PDPM Indian Institute of Information Technology, Design and Manufacturing, Jabalpur

*(An Institute of National Importance established by Ministry of Education, Govt. of India)*

## CERTIFICATE

This is to certify that the Design Project (DS3001) titled **AI-based Smart Inhaler with Personalized Asthma Care** submitted by

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in partial fulfilment of the requirements for the degree of Bachelor of Technology (B.Tech.)/Bachelor of Design (B. Des) at PDPM Indian Institute of Information Technology, Design and Manufacturing, Jabalpur, is an original work carried out under my/our guidance and supervision.

To the best of my knowledge, the project complies with the institute's ethical guidelines.

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# ABSTRACT

This report delves into the design and potential of a smart inhaler system enhanced with an innovative add-on device, a wearable band, and a mobile application. The goal is to assess the feasibility, efficiency, and user-friendliness of this solution for improving respiratory care. The add-on device, designed to seamlessly integrate with traditional inhalers, includes sensors to monitor inhalation patterns and Bluetooth for real-time connectivity, ensuring minimal interference with standard usage. Additionally, the system incorporates a wearable band equipped with a heart rate monitor and pulse oximeter to provide real-time data on vital signs, offering a more comprehensive view of the user's health. The mobile application complements the hardware by enabling usage tracking, personalized reminders, and actionable health insights. The evaluation examines critical design elements such as functionality, user experience, integration, and compatibility, highlighting both strengths and areas for improvement. This holistic approach aims to optimize the system, fostering better patient adherence, effective monitoring, and improved overall respiratory and health management.

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## Annexure

# 1. INTRODUCTION:

## 1.1 Overview:

Asthma and Chronic Obstructive Pulmonary Disease (COPD) are among the most prevalent chronic respiratory diseases, affecting over 300 million people globally. Despite the availability of effective treatments, such as inhalers, improper usage and low adherence rates often lead to severe health complications, including frequent hospitalizations and, in some cases, fatal exacerbations. Studies suggest that nearly 50% of asthma patients fail to use their inhalers correctly, highlighting a critical gap in existing respiratory care solutions[1].

## 1.2 Need For Innovation:

The lack of technological integration in traditional inhalers creates several challenges:

- Patients often forget to take their medication on time, leading to poor adherence.
- There is no feedback mechanism to help users ensure correct usage techniques, which is crucial for effective drug delivery.
- Environmental factors such as air pollution, humidity, and pollen counts can exacerbate symptoms, yet traditional inhalers provide no warnings or proactive measures.

To address these challenges, this project focuses on the development of a **add on device for inhaler,** an innovative healthcare device designed to improve medication adherence, optimize treatment, and empower patients to manage their condition effectively. By integrating advanced technologies such as sensors, artificial intelligence (AI), and real-time monitoring, this solution aims to revolutionize asthma and COPD management.

This project focuses on developing an inhaler add-on device that:

- Provides tailored medication schedules.
- Provides reminders and alerts.
- Tracks real-time inhaler usage and adherence.
- Offers feedback to improve patient outcomes.
- Features a mobile app for patient and doctor interaction.

## 1.3 How Innovative Is The Solution Compared To Traditional Inhalers?

| **Features** | **Traditional Inhaler** | **Add on Device for Inhaler** |
|---|---|---|
| Medication Adherence | No mechanism to track or ensure adherence to medication schedules. | Tracks usage in real-time and sends personalized reminders to patients to ensure adherence. |
| Usage Feedback | Does not provide feedback on correct usage. | Detects improper usage (e.g., insufficient inhalation force) and provides instant feedback via the app. |
| Environmental Monitoring | No awareness of environmental factors like air pollution or humidity. | Monitors environmental triggers through sensors and alerts patients when conditions worsen. |
| Data Analytics | Cannot log or analyze usage data over time. | Syncs data to an app, generating detailed adherence reports for patient and doctor review. |

| | | |
|---|---|---|
| Proactive Healthcare | Reactive only—used during symptoms or exacerbations. | Proactively reminds patients about preventive medication and alerts them to avoid environmental triggers. |
| Healthcare Integration | Functions as a standalone device with no integration into the healthcare system. | Integrates with cloud systems, enabling remote monitoring, teleconsultations, and real-time interventions. |

## 1.4 Problem Statement:

**1. *Incorrect Inhaler Usage*:**

Many patients struggle to achieve proper inhalation technique, which is critical for effective medication delivery to the lungs. This often leads to insufficient drug intake and reduced treatment efficacy.

**2. *Non-Adherence to Medication Regimens*:**

Consistent use of prescribed inhalers is essential for managing asthma effectively. However, patients often forget doses, skip treatments, or fail to adhere to their medication schedule, increasing the risk of exacerbations and complications.

**3. *Absence of Personalized Feedback*:** Asthma varies greatly between individuals due to differences in triggers, severity, and treatment responses. Traditional inhalers lack mechanisms to provide real-time feedback or actionable insights, leaving patients unaware of their adherence and disease management quality.

**4. *Frequent Doctor Visits*:**

Without access to real-time condition monitoring, asthma patients must frequently visit their doctors to report their symptoms and discuss their management progress. This reliance on in-person consultations can be inconvenient and may delay timely adjustments to their treatment plans.

## 1.5 Goals:

1. **Help Patients Stick to Their Treatment** Ensure users take their medication on time with helpful reminders and real-time tracking of inhaler usage.
2. **Provide Instant Monitoring** Design a device that keeps track of inhaler usage and environmental factors, offering real-time updates and alerts.
3. **Offer Personalized Support** Use AI to analyze each patient's unique data and provide tailored advice to improve their asthma care.
4. **Strengthen Doctor-Patient Communication** Create a dashboard for doctors that gives clear insights into how patients are doing, making it easier to adjust treatments.
5. **Make Technology Simple and Seamless** Build an easy-to-use app and smart device that work together smoothly, providing real-time updates and helpful notifications.
6. **Prevent Problems Before They Happen** Use predictive technology to identify risks like missed doses or bad environmental conditions, giving users early warnings.
7. **Support Remote Care** Allow doctors to monitor patients' health remotely, reducing the need for frequent clinic visits.
8. **Empower Patients Through Knowledge** Give users detailed reports and insights about their condition so they can understand their health and make better decisions.

# 2. LITERATURE REVIEW:

The advent of smart device for inhalers has revolutionized the management of respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD). These devices leverage IoT, artificial intelligence, and mobile technology to provide real-time monitoring, personalized insights, and improved medication adherence. Over the past decade, several companies—including **Lupin**, **Propeller Health**, **Hailie**, and **Findair**—have developed innovative smart devices for inhalers, each with unique features and capabilities. This section reviews the existing solutions, highlighting their strengths, limitations, and the gaps they leave unaddressed. By analyzing these technologies, we aim to identify opportunities for innovation in our AI-powered smart inhaler project.

**1. Lupin's Smart Device (India)**

Lupin launches "Adhero," first-of-its-kind connected Smart Device with inhaler in India to support treatment of respiratory disease.

**Features**:

- First-of-its kind smart device launched in India to track usage pattern of metered dose inhaler (MDI) by patients.
- Reusable device with built-in sensors to track daily usage and consumption pattern.
- Companion app MyAdhero connects the device to smartphones via Bluetooth through which patients can access information and set reminders.
- Physicians using the app can monitor patient adherence to therapy to improve clinical outcomes.

**2. Propeller Health**

Propeller is a doctor-recommended program that includes sensors for your inhalers and a mobile app or online portal, plus personalized support to help you every step of the way.

**Features**:

- Propeller sensors capture unique signals that passively record events, such as medication usage or respiration, and transmit data to Propeller via Bluetooth or hub connection.
- The mobile app for iOS or Android empowers patients to self-manage chronic conditions. Disease education, Trigger management, Medication use data, Healthy habit formation
- Support ensures patients, caregivers, and clinicians have the resources they need to confidently navigate the Propeller Platform, including product and technical assistance.

**3. Findair**

FindAir System is a set of tools for cooperation between patient and doctor that enhances every remote consultation. Data collected by smart inhalers is shared with the patient and the doctor so that they can work together towards the better care. FindAir System is a set of tools for cooperation between patient and doctor that enhances every remote consultation. Data collected by smart inhalers is shared with the patient and the doctor so that they can work together towards the better care.

**Features**:

- Usage time and location
- Weather conditions on inhaler use
- Air pollutants in usage area
- Medication adherence

**4. Hailie Sensors (Australia)**

The Hailie® sensor attaches to your inhaler and monitors your medication usage. The Hailie® app provides visualization of your medication usage and medication reminders.

The Hailie® sensor records the date and time the medication is actuated, and stores this information in memory. The Hailie® sensor uploads medication usage to a compatible software reporting application for review by medication users, healthcare professionals, managed providers and payors.

**Features**:

- Tracks your inhaler medication usage for asthma and COPD control
- Reminds you when it is time to take your prescribed doses with audiovisual cues
- Uploads your medication usage data directly to your mobile device using *Bluetooth*® enabled communications
- Displays your medication usage data via the Hailie® app to help you manage your condition better and to share with your health professional
- Refill friendly. Each time you refill your prescription, simply attach your Hailie® sensor onto your new inhaler
- Available in Rechargeable and Non-Rechargeable version

# 3. METHODOLOGY:

## 3.1 USER RESEARCH:

In context to these problem statements, there is a need for smart solution in treatment of asthma patients that care them like a nurse in hospital. A device that can care them everywhere. To understand the requirements and preferences of patients, we conducted an extensive user survey. This involved creating a form for asthma patients that are diagnosed with asthma. We distributed these forms both online and offline, receiving several responses to date. Hard copies were also provided in clinics to ensure accessibility. We personally visited doctors to discuss the issue, gaining valuable insights into the challenges of managing asthma. Similarly, we engaged in one-on-one discussions with asthma patient to understand their perspectives and difficulties.

- We focused on gathering insights into daily challenges, inhaler usage habits, and factors affecting medication adherence.
- There are total 14 questions in Survey form of Asthma patients which included frequency of inhaler usage, awareness of asthma triggers, and what type of features they find very useful in a smart inhaler.

**Key Parameters Identified from Survey:**

In our survey of patients regarding the type of inhaler they predominantly use, the results indicated a clear preference for Metered-Dose Inhalers (MDIs).

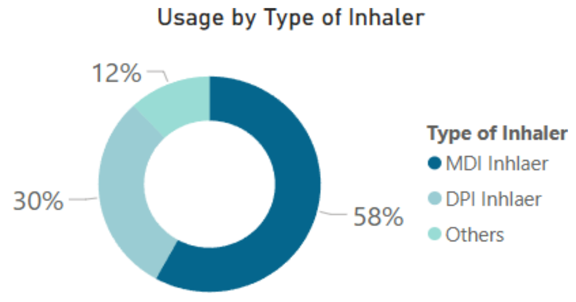



**Fig. 1** What type of inhaler they used?

From Fig. 1, 58% of the respondents reported using MDI inhalers, while 30% used Dry Powder Inhalers (DPIs), and the remaining 12% utilized other types of inhalers. Additionally, discussions with doctors revealed that they often recommend MDI inhalers to their patients. Given this majority, we have decided to prioritize the development of a smart device tailored specifically for MDI inhalers. Future iterations may expand to include smart devices for other types of inhalers based on user demand and feedback.

