعلق بجودة الهواء ، مثل السعال أو الربو أو الحساسية أو ضيق التنفس؟

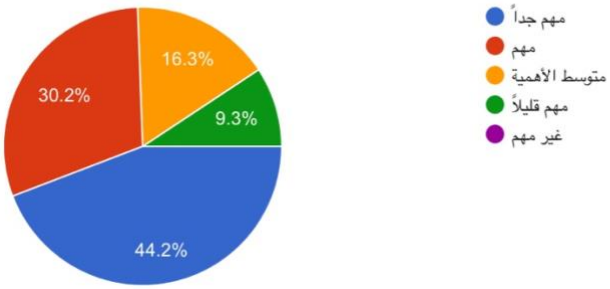
43 ردًا



Q10
إلى أي مدى تعتقد أن أنظمة مراقبة جودة الهواء فعالة في الحد من تلوث الهواء أو تخفيفه ؟ 43 ردًا 
Q11

ما مدى أهمية أن يكون لديك نظام لمراقبة جودة الهواء يمكن تخصيصه وفقًا لظروفك الصحية التنفسية المحددة؟

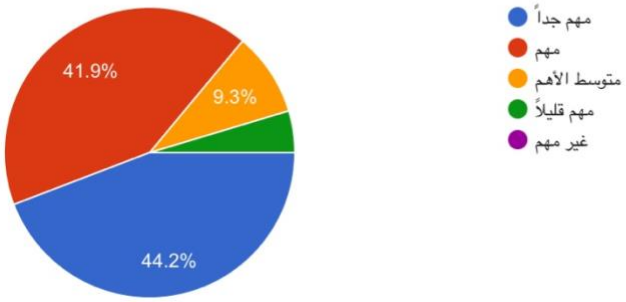
43 ردًا

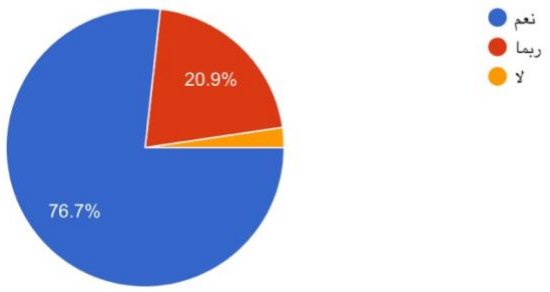


Q12

ما مدى أهمية وجود تطبيق يوفر معلومات وتقارير دورية عن جودة الهواء؟

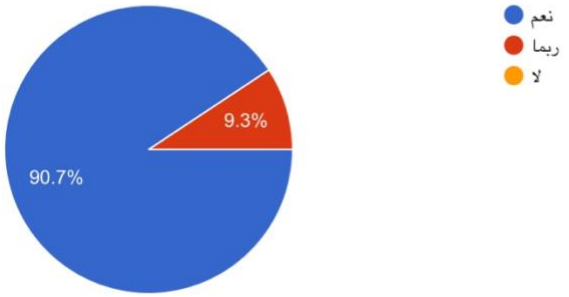
43 ردًا



Q13
هل ترغب بامتلاك نظام تهوية ذاتي في الأماكن المغلقة المكتظة؟ 43 ردًا 
Q14

أرغب بوجود تطبيق يقوم بتنبيهي عندما تكون جودة الهواء غير مناسبة

43 ردًا



Q15

هل لديك أي اقتراحات أو آراء لتطبيق يقوم بمراقبة جودة الهواء ويساعد المستخدم لتخصيص تنبيهات تتوافق مع حالته الصحية؟

17 ردًا

لا
ان يكون سلس وسهل للاستخدام وبلغة واضحة لكبار السن
اشعار المستخدم باوقات تكون جودة الهواء في هذي المنطقه جيده لكي يتم تجنب الاوقات الاخرى
لا شكرا
.
تطبيق الطقس
ارسال اشعارات تنبيهيه في حال كان الهواء مغبر وليس نقي ، حتى يتم تنبيه الاشخاص المصابين بالربو
اعلامي بتغيرها درجة الحرارة المتوقعة ووجود غبار ، هواء جاف ، رطوبة وغيرها من العوامل الجوية بالإضافة إلى تنبيهات الوقاية
تطبيق جوده هواء الرياض
لا ولكن مهتمه
بغض النظر عن الحالات الصحية المحتاجة فوجود مثل هذا التطبيق يساعد على تعزيز الأمن الصحي كأسلوب حماية وقائي بالذات للصغار أو في حال حدوث مشاكل في الجو داخل الغرف أثناء النوم فهو مفيد للجميع.
فكره جميلة تدعم المدن الذكية وأتمنى تطبيقها في المستشفيات ومناطق لعب الأطفال
اقتراح اجراءات لتخفيف التلوث
تحديد الاماكن والاوقات التي تتميز بهواء نقي. طرق مناسبة لتنقية الهواء في حال كانت الاماكن التي اقيم فيها ذات جودة هواء سيئ.
اضافة جهاز خارجي يتم التحكم به عبر التطبيق لتنقية الهواء