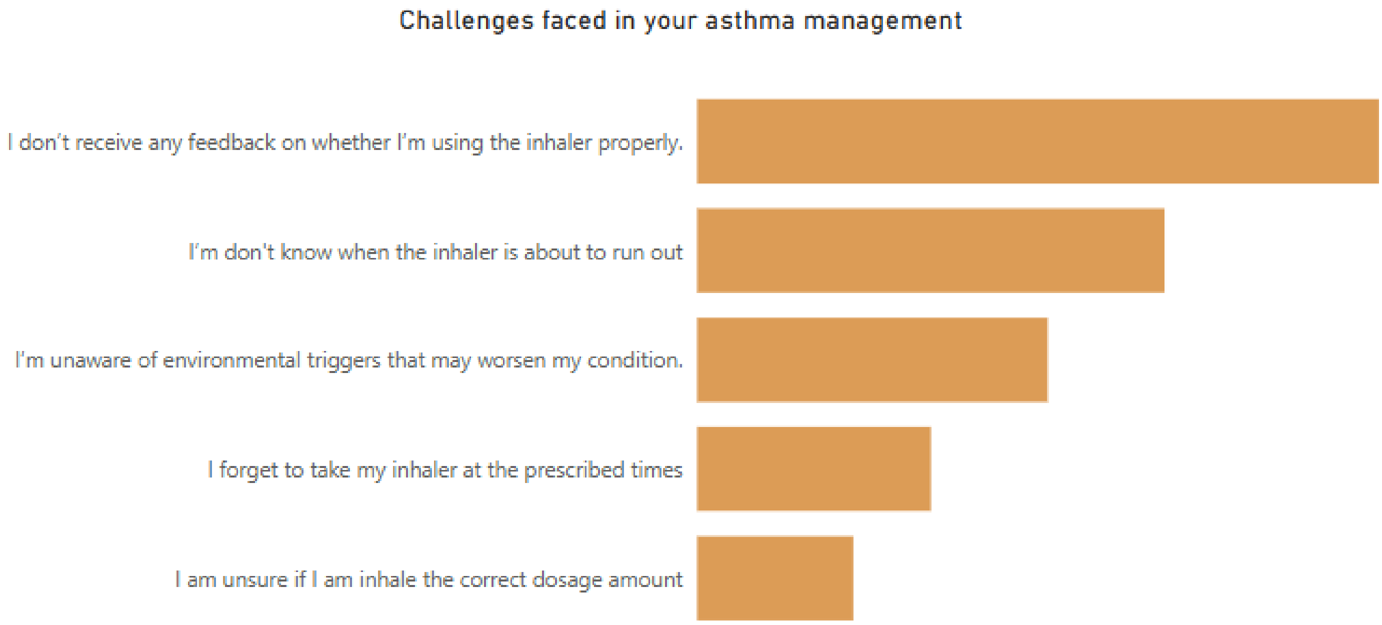



**Fig. 2** What challenges do you face while asthma management or using an inhaler?

From our survey, we learned about several challenges people face while managing their asthma. Many shared that they don't get any feedback on whether they're using their inhaler correctly, which makes them unsure if they're doing it right. Doctors also highlighted that patients often struggle to know if they're inhaling the medication properly, which can affect its effectiveness. Others mentioned they often don't know when their inhaler is about to run out, leaving them worried about running out of medication. Some also found it hard to identify environmental triggers that could make their asthma worse. Forgetting to take their inhaler on time was another common issue, along with concerns about whether they're inhaling the right amount of medication. These insights show a clear need for better support, like reminders, feedback, and tracking, to help people manage their asthma more effectively.

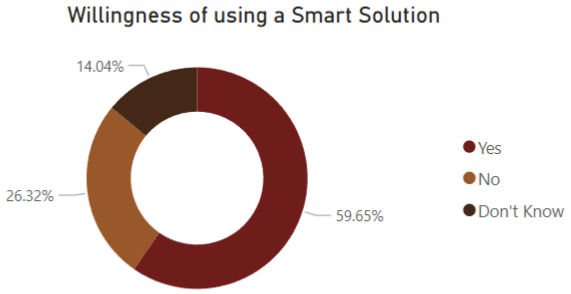



**Fig. 3** Would you adopt Smart Solution?

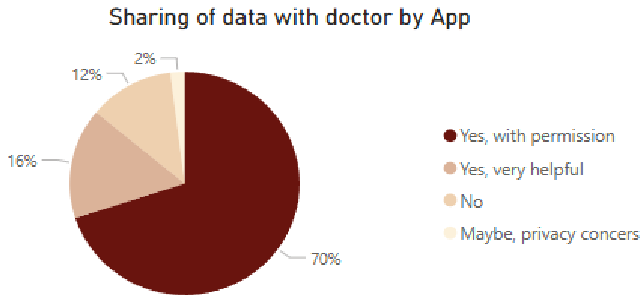



**Fig. 4** Would you share your health data with your doctor?

In addition to exploring technical feature preferences, we focus on questions (Fig. 3,4,5) that assess users' willingness to adopt a smart solution, their openness to sharing health data with their doctors, and their budget for such a solution. Through these and other targeted questions, we identify both **functional requirements**—the specific features and capabilities users expect—and **non-functional**

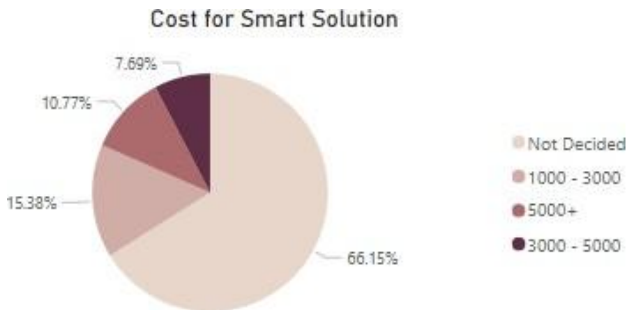



**Fig.5** How much you pay for Smart Solution?

**requirements**, such as usability, affordability, and data security concerns. This approach ensures that the design and development align with user needs and expectation.

## 3.2 Functional Requirements:

**1. Recording Inhaler Usage**

The device must be equipped with sensors to accurately track and record usage events, including:

- The timestamp of each inhalation.
- The number of doses administered.
- Environmental factors (e.g., temperature, humidity, air quality) that might affect respiratory health.

**2. AI-Driven Data Analysis**

The system must employ Artificial Intelligence to analyze usage data and provide personalized insights, such as:

- Adherence patterns to prescribed medication schedules.
- Predictive alerts for potential health issues based on trends.

**3. Mobile Application for Interaction**

A companion mobile app must facilitate interaction between patients, doctors, and the device, offering:

- A user-friendly dashboard for patients to view their usage history, medication adherence, and AI-generated insights.
- Notifications and reminders for medication schedules.
- Data-sharing capabilities with healthcare providers to enable better monitoring and timely interventions.
- Emergency alerts or suggestions for follow-up actions based on device analysis.
- Alerts when inhalation technique is incorrect, including guidance to improve technique.

## 3.3 Non - Functional Requirements:

**1. Performance Requirements**

- The device must process inhalation data and provide alerts within 1 second of incorrect usage.
- The AI analysis must generate actionable insights within 30 seconds of data synchronization.

**2. Usability Requirements**

- The mobile app must feature a highly intuitive design to accommodate users of diverse ages and technical abilities.
- Alerts and recommendations must be presented in a clear, concise, and actionable format.

**3. Security Requirements**

- Patient data must be secured using end-to-end encryption during storage and transfer.
- The device and application must comply with regional healthcare and data privacy regulations such as HIPAA, GDPR, and India’s PDP Bill.

**4. Scalability Requirements**

- The system must scale to handle increasing data loads with up to 1 million active users efficiently.
- Cloud infrastructure must adapt dynamically to user growth without impacting performance.

**5. Maintainability Requirements**

- Software updates, including security patches and feature enhancements, must be deliverable through OTA updates.
- Maintenance should involve minimal downtime, with user notifications before planned updates.

**6. Environmental Requirements**

- The device must operate reliably in various environmental conditions (e.g., temperatures from 0°C to 50°C).
- Materials used in the device must be durable and environmentally friendly, ensuring long-term usage.

## 3.4 Conceptual Design:

### 3.4.1 *Proposed System:*

A Smart Device for inhaler has been proposed. The proposed system will not only smarter the traditional system of using Inhaler, but also increase the efficiency by accurate prediction of the availability, the amount of doze of medicine depending on the patient's context. The proposed architecture is shown in Fig. 6

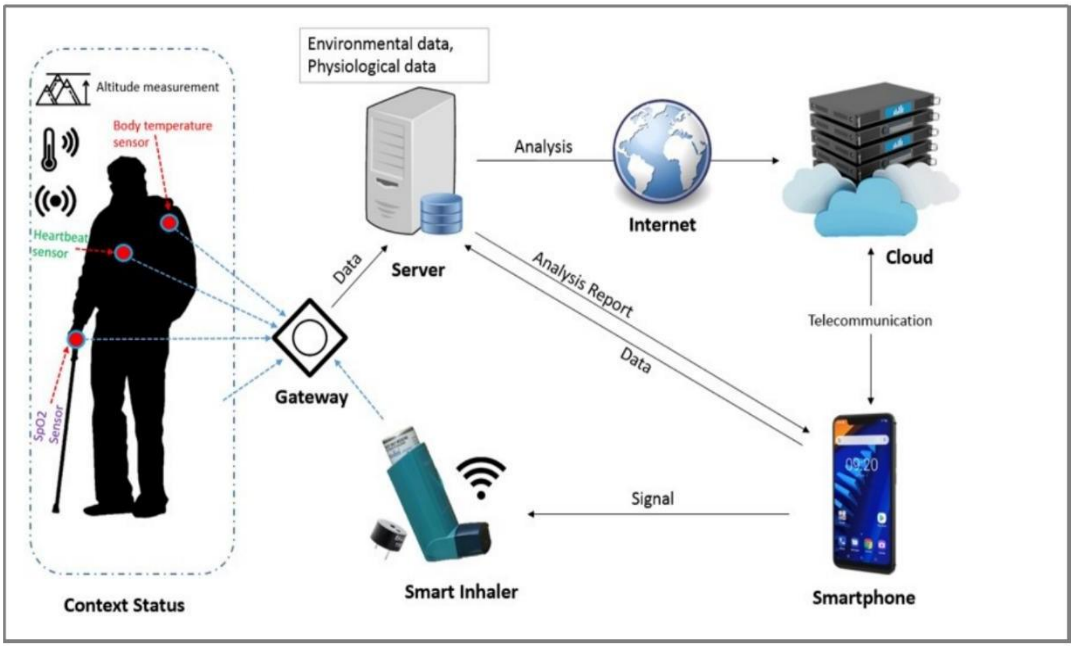



**Fig. 6** Proposed Architecture

*Source: IoT Based Smart Inhaler for Context-Aware Service Provisioning by ResearchGate.net*

### 3.4.2 *Implementation:*

The proposed system has been implemented to validate the efficiency of the system. The implementation architecture has been shown in Fig. 7

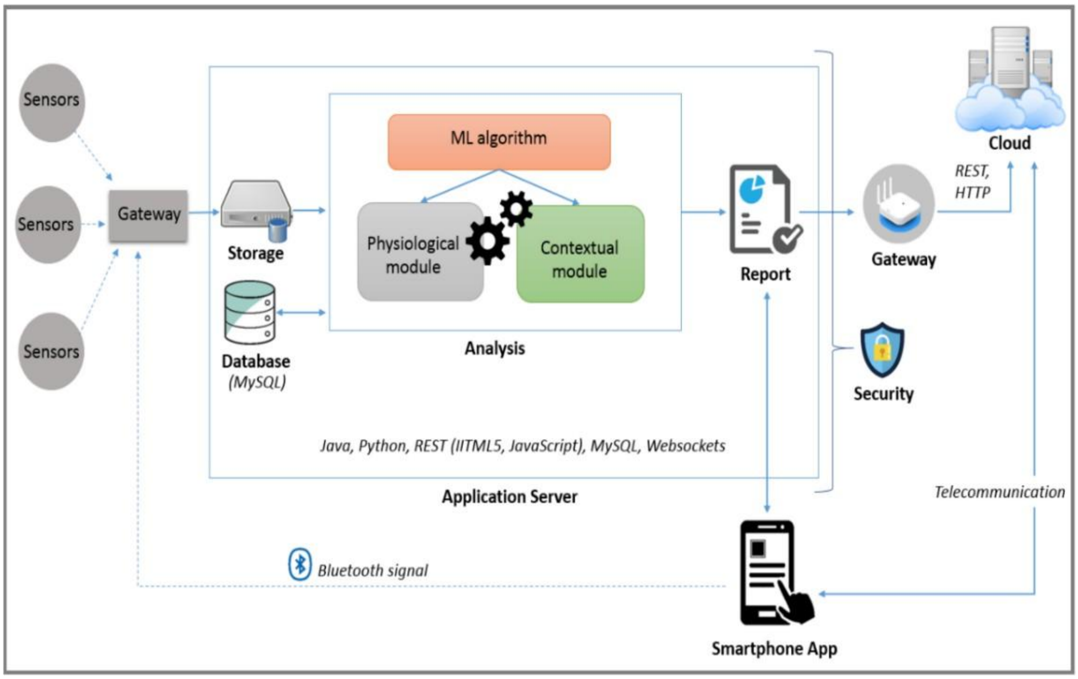



**Fig. 7** Implementation of the Proposed Architecture

*Source: IoT Based Smart Inhaler for Context-Aware Service Provisioning by ResearchGate.net*

### *3.4.3 Conceptual Flow:*

1. **Data Recording**: Data is collected from a user's smart device and health band, capturing key health and activity parameters.
2. **Data Collection**: The system gathers essential metrics such as heart rate, steps, sleep patterns, etc.
3. **Data Processing**: The collected data is processed and transmitted to a cloud-based system for further analysis.
4. **Mobile App Integration**: The processed data is retrieved from the cloud and integrated into a mobile application.
5. **App Notification**: The app sends notifications to the user, providing real-time updates and alerts based on the analyzed data.
6. **Data-Driven Adjustments**: Insights derived from the data analysis are used to suggest personalized adjustments or recommendations for improving health and wellness.

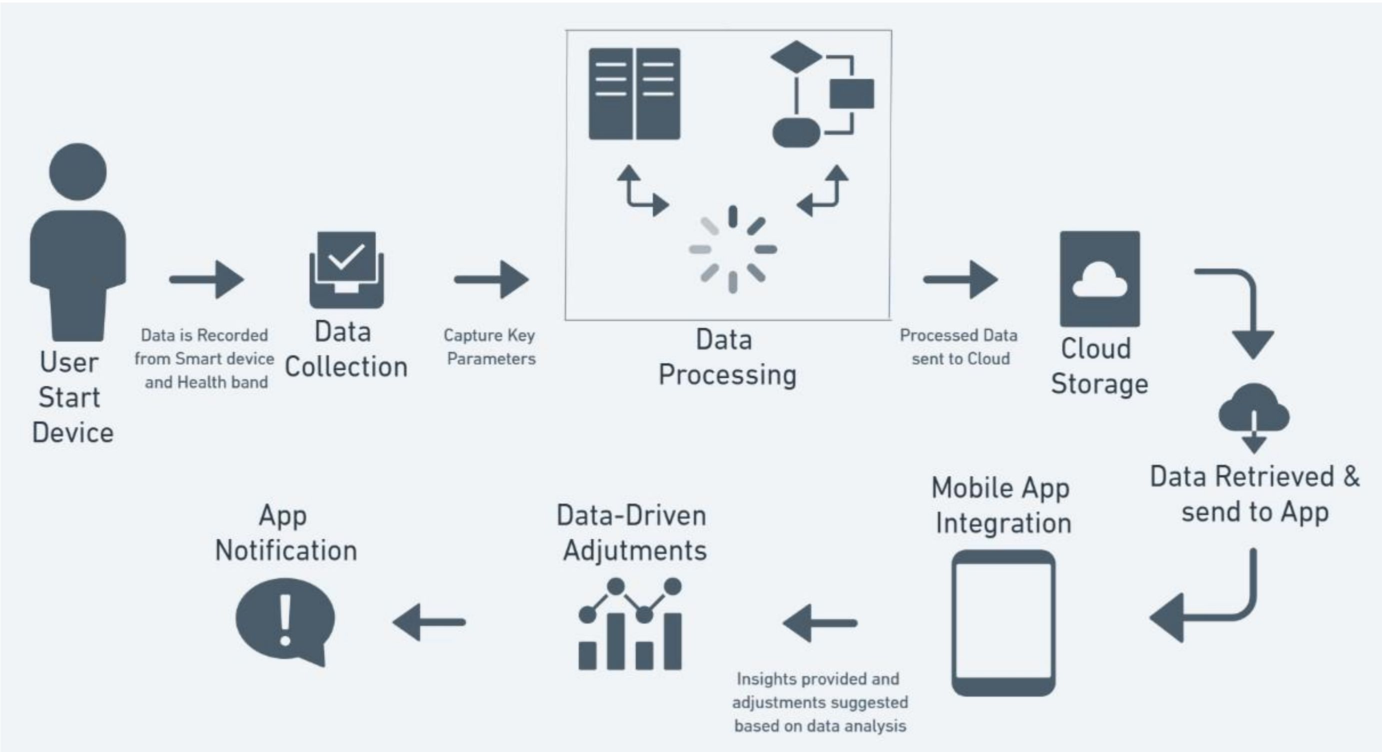



**Fig. 18** Workflow

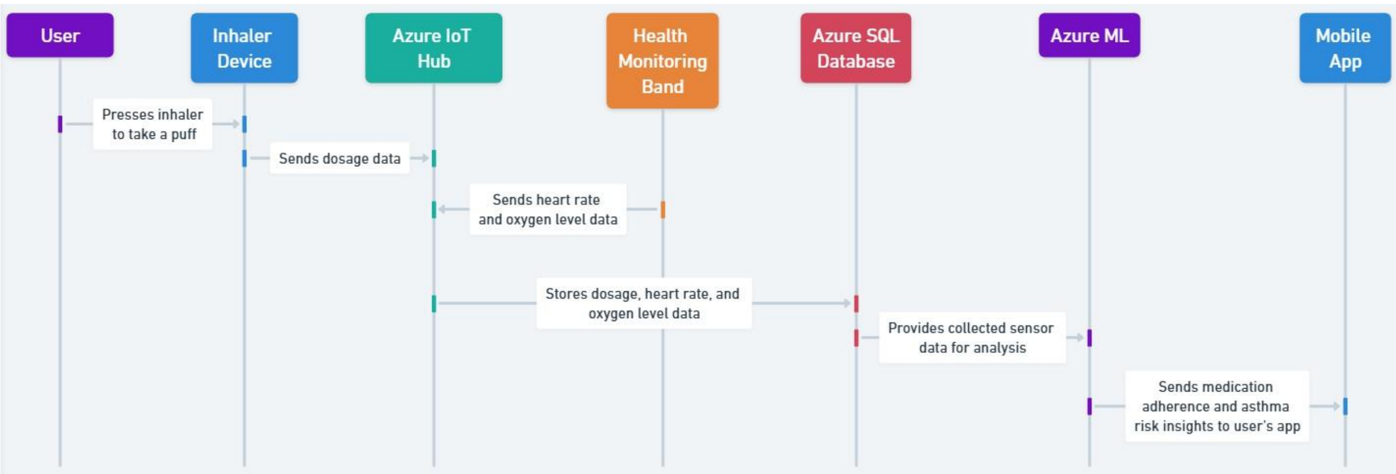



**Fig. 19** Cloud Workflow

# 4. DESIGN AND DEVELOPMENT:

## 4.1 HARDWARE DESIGN:

The **Design Phase** focuses on planning an efficient, reliable, and cost-effective hardware system to meet the project's functional requirements. Key objectives include defining functional goals, selecting components, and creating a blueprint for prototyping.

**Design Constraints:**

1. **Size:** Compact form factor for portability or application-specific requirements.
2. **Power:** Energy-efficient design, crucial for battery-operated systems.
3. **Cost:** Optimized component selection to balance functionality and budget.
4. **Functionality:** Support for core features like sensing, processing, and communication.

The hardware must align with project goals by fulfilling both functional and non-functional requirements. Functionally, it should support sensing, data processing, and communication, with potential user interface capabilities. Non-functional requirements emphasize power efficiency for extended battery life, durability to withstand environmental conditions, portability for ease of use, scalability for future upgrades, and cost-effectiveness to balance functionality and budget constraints.

**Component Research and Selection:**

### 4.1.1 SENSORS:

### 1. DIFFERENTIAL PRESSURE SENSOR:

**Purpose:** Measures differential pressure, specifically designed for low-pressure applications like airflow detection in medical and industrial settings.

**Model:** Sensirion SDP31-500PA.

**Operating Principle:** Based on MEMS (Micro-Electro-Mechanical System) technology, the sensor utilizes a thermal measurement principle to determine differential pressure with high accuracy and sensitivity.


**Fig. 8** Sensirion SDP 31
*Source: https://sensirion.com*

**Key Specifications**

- **Measurement Range: -** 500 to 500 Pa (- 2 to 2 in $H_2O$)
- **Accuracy:** 3 %
- **Resolution:** 16 bits
- **Response Time:** 45 ms in triggered mode and 0.5 ms in continuous mode.

**Electrical Characteristics**

- **Operating Voltage:** 3 – 3.6 V
- **Average Supply Current:** 3800 uA
- **Power Consumption:** 0.02 W
- **Output Type:** $I^2C$.