Appendix B: Interviews

- **Interview questions:**

1-كيف تكون على اطلاع على جودة الهواء في منطقتك أو في الأماكن التي تتردد عليها كثيرًا ، مثل مكان عملك أو الأماكن العامة؟

2- هل عانيت أو أحد أفراد أسرتك من قبل من أي مشاكل تنفسية تتعلق بنوعية الهواء الرديئة ، وإذا كان الأمر كذلك ، فما هي؟

3- ماهي الاجراءات التي تتبعها لتحسين جودة الهواء داخل وخارج المنزل؟

4- هل سبق أن استخدمت أي أجهزة أو تقنيات مراقبة لتتبع جودة الهواء ؟ في حالة نعم ، فما هي؟ وما المميزات التي أعجبتك فيها وما هي الأشياء التي تود تعديلها فيها؟

5-هل باعتقادك ان انظمة مراقبة جودة الهواء تساهم في تقليل المخاطر الصحية التنفسية؟ ولماذا؟

6 - في حال تم إنشاء تطبيق لمراقبة جودة الهواء كيف تعتقد أنه سيؤثر على روتين يومك ونمط حياتك؟ ماهي المميزات التي ترغب أن يحتويها التطبيق؟

7- اذا تم انشاء تطبيق لمراقبة جودة الهواء، ماهي التنبيهات التي ترغب أن تصلك؟ وكيف تود تخصيصها؟ وما هي التفاصيل التي ترغب بها في التنبيه؟

- **Interview transcriptions:**

Interview 1	
Date: 8/4/2023 Location: interviewee's home Duration: 10 minutes	
Interviewee: Arwa Mohammed	Interviewer: Noura Alangri
Reminders: - the interviewee's she constantly questions the quality of the air. Also, she has kids who have allergies in their chest. - the interviewee's age is 36.	
Answers	**Questions**

1-كيف تكون على اطلاع على جودة الهواء في منطقتك أو في الأماكن التي تتردد عليها كثيرًا ، مثل مكان عملك أو الأماكن العامة؟	في الواقع ليست لدي الخبره الكافيه عن جودة الهواء لاني لا املك اي جهاز او اي شي يخبرني عن حال جودة الهواء
2- هل عانيت أو أحد أفراد أسرتك من قبل من أي مشاكل تنفسية تتعلق بنوعية الهواء الرديئة ، وإذا كان الأمر كذلك ، فما هي؟	نعم اعاني غالباً من غرف الملحق عند اشعال النار ينحبس الهواء والموجودين بالغرفة لا يشعرون بذلك ايضاً الغرف التي تكثر فيها الورود تزيد من ثاني اكسيد الكربون وتسبب اختناق
3- ماهي الاجراءات التي تتبعها لتحسين جودة الهواء داخل وخارج المنزل؟	احاول الاكثار من التهوية وفتح النوافذ حتى يدخل الهواء الخارجي
4- هل سبق أن استخدمت أي أجهزة أو تقنيات مراقبة لتتبع جودة الهواء ؟ في حالة نعم ، فما هي؟ وما المميزات التي أعجبتك فيها وما هي الأشياء التي تود تعديلها فيها؟	لا للاسف لم يسبق لي التجربة لكن استطلع الى تجربه افضل تفيدني من ناحية معرفة حالة جودة الهواء حفظاً لصحتنا
5-هل باعتقادك ان انظمة مراقبة جودة الهواء تساهم في تقليل المخاطر الصحية التنفسية؟ ولماذا؟	بالتأكيد، لأن سوء جودة الهواء او زيادة ثاني اكسيد الكربون تسبب اختناق والاختناق يؤدي الى الوفاة والعياذ بالله فمراقبة جودة الهواء مهمه جداً للصحة
6 - في حال تم إنشاء تطبيق لمراقبة جودة الهواء كيف تعتقد أنه سيؤثر على روتين يومك ونمط حياتك؟ ماهي المميزات التي ترغب أن يحتويها التطبيق؟	اعتقد انه سيكون رائع جداً بسبب انني سأكون على اطلاع دائم بجودة هواء منزلي او الاماكن التي اذهب اليها باستمرار، اود ان يكون هناك تنبهيات تخبرني في حال تلوث الهواء ايضاً التطبيق يكون سهل وواضح وسلس في التعامل
7- اذا تم انشاء تطبيق لمراقبة جودة الهواء، ماهي التنبيهات التي ترغب أن تصلك؟ وكيف تود تخصيصها؟ وما هي التفاصيل التي ترغب بها في التنبيه؟	تنبيهات تقدم لي تحذيرات في حال تلوث الهواء او زيادة ثاني اكسيد الكربون اهم شي يكون في التنبيه هو معلومات عن جودة هواء الغرفه وممكن مدى الخطوره