**Physical and Environmental Specifications**

- **Size/Dimensions:** 8.5mm X 5.5mm X 5.15mm (Length X Breadth X Height)
- **Operating Temperature Range:** -30°C to 85°C.

**Applications**

- **Real – Time Feedback:** Providing feedback via connected apps or devices to ensure the patient uses the inhaler correctly.
- **Personalized Therapy:** Collecting data for tracking patient usage patterns and customizing treatment plans based on respiratory performance.

The **Sensirion SDP31** is ideal for the smart inhaler due to its compact size, ultra-low power consumption (0.02 mW), and high precision. Its differential pressure measurement capability (±500 Pa) makes it well-suited for accurately detecting small pressure changes associated with breathing. Additionally, its fast response time ensures real-time monitoring, critical for medical applications. Its digital I2C interface simplifies integration with microcontrollers, reducing complexity.

## 2. Gas Sensor

**Purpose:** Measures gas concentrations, like carbon monoxide (CO), nitrogen dioxide ($NO_2$), ethanol ($C_2H_5OH$), Hydrogen ($H_2$), ammonia ($NH_3$), methane ($CH_4$) for air quality monitoring.

**Model:** MiCS-4514.

**Operating Principle:** A metal-oxide (MOX) semiconductor sensor that detects gas concentrations based on changes in its conductivity when exposed to targeted gases.


**Fig. 9** Gas Sensor (MiCS-4514)
*Source: https://www.amazon.in/*

**Key Specifications**

- **Measurement Range:** 1 – 1000ppm (Carbon monoxide CO) 0.05 – 10ppm (Nitrogen dioxide $NO_2$) 10 – 500ppm (Ethanol $C_2H_5OH$) 1 – 1000ppm (Hydrogen $H_2$) 1 – 500ppm (Ammonia $NH_3$) >1000ppm (Methane $CH_4$)
- **Accuracy:** 0.25 ppm
- **Resolution:** 1 ppm for CO and 50 ppb for $NO_2$
- **Response Time:** < 10s.

**Electrical Characteristics**

- **Operating Voltage:** 3.3 – 5.5 V
- **Average Supply Current:** 32 mA
- **Power Consumption:** 0.45 W
- **Output Type:** $I^2C$.

**Physical and Environmental Specifications**

- **Size/Dimensions:** 37 mm X 27 mm X 6 mm (Length X Breadth X Height).
- **Operating Temperature Range:** -30°C to 85°C.

**Applications**

- **Air Quality Assessment:** Monitoring the surrounding air for harmful gases (e.g., CO and $NO_2$) to avoid inhaler use in environments with poor air quality.
- **Personalized Alerts:** Providing users with real-time notifications if the air quality is hazardous, suggesting delays in usage until safer conditions are present.

The **MiCS-4514** enhances the inhaler add-on by providing real-time detection of harmful gases like CO and $NO_2$, which are critical for respiratory health. It ensures user safety by alerting them to poor air quality, preventing inhaler use in hazardous conditions. Compact, cost-effective, and easy to integrate, it supports smart features like data logging and environmental insights, improving treatment efficacy and aligning with the device's goal of personalized respiratory care.

### 3. Temperature and Humidity Sensor

**Purpose:** Measures ambient temperature and relative humidity for environmental monitoring.

**Model:** AHT10.

**Operating Principle:** Uses a capacitive humidity sensing element and a temperature sensor with a digital I2C interface to deliver high-precision measurements.

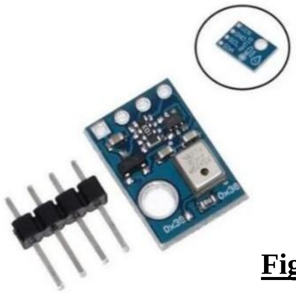


**Fig. 10** Temperature & Humidity Sensor (AHT10)
*Source: https://robu.in/*

**Key Specifications**

- **Measurement Range:** -40 ℃ - 85 ℃ (Temperature) & 0 – 100 %RH (Humidity).
- **Accuracy:** ± 0.3 ℃ (Temperature) & ± 2 %RH (Humidity).
- **Resolution:** 0.01 ℃ (Temperature) & 0.024 %RH (Humidity).
- **Response Time:** 5 – 30 s (Temperature) & 8 s (Humidity).

**Electrical Characteristics**

- **Operating Voltage:** 1.8 – 3.6 V
- **Average Supply Current:** 23 uA
- **Power Consumption:** 0.07 uW
- **Output Type:** $I^2C$.

**Physical and Environmental Specifications**

- **Size/Dimensions:** 37 mm X 27 mm X 6 mm (Length X Breadth X Height).
- **Operating Temperature Range:** -40 ℃ - 85 ℃.

**Applications**

- **Environmental Monitoring:** Measures ambient humidity and temperature to ensure conditions are optimal for effective inhaler use.
- **Inhaler Efficacy Optimization:** Tracks environmental factors that can affect medication aerosolization and delivery.
- **User Guidance:** Alerts users if humidity or temperature conditions fall outside recommended ranges for safe inhaler use.

The **AHT10** temperature and humidity sensor is an ideal choice for the inhaler add-on, offering high accuracy and low power consumption. Monitoring humidity and temperature ensures optimal inhaler use by verifying environmental conditions that affect medication delivery. Its compact size, digital output (I2C), and fast response time make it easy to integrate into the device, enhancing performance without compromising portability. Cost-effective and reliable, the AHT10 adds critical environmental monitoring capabilities, supporting better respiratory health management.

### 4. Heart Rate and Pulse Oximeter Sensor

**Purpose:** The MAX30102 is an integrated pulse oximetry and heart-rate monitoring sensor designed for medical and fitness applications.

**Model:** MAX30102.

**Operating Principle:** The sensor uses optical measurement, emitting red and infrared light into the skin and measuring the reflected light to determine blood oxygen levels (SpO2) and heart rate. The Photoplethysmogram (PPG) principle tracks the changes in blood volume in the capillaries.

**Fig. 11** MAX30102
*Source: https://robu.in/*

**Key Specifications:**

- **Measurements:** Blood oxygen saturation (SpO2), heart rate, PPG waveform.
- **LED Wavelengths:**
  - Red: ~660 nm.
  - Infrared: ~880 nm.
- **Data Resolution:** 18-bit or higher.

**Electrical Characteristics:**

- **Supply Voltage:** 1.8V for core operations & 3.3V for LEDs.
- **Current Consumption:** Low-power standby mode: ~0.7 µA.

**Interface:**

- Digital I²C interface for data communication.

**Physical Properties:**

- Compact size: 20.3mm x 15.4mm x 2mm (L x W x H).

**Applications:**

1. **Vital Sign Monitoring:** Tracks real-time SpO2 and heart rate during inhaler use to monitor the effectiveness of medication.
2. **Usage Feedback:** Alerts users if vital signs show irregular patterns during treatment.
3. **Emergency Indicators:** Detects critical drops in oxygen levels during an asthma attack or other respiratory distress.

The **MAX30102** is highly compact, power-efficient, and capable of providing real-time, non-invasive vitals monitoring. Its compatibility with portable devices and advanced health metrics makes it an excellent addition to enhance the inhaler add-on, supporting personalized healthcare and treatment optimization.

### 4.1.2 MICROCONTROLLER:

**Purpose:** Microcontroller with built-in Bluetooth Low Energy (BLE) capability and onboard environmental, motion, and light sensors for wireless communication and sensor integration.

**Model/Part Number:** Seeed Studio XIAO nRF52840 Sense.


**Fig. 12** nRF52840 Sense
*Source: https://www.amazon.in/*

**Operating Principle:** Based on a Nordic Semiconductor SoC (System on Chip), the device uses a 32-bit ARM Cortex-M4 processor and integrates multiple sensors and wireless communication on a single platform.

**Processor and Memory:**

- **Processor:** 32-bit ARM Cortex-M4 with FPU.
- **Clock Speed:** 64 MHz.
- **Flash Memory:** 1 MB.
- **RAM:** 256 KB.

**Wireless Connectivity:**

- **Bluetooth:** BLE 5.0 (supports Long Range, 2 Mbps, and Advertising Extensions).
- **Other Protocols:** 802.15.4 (Zigbee, Thread), NFC, ANT, and proprietary 2.4 GHz.
- **Range:** Up to 200 meters (line of sight, BLE 5 Long Range).

**Interfaces:**

- **Digital Interfaces:** I2C, SPI, UART, QSPI (for external storage).
- **Analog Input:** 12-bit ADC.

**Power and Consumption:**

- **Operating Voltage:** 3.3 V.
- **Power Consumption:**
    - 1 µA in sleep mode.
    - ~5.3 mA during radio transmission.
- **Battery:** Compatible with coin-cell, LiPo, and other sources.

**Form Factor:**

- **Dimensions:** 21 mm X 17.8 mm X 6 mm.

The **nRF52840 Sense** is an ideal solution for your inhaler add-on device due to its robust processing capabilities, built-in BLE for wireless features, and versatility in environmental monitoring. Its scalability and integration support make it a strong candidate for enhancing the functionality of IoT-enabled medical devices.

### 4.1.3 BATTERY:

**Purpose:** The **WLY102535 & WLY450838** is a rechargeable Lithium-Polymer (LiPo) battery designed to provide a reliable, compact, and lightweight power source for portable electronic devices.

**Model:** WLY102535 950 mAh 3.7V & WLY450838 120 mAh 3.7V

**Operating Principle:** This single-cell LiPo battery operates using lithium-ion technology with a polymer electrolyte. During discharge, lithium ions move from the anode (graphite) to the cathode (lithium cobalt oxide or a similar material), generating an electric current. During charging, the ions flow in reverse.

**Fig. 13** LiPo Battery (a) 950 mAh (b) 120 mAh
*Source: https://www.amazon.in/*

**Electrical Characteristics:**

- **Nominal Voltage:** 3.7 V
- **Capacity:** 950 mAh & 120 mAh
- **Energy:** ~3.5 Wh
- **Charge Voltage:** 4.2V (max).

**Physical Dimensions:**

- **Size:** 10 mm x 25 mm x 35 mm & 38mm X 8mm X 4.5mm (L X B X H).
- **Weight:** Approximately 20 g & 2 g.

**Performance:**

- **Operating Temperature:**
    - Discharge: -20°C to 60°C.
    - Charge: 0°C to 45°C.
- **Self-Discharge Rate:** ~3% per month at room temperature.

### 4.1.4. Buzzer:

**Purpose:** To generate an audible sound for alarms, alerts, or notifications in smart device for inhaler.

**Model:** 3V Active Electromagnetic Buzzer

**Operating Principle:** When powered by a 3V DC supply, the internal circuit generates an oscillating signal. This drives an electromagnetic coil that vibrates a diaphragm, producing sound.