Interview 2	
Date: 8/4/2023 Location: interviewee's home Duration: 10 minutes	
Interviewee: Tahani	Interviewer: Abeer
Reminders: The interviewee is always concerned in the air quality. She also has a dust allergy. The interviewee is in his forties.	
Answers	**Questions**
عبر مواقع التواصل الاجتماعي مثل تويتر أو الواتس اب، وبرامج الطفس.	1-كيف تكون على اطلاع على جودة الهواء في منطقتك أو في الأماكن التي تتردد عليها كثيرًا ، مثل مكان عملك أو الأماكن العامة؟
نعم أعاني من حساسية تنفسية بسبب التعرض للجو عندما تكون مستويات الغبار مرتفعة، وأواجه صعوبة في معرفة ذلك، حيث أني أحيانا أخرج من المنزل وأتفاجأ فيما بعد بأن الجو غير مناسب للخروج.	2- هل عانيت أو أحد أفراد أسرتك من قبل من أي مشاكل تنفسية تتعلق بنوعية الهواء الرديئة ، وإذا كان الأمر كذلك ، فما هي؟
لتحسين جودة داخل المنزل أحرص على إغلاق الشبابيك عندما يكون الجو خارجا غير جيد، لكن عندما يكون الجو الخارجي جيد أقوم بفتح الشبابيك حتى يتجدد الهواء داخل المنزل، فيما يتعلق بجودة الهوا لخارج المنزل أحرص على على ارتداء الكمامة عندما يكون الجو غير جيد.	3- ماهي الاجراءات التي تتبعها لتحسين جودة الهواء داخل وخارج المنزل؟
لا لم يسبق لي تجربتها ولكن اتمنى تجربتها لانها ستكون مفيدة جدا.	4- هل سبق أن استخدمت أي أجهزة أو تقنيات مراقبة لتتبع جودة الهواء ؟ في حالة نعم ، فما هي؟ وما المميزات التي أعجبتك فيها وما هي الأشياء التي تود تعديلها فيها؟
نعم بالطبع لأنها تساعد في تنبيه الشخص إذا كان الجو غير مناسب فيأخذ احتياطاته أو علاجاته اذا كان مصاب بالربو مثلا، أيضا تساعد الأمهات اذا	5-هل باعتقادك ان انظمة مراقبة جودة الهواء تساهم في تقليل المخاطر الصحية التنفسية؟ ولماذا؟

	كان لديهم أطفال مصابين بالربو و كبار السن أيضا.
6 - في حال تم إنشاء تطبيق لمراقبة جودة الهواء كيف تعتقد أنه سيؤثر على روتين يومك ونمط حياتك؟ ماهي المميزات التي ترغب أن يحتويها التطبيق؟	أعتقد أني سأستمتع أكثر بالأنشطة اليومية، لأني سأبتعد عن المثيرات للحساسية، وسأعرف الأيام المناسبة للخروج، وأيضا سيساعدني على أخذ الوقاية وأخذ الاحتياطات اللازمة لأطفالي. فيما يخص الميزات أرغب بوجود قياسات لمستوى الأكسجين ومعدل الغبار والأتربة .
7- اذا تم انشاء تطبيق لمراقبة جودة الهواء، ماهي التنبيهات التي ترغب أن تصلك؟ وكيف تود تخصيصها؟ وما هي التفاصيل التي ترغب بها في التنبيه؟	أرغب بتلقي تنبيهات عندما يرتفع مستوى التلوث عن المستوى الطبيعي حتى أكون على اطلاع دائم، وأود أيضا تخصيص مستوى محدد للغبار بحيث تصلني تنبيهات مخصصة للأشخاص المصابين بالحساسية.

Interview 3	
Date: 8 April 2023 Location: interviewee's home Duration: 30 min	
Interviewee: Ghada	Interviewer: Lujain
Reminders:	
Answers	**Questions**
تطبيق الطقس يوضح لي الحالة الجوية الخارجية الى حد كبير وليس دقيق جدا، لكن لا يوجد تطبيق يوضح لي جودة الهواء في الأماكن المغلقة الخاصة أو العامة مثل المولات والمستشفيات.	1-كيف تكون على اطلاع على جودة الهواء في منطقتك أو في الأماكن التي تتردد عليها كثيرًا ، مثل مكان عملك أو الأماكن العامة؟

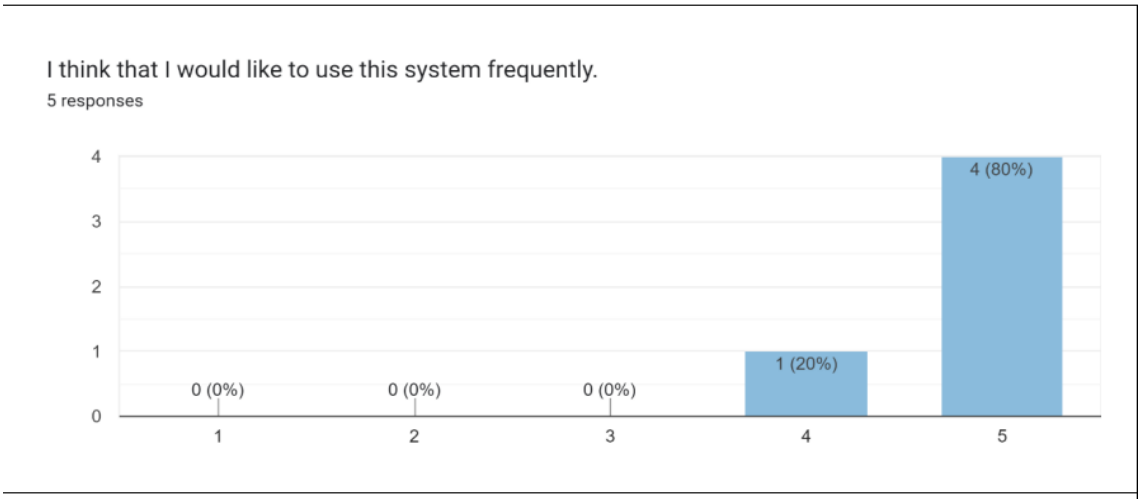
2- هل عانيت أو أحد أفراد أسرتك من قبل من أي مشاكل تنفسية تتعلق بنوعية الهواء الرديئة ، وإذا كان الأمر كذلك ، فما هي؟	نعم، كتمة وضيق تنفس تستدعي تدخل علاجي بعلاجات مثل البخار والفنتولين والبلميكورت
3- ماهي الاجراءات التي تتبعها لتحسين جودة الهواء داخل وخارج المنزل؟	داخل المنزل فتح النوافذ وخارج المنزل ارتداء الكمامة.
4- هل سبق أن استخدمت أي أجهزة أو تقنيات مراقبة لتتبع جودة الهواء ؟ في حالة نعم ، فما هي؟ وما المميزات التي أعجبتك فيها وما هي الأشياء التي تود تعديلها فيها؟	لم أستخدم اي أجهزة، لكن أطلع على حالة الهواء من تطبيقات الطقس، يعجبني فيه أنه يوضح نسبة الغبار (إذا كانت النسبة عالية لا أفتح النوافذ للتهوية اليومية) ويوضح نسبة الرطوبة. وتعجبني خاصية توضيح هل الطقس مناسب للركض في الخارج أو لا، أود لو كان معزز بزيادة من الاقتراحات وتناسب أعمار مختلفة واضافة رياضات أخرى مثلا السباحة. ولدي اقتراحات كأمراة أود لو كانت تطبيقات الطقس توضح هل الطقس في الخارج يحتاج ترطيب للبشرة مثلا في الجو الجاف ويعطيني تنبيهات، ويعلمني في حال كان لا يصلح الجو لتسريح الشعر بالسشوار في حال كان الجو يحوي رطوبة عالية.
5-هل باعتقادك ان انظمة مراقبة جودة الهواء تساهم في تقليل المخاطر الصحية التنفسية؟ ولماذا؟	نعم ؛فعلى الأقل قد يتجنب الشخص الخروج او التواجد في أماكن لاتناسب وضعه الصحي . أو إتخاذ إجراءات كلبس الكمامة ...
6 - في حال تم إنشاء تطبيق لمراقبة جودة الهواء كيف تعتقد أنه سيؤثر على روتين يومك ونمط حياتك؟ ماهي المميزات التي ترغب أن يحتويها التطبيق؟	أرغب أن يحتوي على تنبيه جرسي بحيث أحدد أنا (المستخدم)مالخطر الذي يهمني أن أتلقى تنبيه بشأنه لأتصرف بالمناسب
7- اذا تم انشاء تطبيق لمراقبة جودة الهواء، ماهي التنبيهات التي ترغب أن تصلك؟ وكيف تود تخصيصها؟ وما هي التفاصيل التي ترغب بها في التنبيه؟	تنبيه عن الغبار تنبيه عن الرطوبة تنبيه عن نقص الاكسجين او ارتفاع الهيدروجين فهو مناسب للغرف ..الخ أختارها بأيقونة بحيث إذا وصلت لحد معين تعطي تنبيه لي وتوضح فيه التفاصيل الرقمية بشكل مقارنه بين الطبيعي وماهو عليه الان ومن الممكن وضع مؤشر ملون بحيث يكون الاحمر اكثر خطرا والازرق هو الوضع الطبيعي بحيث يزداد اللون الاحمر كلما زار الخطر الصحي