**Fig. 14** 3V Buzzer
*Source: https://robu.in/*

**Specifications**

- Voltage: 3V DC
- Current: ~30 mA
- Sound Level: ~85 dB at 10 cm
- Frequency: ~2300 Hz
- Dimensions: ~12 mm diameter, 9 mm height

**Manufacturing Drawings & CAD Model:**

### 4.1.5 Manufacturing Drawing:

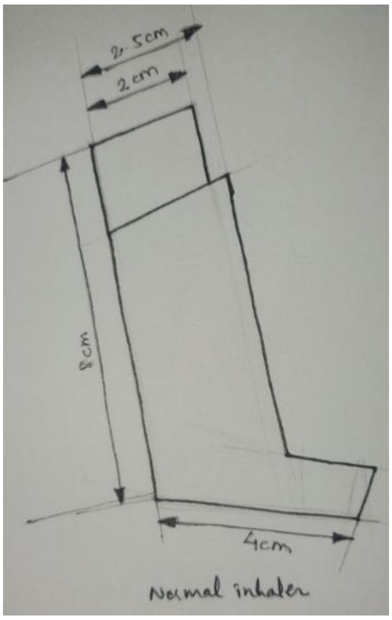



**Fig. 15** Normal MDI Inhaler

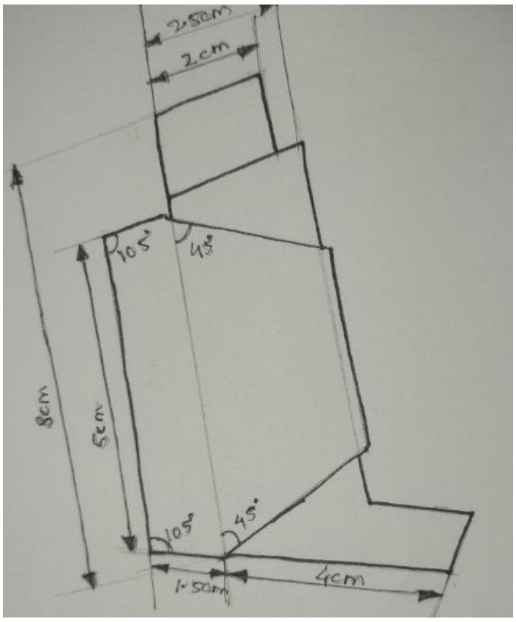



**Fig. 16** Inhaler with Smart Device (Side View)

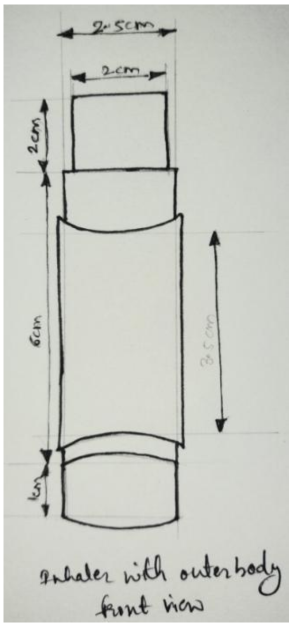



**Fig. 17** Inhaler with Smart Device (Front View)

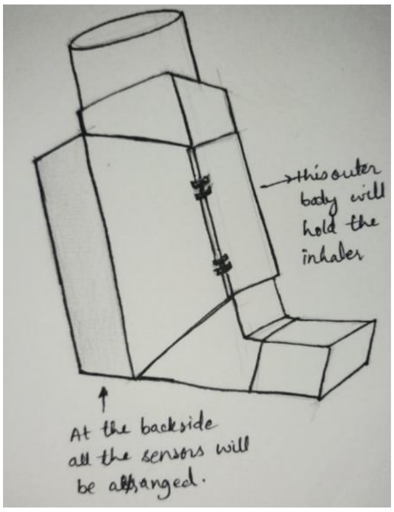



**Fig. 18** Inhaler with Smart Device

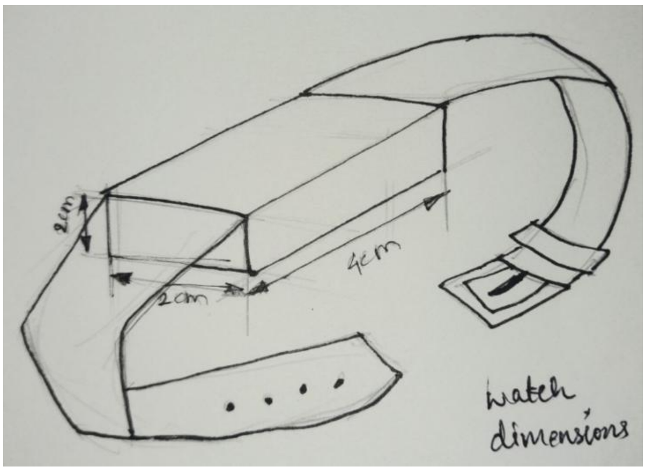



**Fig. 19** Health Monitoring Smart band comes with smart device

## 4.1.6 CAD Model:

### 1. Smart Device To Be Attached On Inhaler

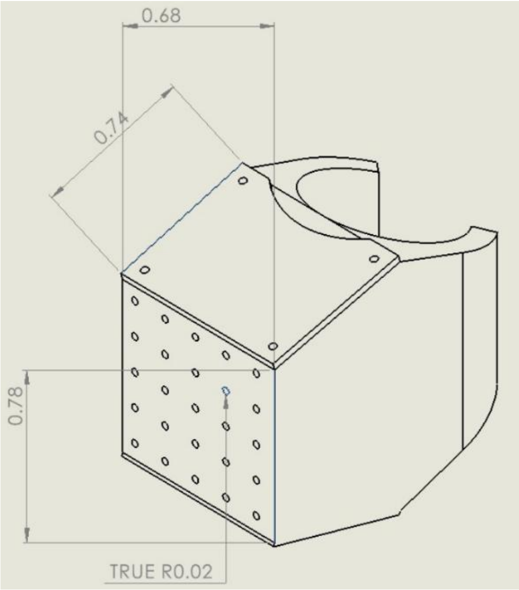



**Fig. 20** Isometric View

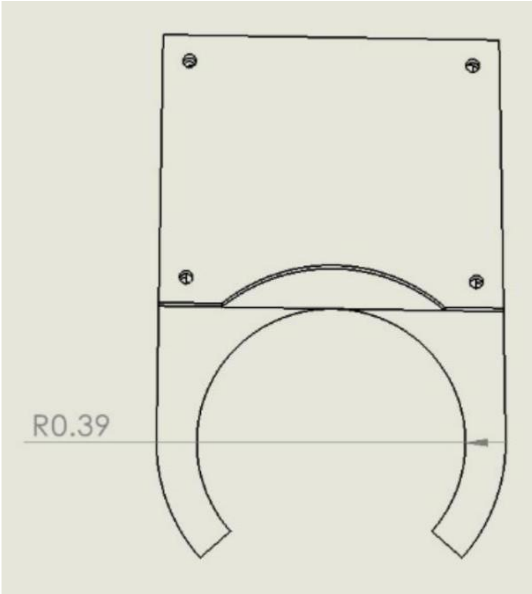



**Fig. 21** Top View

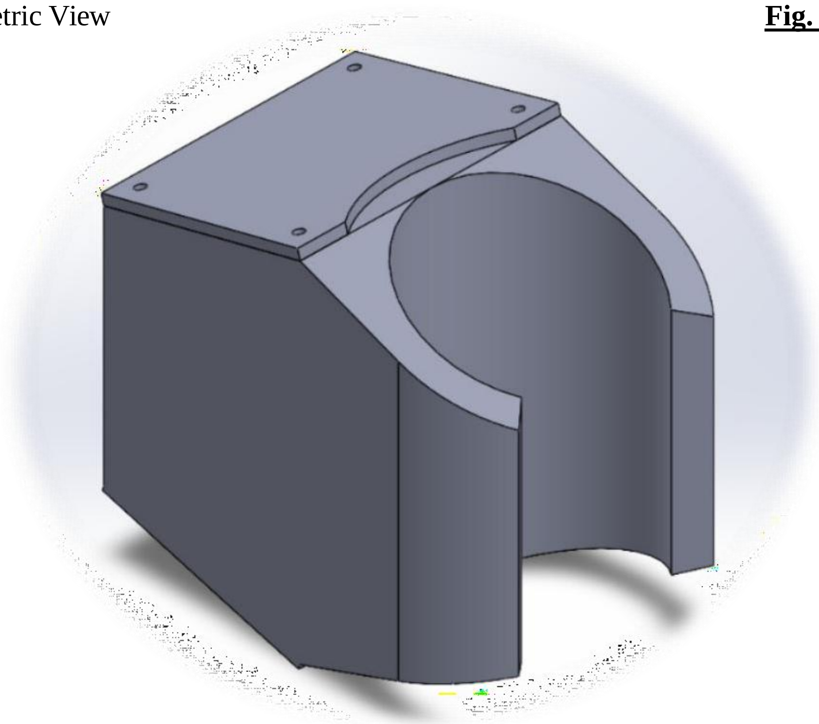


**Fig. 22** Smart Device CAD Model

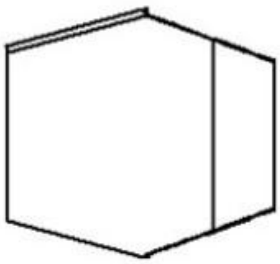


**Fig. 23** Side View

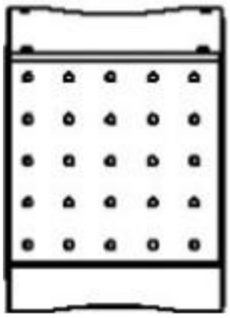


**Fig. 24** Front View

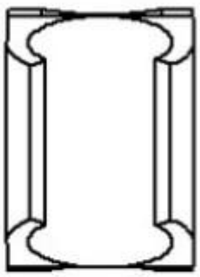


**Fig. 25** Back View

## 2. Smart Health Band

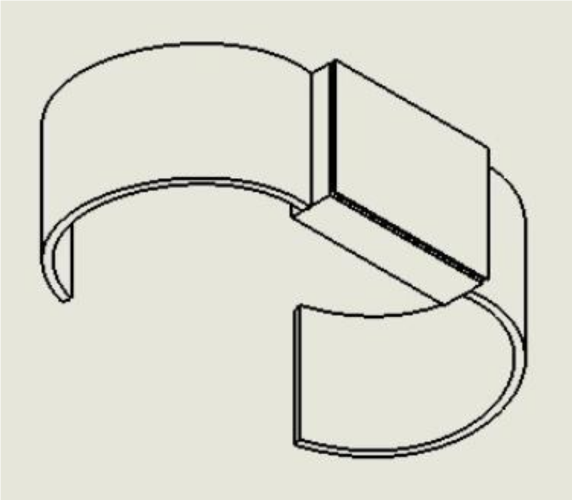


**Fig. 26** Isometric View

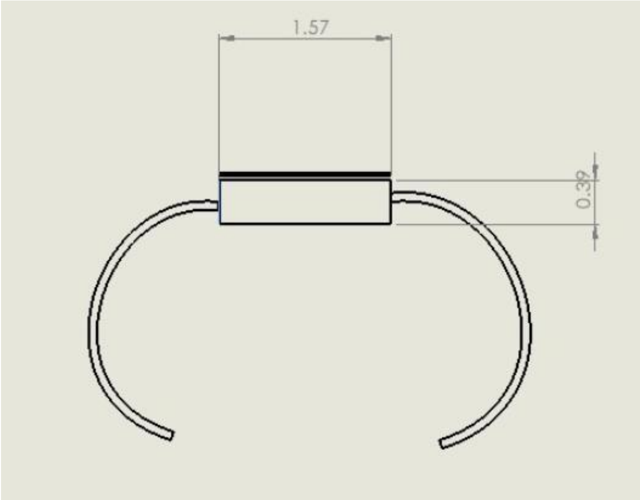



**Fig. 27** Side View

**Fig. 28** Smart Hand Band CAD Model

For 3D printing the inhaler add-on and smart band, the **Fused Deposition Modelling (FDM)** process was chosen due to its cost-effectiveness, material versatility, and ability to create functional prototypes with high precision. **PLA** was selected for the inhaler add-on to ensure biocompatibility and durability, while **TPU** was used for the smart band to provide flexibility and comfort. The design was optimized for layer adhesion, strength, and minimal material wastage, ensuring structural integrity and ease of use. Post-processing techniques like sanding and annealing were applied to enhance surface finish and durability.