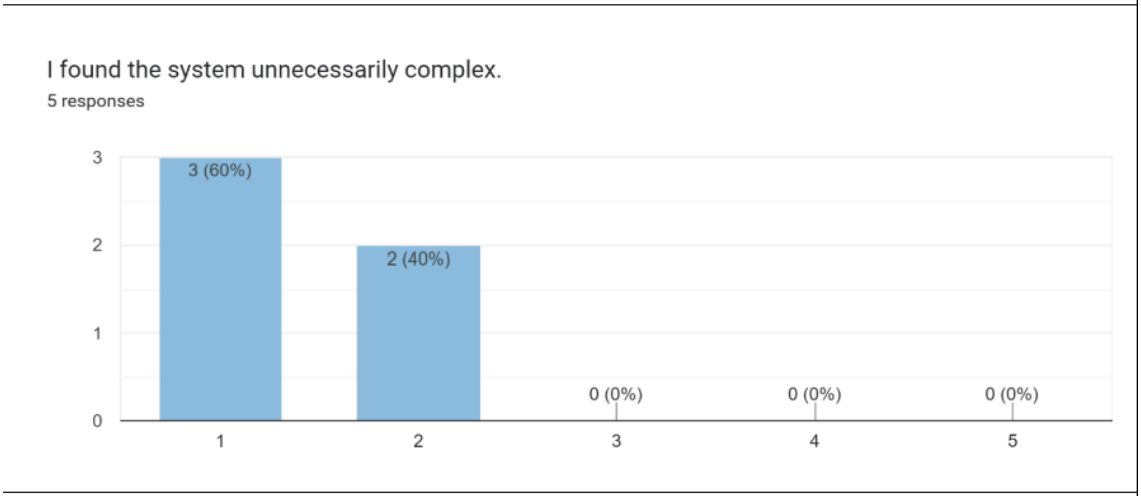
Interview 4	
Date:7 April 2023 Location: Snapchat Duration: 10 minutes	
Interviewee: Eman	Interviewer: Ebtisam
Reminders: The interviewee is constantly interested in knowing the quality of the air. Also, she and some of her children suffer from allergies in their chests and also suffer from asthma. The age of the interviewee is 35.	
Answers	**Questions**
عن طريق وسائل التواصل الاجتماعي ، والتلفاز.	1-كيف تكون على اطلاع على جودة الهواء في منطقتك أو في الأماكن التي تتردد عليها كثيرًا ، مثل مكان عملك أو الأماكن العامة؟
نعم ، عانينا من مشاكل الربو والحساسية حتى أصبحت مزمنة.	2- هل عانيت أو أحد أفراد أسرتك من قبل من أي مشاكل تنفسية تتعلق بنوعية الهواء الرديئة ، وإذا كان الأمر كذلك ، فما هي؟
داخل المنزل عن طريق فتح النوافذ لتهوية المكان ، ما في حالة الغبار او رائحة الدخان اغلاق النوافذ، أيضا من الحلول البسيطة وش رذاذ الماء في الهواء للتخفيف من جودة الهواء السيئة ، اما خارج المنزل لبس الكمامة .	3- ماهي الاجراءات التي تتبعها لتحسين جودة الهواء داخل وخارج المنزل؟
لا لم يسبق لي أجهزة مراقبة لتتبع جودة الهواء ابدًا	4- هل سبق أن استخدمت أي أجهزة أو تقنيات مراقبة لتتبع جودة الهواء ؟ في حالة نعم ، فما هي؟ وما المميزات التي أعجبتك فيها وما هي الأشياء التي تود تعديلها فيها؟
نعم ستساعد هذه الأنظمة في تقليل المخاطر لأنها تزودنا بكيفية التعامل مع تلوث الهواء أو أي شيء يؤثر علينا.	5-هل باعتقادك ان انظمة مراقبة جودة الهواء تساهم في تقليل المخاطر الصحية التنفسية؟ ولماذا؟