## 4.2 Software Design:

### 4.2.1 System Architecture:

**Overview:** The system architecture is divided into three main layers:

1. **Device Layer**: Smart inhaler equipped with sensors to measure airflow, environmental conditions (e.g., humidity, temperature, air quality), and usage frequency.
2. **Cloud Layer**: Azure IoT Hub and Azure AutoML for data storage, processing, and predictive modelling.
3. **Application Layer**: React Native-based mobile application to display analytics and send notifications.

**Data Pipeline**:

1. Sensor data is collected by the smart inhaler and sent to Azure IoT Hub.
2. Data is processed and stored in Azure Storage.
3. Azure AutoML analyzes the data and predicts asthma attacks.
4. Notifications and insights are displayed on the mobile application.

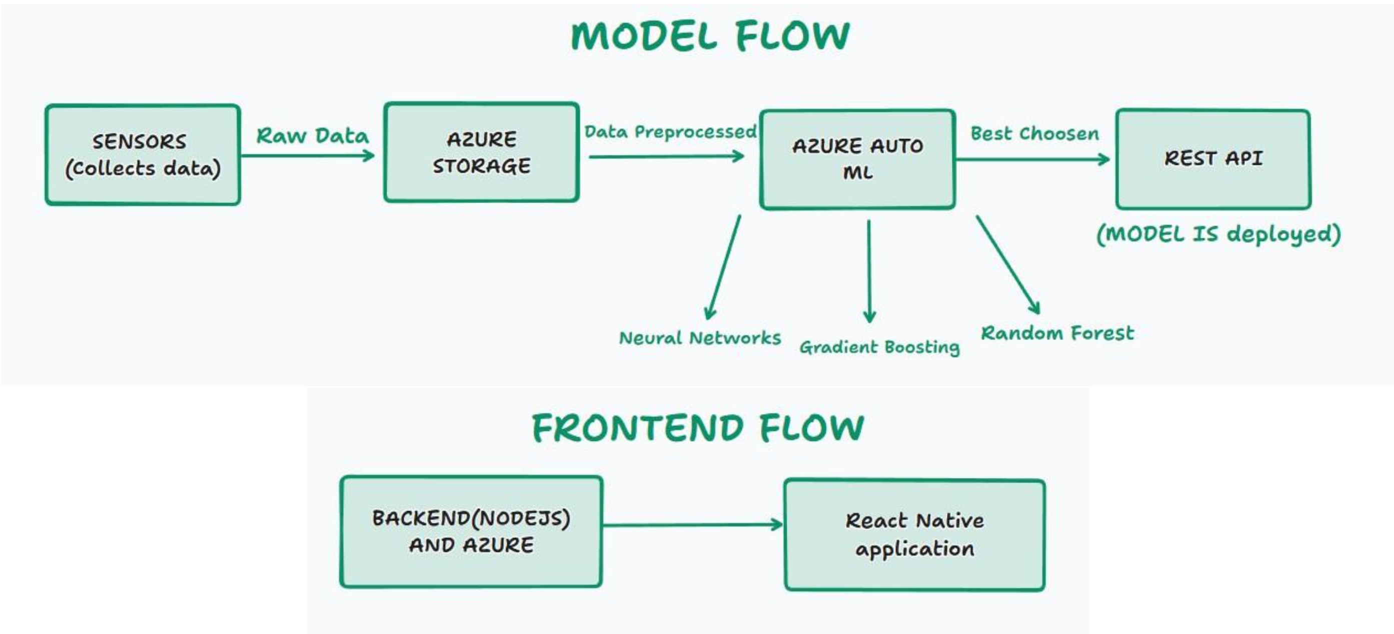



**Fig. 29** Data Flow of Device (a) Sensor to Cloud (b) Cloud to App

### 4.2.2 AI Model Design:

**1. Type of Model:**

- The model will leverage supervised learning to predict the likelihood of an asthma attack based on patient-specific and environmental factors.
- Possible algorithms include:
  - Gradient Boosting Algorithms: XGBoost, LightGBM, or CatBoost for structured data.
  - Recurrent Neural Networks (RNNs) or LSTMs: For temporal or sequential data (e.g., air quality index changes).

**2. Dataset Requirements:**

- Patient-Specific Data:
  - Demographics (e.g., age, gender, weight, smoking history).
  - Medical history (e.g., asthma severity, prior attack records, comorbidities).

- Medication adherence and usage frequency.

- Sensor Data:
  - Respiratory parameters (e.g., peak expiratory flow rate).
  - Heart rate, oxygen levels, and breathing patterns.
- Environmental Data:
  - Air pollution levels (e.g., PM2.5, PM10).
  - Weather parameters (temperature, humidity, wind speed).
  - Allergen exposure (pollen levels).

***Binary classification:*** 1 for asthma attack occurrence, 0 for no attack.

**3. Data Preprocessing:**

- Handling Missing Data
- Feature Engineering:
  - Calculate moving averages for pollution levels and vitals.
  - Create time-based features (e.g., season, time of day).
  - Extract anomaly patterns (e.g., sharp drops in oxygen levels).
- Normalization/Standardization: Normalize continuous features (e.g., heart rate, AQI).
- Balancing the Dataset: Apply techniques like SMOTE or class-weight adjustments for imbalanced classes.

**4. Model Evaluation Metrics:**

- Accuracy and Precision: Key for minimizing false positives.
- Recall (Sensitivity): Prioritize catching all asthma attacks to avoid life-threatening scenarios.
- F1 Score: Ensures a balance between precision and recall.
- ROC-AUC Score: Evaluates how well the model separates attack vs. non-attack cases.

**5. Implementation:**

- Feature Selection Tools**:** Recursive Feature Elimination (RFE), SHAP values for explainability.
- Model Selection: Compare multiple models for performance, e.g.:
  - Decision Trees for explainability.
  - LSTMs for temporal correlation.
  - Gradient Boosted Models for overall predictive performance.
- Frameworks and Tools: TensorFlow, Pytorch, Scikit-Learn.

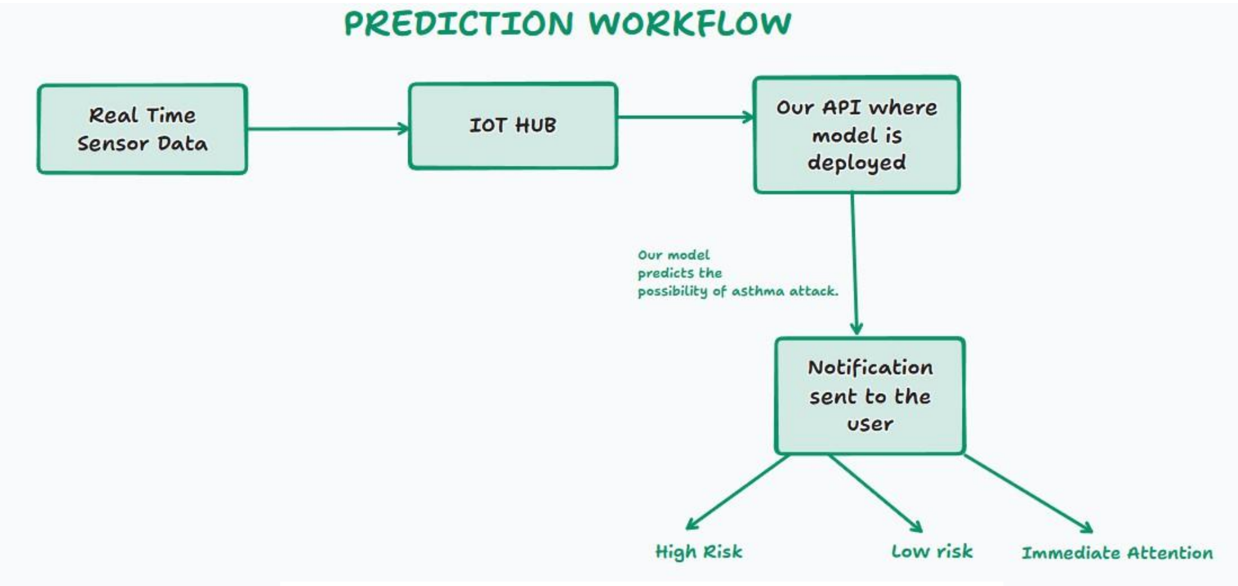



**Fig. 30** Prediction Workflow of Asthma attack

1. **Capturing Real-Time Data**: The inhaler is equipped with sensors that track vital information like breathing patterns, oxygen levels, and environmental factors such as air quality, humidity, and temperature. This ensures that all critical data is collected seamlessly as you go about your day.
2. **Processing Through the IoT Hub**: Once the sensors gather data, it's sent to an IoT hub, which acts like a smart middleman. The IoT hub ensures that the data is securely transferred and ready for deeper analysis.
3. **Analyzing with a Predictive Model**: The data is then analyzed by an advanced predictive model, hosted on an API. This model has been trained using a combination of patient health data and environmental conditions to detect patterns that might signal an oncoming asthma attack. The model uses cutting-edge machine learning techniques to provide highly accurate predictions.
4. **Sending Personalized Notifications**: Based on the analysis, the system sends you a notification through a mobile app. These alerts are designed to be simple yet actionable:
   - **High Risk**: A warning that an asthma attack might be imminent, encouraging you to take precautions.
   - **Low Risk**: A gentle reminder to stay alert and monitor your condition.
   - **Immediate Attention**: A critical alert advising you to seek medical help right away.

### 4.2.3 App Design:

The companion app for the Smart Inhaler is designed to provide a seamless and intuitive user experience while ensuring asthma management is effective and hassle-free. Below is an overview of the app's design and functionality:

**Features**

**1. Dosage Tracking**

**What It Does:**

- Tracks the amount of medication inhaled and checks if the technique is correct.
- A buzzer alerts users when the inhalation is improper.
- Sends low-medication alerts to help users refill on time.

**Why It's Useful:**

- Better Treatment: Ensures proper inhaler use for improved health.
- Prevents Risks: Instant feedback prevents misuse and under-treatment.
- No Last-Minute Stress: Low-med alerts avoid emergencies.

**How It Works:**

- Firmware: Sensors detect inhalation technique and activate the buzzer for errors.
- IoT Integration:
  - Azure IoT Hub sends inhalation and dosage data to the cloud.
  - Azure SQL Database stores real-time dosage data.
- Analytics: Azure AutoML analyzes inhalation patterns.
- Mobile App:
  - Built with React Native to show feedback and dosage updates.
  - Sends alerts when the medication supply runs low.

**2. Medication Reminders**

**What It Does:**

- Allows users to set customized reminders for their medication schedule via the app.
- Sends notifications at the right time to ensure users stick to their prescribed treatment plan.

**Why It's Useful:**

- Prevents Missed Doses: Ensures consistent medication, keeping asthma and COPD under control.
- Better Health: Reduces flare-ups and helps manage conditions effectively.
- Simplifies Life: Perfect for busy or elderly users juggling multiple meds.
- Encourages Ownership: Keeps users committed to their treatment.

**How It Works:**

- Mobile App:
  - Built with React Native to let users set and customize reminders.
  - Utilizes native notification APIs like Android's AlarmManager.
- Cloud Backend:
  - Azure Functions handle background scheduling and trigger notifications.
  - Azure SQL Database stores user reminder preferences.
- Notifications:
  - Azure Notification Hubs deliver timely reminders to users' devices.

**3. Environmental Monitoring**

**What It Does:**

- Continuously monitors environmental factors like air quality, pollen, dust, and temperature.
- Sends alerts when conditions are unfavourable (e.g., high pollutants or extreme temperatures), helping users take preventive actions.

**Why It's Useful:**

- Prevents Flare-Ups: Alerts warn users about potential asthma triggers, reducing attack risks.
- Encourages Proactive Care: Helps users avoid triggers like high pollen or extreme weather.
- Boosts Safety: Real-time alerts help users act quickly in changing conditions.

**How It Works:**

- IoT Sensors: Integrate sensors for air quality (AQI), temperature, and humidity into the inhaler.
- Data Collection:
  - Use Azure IoT Hub to send sensor data to the cloud.
  - Store historical environmental data in Azure SQL Database.
- Machine Learning:
  - Azure AutoML analyzes environmental data and links it to asthma symptoms.
  - Trains models to predict asthma attack risks based on environmental changes.
- Mobile App:
  - Display environmental data and send real-time alerts using React Native.
  - Provide actionable advice (e.g., staying indoors) when needed.

## 4. Find My Device

**What It Does:**

- Helps users locate their inhaler if misplaced by triggering a buzzer when the device is disconnected from Bluetooth.
- Users can also activate the buzzer manually through the app to find the inhaler.

**Why It's Useful:**

- Prevents Loss: Buzzer alerts when the inhaler is left behind, reducing chances of losing it.
- Saves Time: Quickly locates the inhaler during emergencies.
- Ideal for Shared Spaces: Makes it easy to find misplaced inhalers in homes, offices, or schools.

**How It Works:**

- Hardware:
    - Integrates a Bluetooth module and buzzer into the inhaler.
    - Buzzer activates on disconnection or manual trigger.
- Mobile App:
    - Adds a "Find My Device" button using React Native.
    - Uses Bluetooth Low Energy (BLE) APIs to monitor connection status.
- Cloud Backend:
    - Tracks the inhaler's status via Azure IoT Hub.
    - Logs connection events in Azure SQL Database for troubleshooting.

## 5. User Support Features:

A. **User Guide:** Step-by-step setup and feature instructions, like dosage tracking and reminders.
B. **FAQs:** Quick answers to common queries, e.g., setting reminders or light indications.
C. **Video Tutorials:** Simple videos showing how to use the device and app effectively.
D. **Health Resources:** Tips on asthma management, triggers, and links to trusted resources.
E. **Feedback Section:** Space for users to share feedback, report issues, or suggest improvements.

**How it works**:

- Content Management:
    - Store user guides, FAQs, and video tutorials in *Azure Blob Storage.*
- Mobile App:
    - Create a dedicated "Help" section using React Native.
    - Embed video tutorials using *React Native Video.*
- Feedback Module:
    - Build a feedback form using React Native and store responses in *Azure SQL Database.*
    - Analyze feedback trends with *Azure Machine Learning.*

## 6. User Account Features:

**1. Tracking Your Health History**
**What It Does**: The device keeps a record of your medication usage, including when and how much you took. It also tracks important health data like air quality (AQI), oxygen levels, and heart rate. This info is displayed in easy-to-read graphs, helping you and your doctor see patterns over time. By analyzing

these trends, your doctor can give you more personalized advice to better manage your asthma.

**Why It Helps**:

- Take Control: You'll understand your triggers and habits better, making it easier to avoid flare-ups.
- Spot Problem Areas: You can see which environments or conditions make your asthma worse.

**How it works**:

- Backend:
  - Store user medication history, environmental data, and vitals in *Azure SQL Database.*
  - Use *Azure Data Factory* to aggregate and process large datasets for analysis.
- Analytics:
  - Create a data visualization API using *Azure Functions.*
  - Integrate *Power BI Embedded* for interactive graphs and trends in the app.
- Mobile App:
  - Display detailed history using React Native components (e.g., charts and tables).
  - Allow users to filter data by date or parameter.

**2. Sharing Your Data with Doctors**

**What It Does**: With your permission, the device securely shares your health data—like medication history, AQI, oxygen levels, and heart rate—with your doctor. This gives them a detailed view of your condition so they can fine-tune your treatment.

**Why It Helps**:

- Personalized Care: Your doctor can create a treatment plan that's tailored just for you.
- Stay Connected: Even between visits, your doctor stays updated on how you're doing.
- Better Medication Management: Your doctor can adjust your doses or recommend alternatives based on real data.

**How it works**:

- Consent Management:
  - Use *Azure AD B2C* for user authentication and consent tracking.
- Data Sharing:
  - Securely share data with healthcare providers through APIs.
  - Use *Azure API Management* for secure access control.
  - Encrypt data using *Azure Key Vault* before sharing.
- Mobile App:
  - Allow users to view shared data logs and revoke access when needed