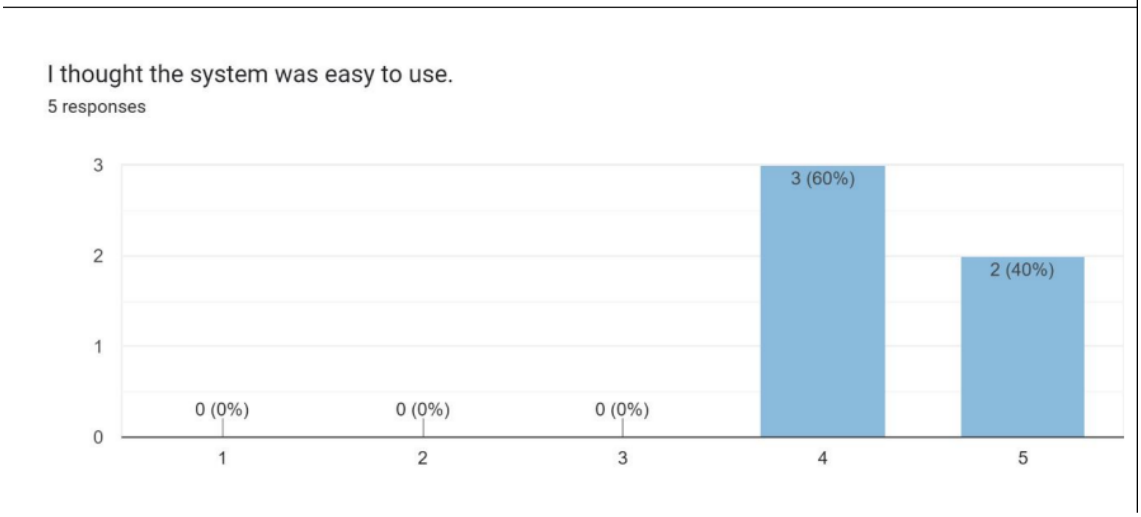
6 - في حال تم إنشاء تطبيق لمراقبة جودة الهواء كيف تعتقد أنه سيؤثر على روتين يومك ونمط حياتك؟ ماهي المميزات التي ترغب أن يحتويها التطبيق؟	نعم سيؤثر للافضل وسيكون هناك اطمئنان ان الهواء جودته عالية ، اما المميزات ان يعلمني بالأماكن التي يكون فيها الهواء ملوث جدا وكيفية التعامل معها ، وان يكون هناك جهاز انذار للتبيه عندنا تكون حودة الهواء سيئة ، وأيضا ان يعلمني بالاماكن التي فيها جودة الهواء عالية وكم نسبتها.
7- اذا تم انشاء تطبيق لمراقبة جودة الهواء، ماهي التنبيهات التي ترغب أن تصلك؟ وكيف تود تخصيصها؟ وما هي التفاصيل التي ترغب بها في التنبيه؟	تنبيهات تصلني عن جودة الهواء في الأماكن التي أكون متواجدة فيها ، وتنبيهات اذا كانت جودة الهواء ضارة ، أيضا تنبيهات الارشادات التي مفروض ان التزم بها في هذه الأماكن .

Appendix C : NFR Usability Test :

• SUS results :

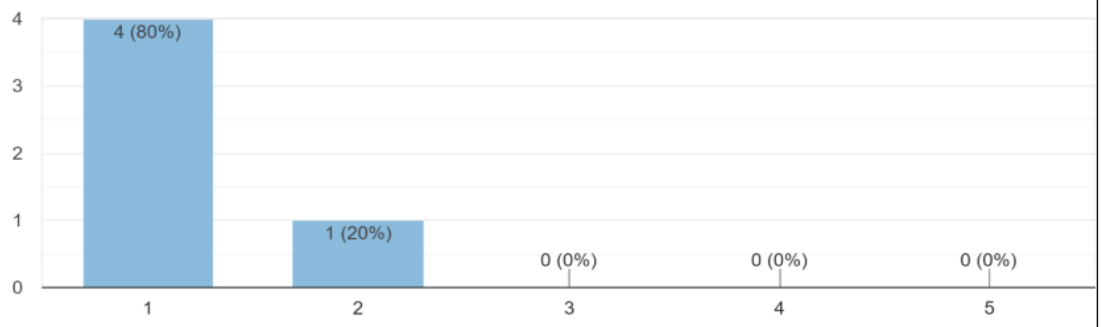






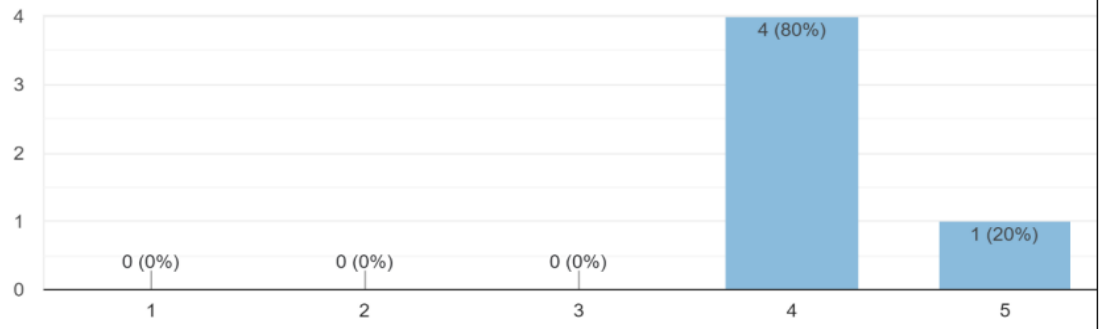
I think that I would need the support of a technical person to be able to use this system.

5 responses



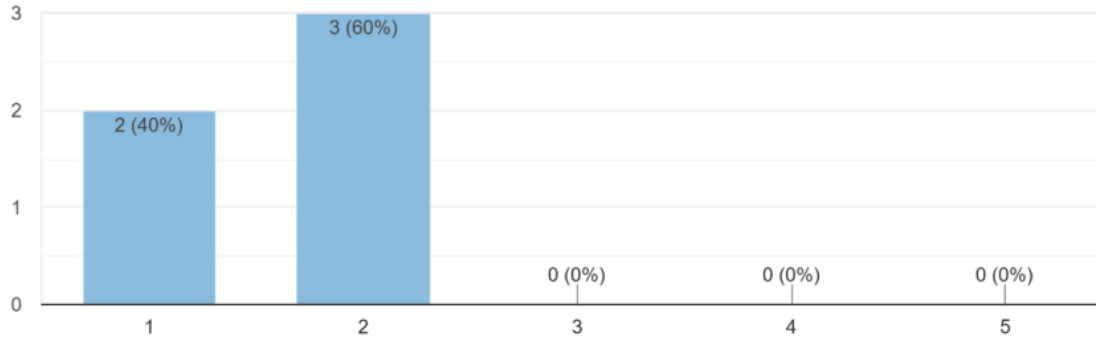
I found the various functions in this system were well integrated.

5 responses



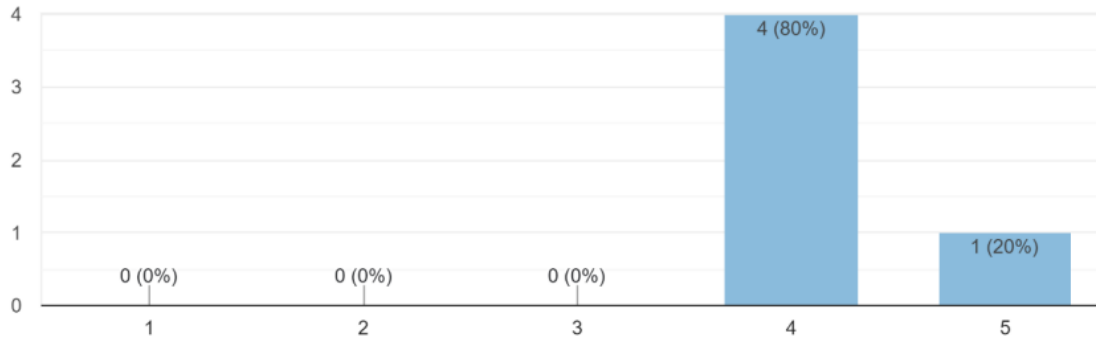
I thought there was too much inconsistency in this system.

5 responses



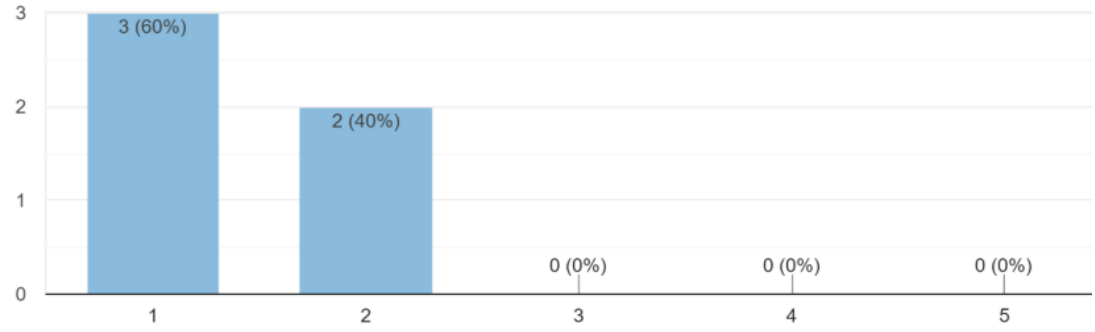
I would imagine that most people would learn to use this system very quickly.

5 responses



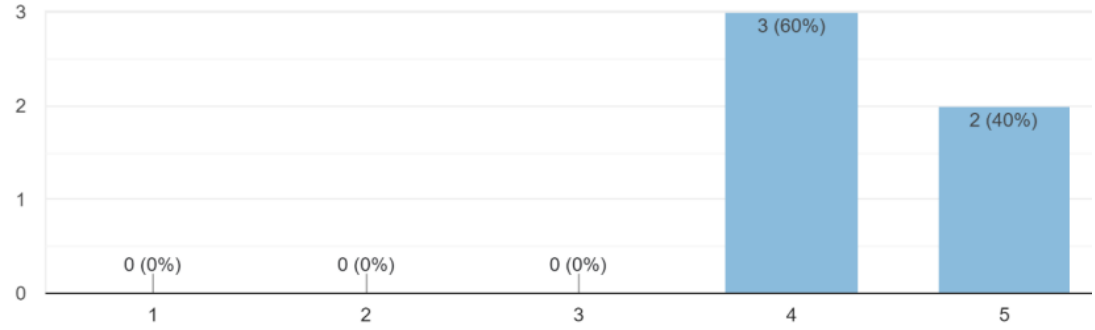
I found the system very cumbersome to use.

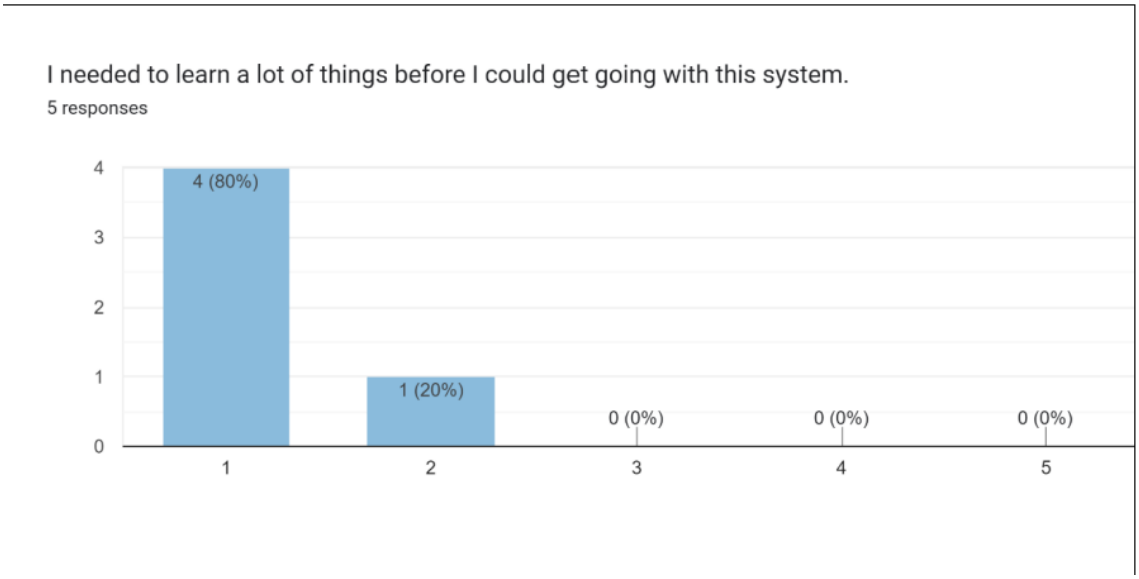
5 responses



I felt very confident using the system.

5 responses




I needed to learn a lot of things before I could get going with this system.
5 responses
4
3
2
1
0
4 (80%)
1 (20%)
0 (0%)
0 (0%)
0 (0%)
1
2
3
4
5