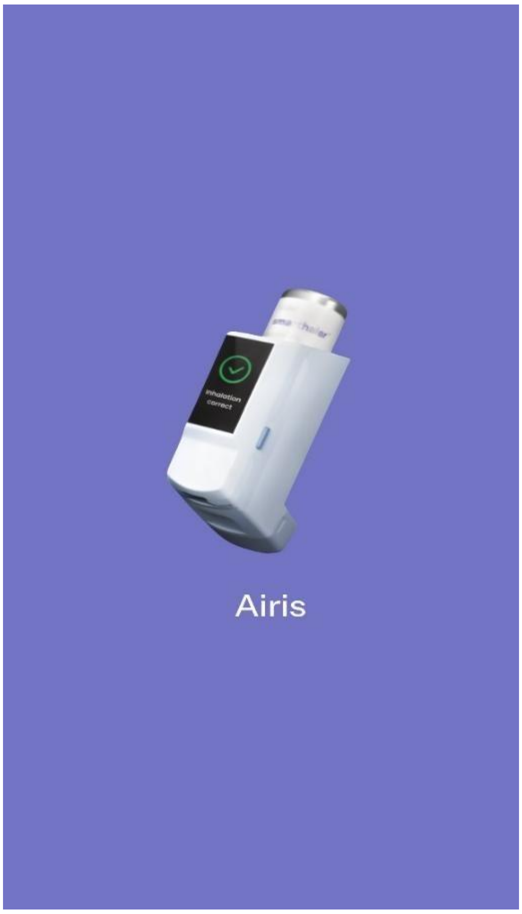



**Fig. 31** Start

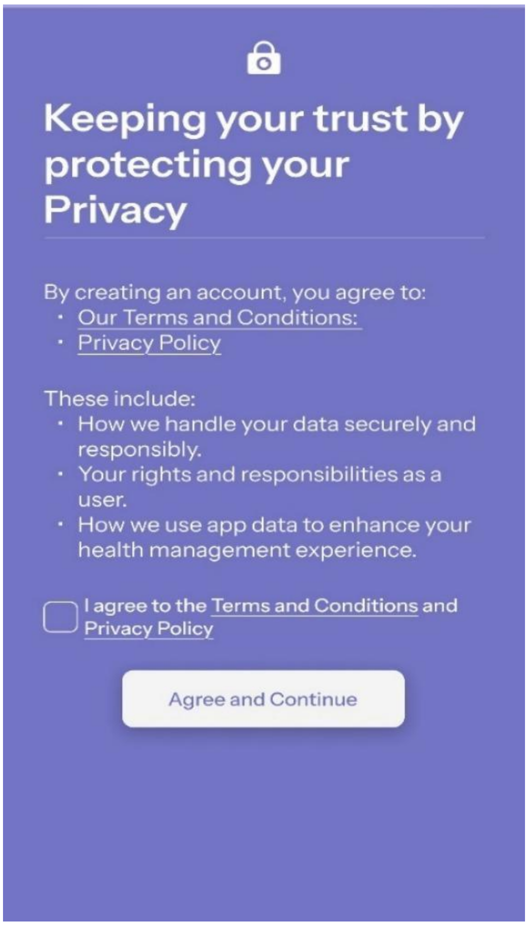



**Fig. 32** Terms and Conditions

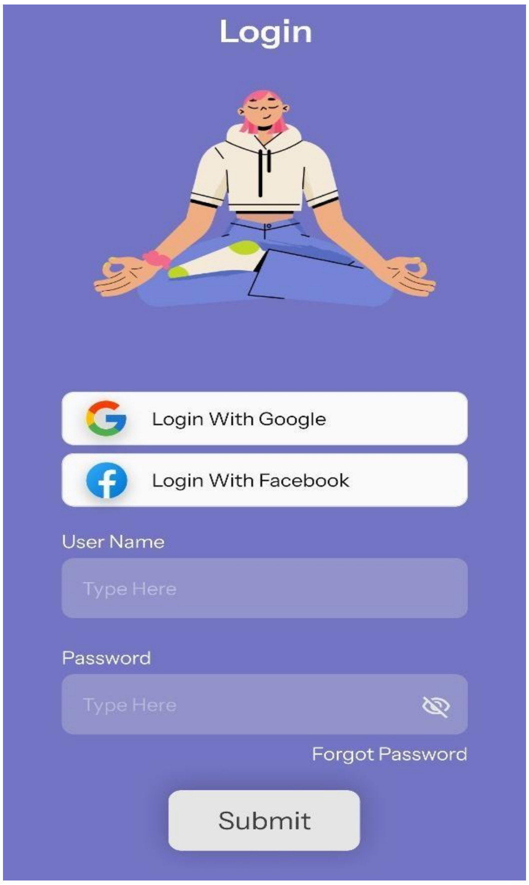



**Fig. 33** User Login

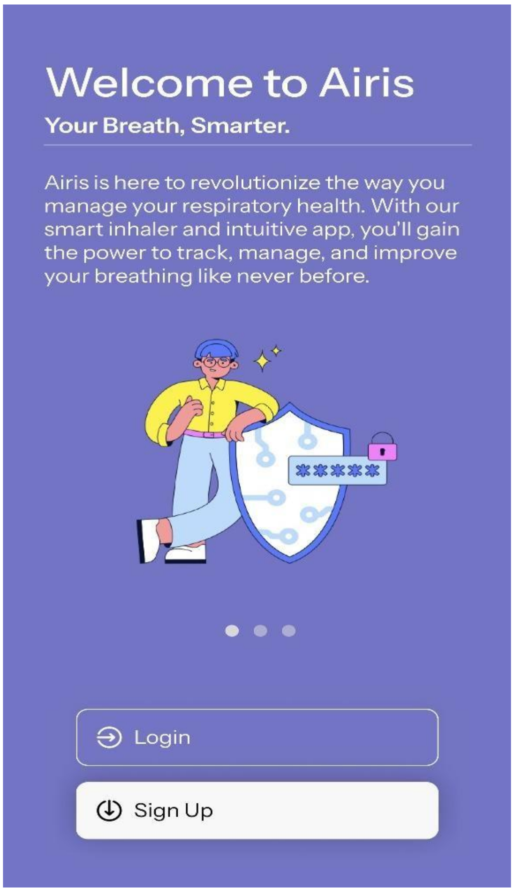



**Fig. 34** Login / Sign Up

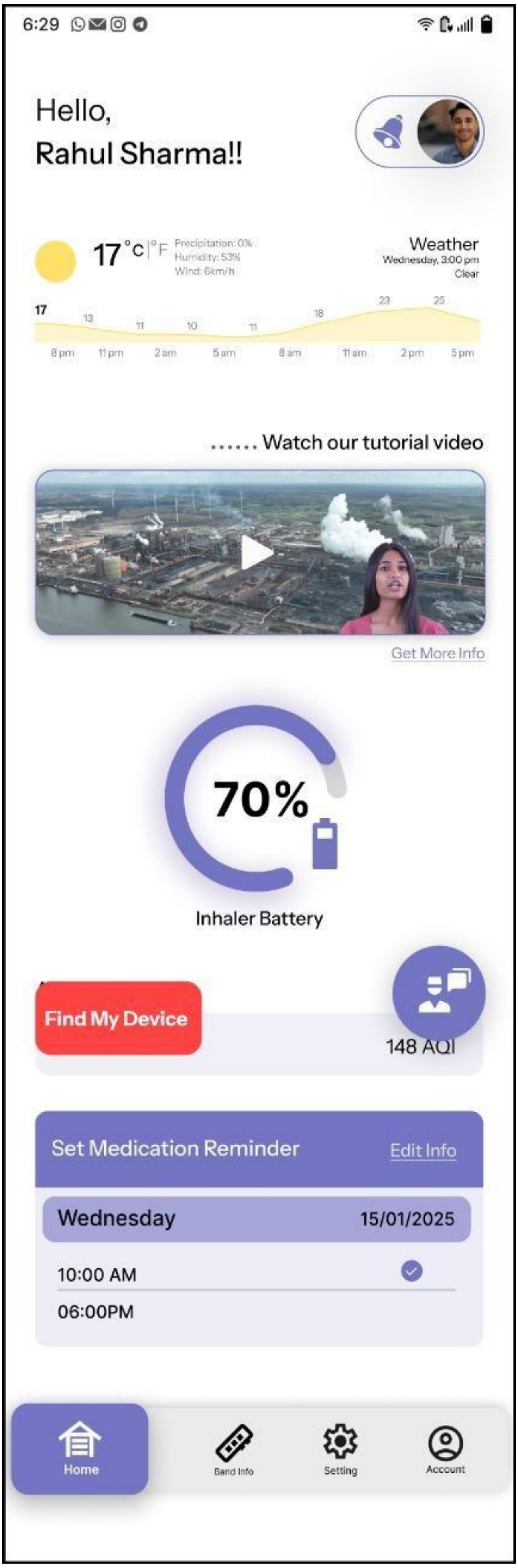



**Fig. 35** Home Page View

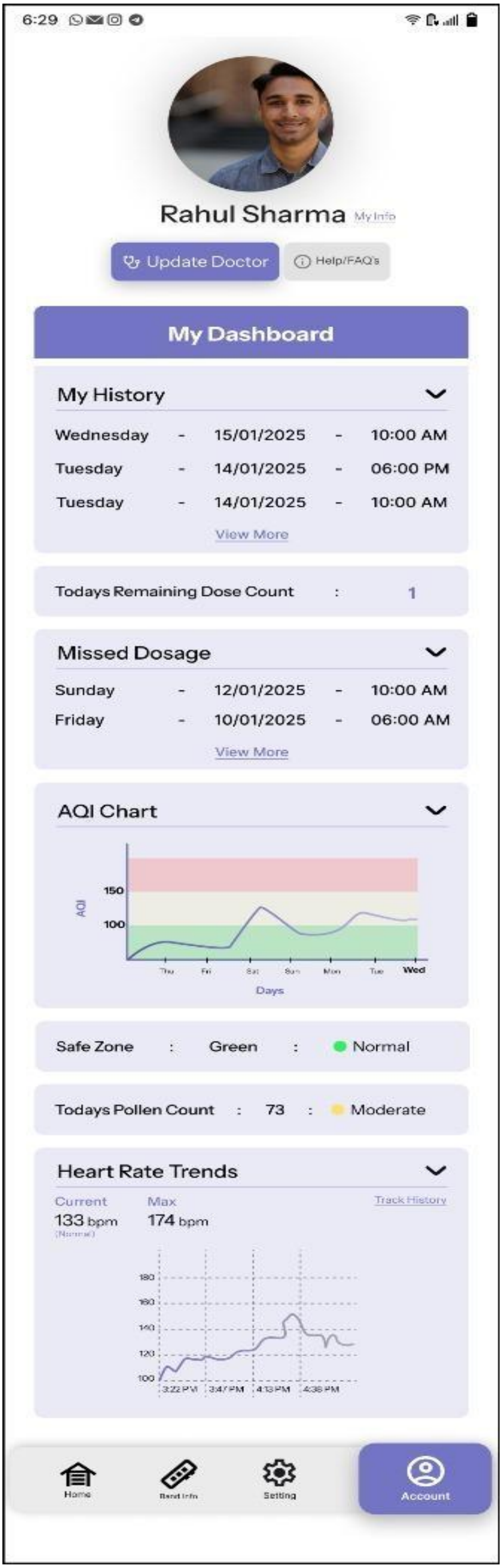



**Fig. 36** User Account View

# FABRICATION PHASE

## 5. Design Improvements:

During the Design evaluation, the committee reviewed our design and found it well-structured and technically sound. No major changes were suggested, and we retained the core design as initially planned. However, based on practical constraints related to component availability and cost-effectiveness, we made a few modifications to ensure smooth project execution.

**a) Change from nRF51840 Sense to ESP32**

- Previously, we planned to use the **nRF51840 Sense** module, but we shifted to **ESP32**.
- Reason for the change – **nRF51840 sense** does not have built-in Wi-Fi but **ESP32**.

**b) Change from 900 mAh Lithium-ion battery to 1250 mAh Lithium-ion battery**

- We initially planned to use a 900mAh battery, but due to stock unavailability on Robu.in and higher prices on other platforms, we opted for a 1250mAh battery instead.
- Reason to choose - The 1250mAh battery on Robu.in was priced lower than the 900mAh battery on other platforms.

These updates were **not based on committee feedback but were necessary for practical implementation**, ensuring smooth procurement and cost savings.

**Committee Feedback & Our Response:**

The committee did not suggest any changes to our design, as they found it well-structured. However, they provided feedback on two key concerns:

1. **Market Scalability & Cost Concerns** The committee pointed out that even after optimizing costs, the estimated price of **₹5000 per unit** remains high for mass adoption in India. We acknowledged this but justified that in **Tier 1 cities**, ₹5000 is an affordable price for healthcare devices. Further cost optimization strategies can be explored for wider accessibility.
2. **Asthma Attack Prediction Concern** The committee raised a critical point that no existing solution globally predicts asthma attacks with certainty. We clarified that our system does not predict asthma attacks but rather provides caution alerts based on:
   - **Patient's health data** (sensor readings like $SpO_2$, heart rate, airflow).
   - **Environmental conditions** (AQI, humidity, temperature).
   - **Historical trends** (previous symptoms and risk levels).
     This helps patients take **preventive action** rather than waiting for severe symptoms to appear.

# 6. Prototyping & Dry run:

## 6.1 SOFTWARE PROTOTYPING & DRY RUN (COMPLETED):

We have successfully completed the software prototyping and dry run, ensuring the core functionalities work as expected.

**IMPLEMENTATION:**

**1. Environment Setup**

- Configured Google Colab for development.
- Installed required Python libraries:
  - pandas, scikit-learn → For data processing and model training.
  - Flask → To create the API server.
  - joblib → For model saving/loading.
  - pyngrok → To expose API for external access.
  - requests → To test API communication.

**2. Detailed Device Simulation**

- Implemented a Python script to simulate sensor data based on real-world conditions.
- Simulated sensors included:
  - **MiCS-4514** → Air Quality (CO, $NO_2$, VOCs).
  - **AHT10** → Temperature & Humidity.
  - **SDP31** → Pressure/Puff detection.
  - **MAX30102** → Heart Rate (HR) & $SpO_2$.
- Developed mock AQI calculation logic (since the formula was not specified in the project report).
- Successfully generated and saved time-series sensor data in cloud_data_log. jsonl format within Colab.

**3. AI Model Training**

- Loaded the simulated dataset from cloud_data_log. jsonl.
- Preprocessed data:
  - Handled missing values (e.g., HR/$SpO_2$ values when no puff detected).
  - Selected relevant features from sensor data.
  - Created a mock 'Risk' target variable for AI-based prediction.
- **Model Training**:
  - Trained a **Decision Tree Classifier** to predict asthma risk levels.
  - Evaluated model performance with test data.
  - Saved the trained model as asthma_model. joblib for deployment.

**4. API Server Implementation**

- Developed an **API server using Flask**:
  - Loads the trained asthma_model. joblib.
  - Implements a /predict endpoint to accept sensor data (JSON format) and return a risk prediction.
- Successfully configured the API server for external access using ngrok.
  - API is currently running and accessible via an ngrok public URL.

**5. Simulate API Call (Final Testing Step)**

- Develop a Python script (app_caller.py) to:
  - Send a sample JSON request with sensor data to the API.
  - Validate that the API returns correct risk predictions in response.

**Future Considerations**

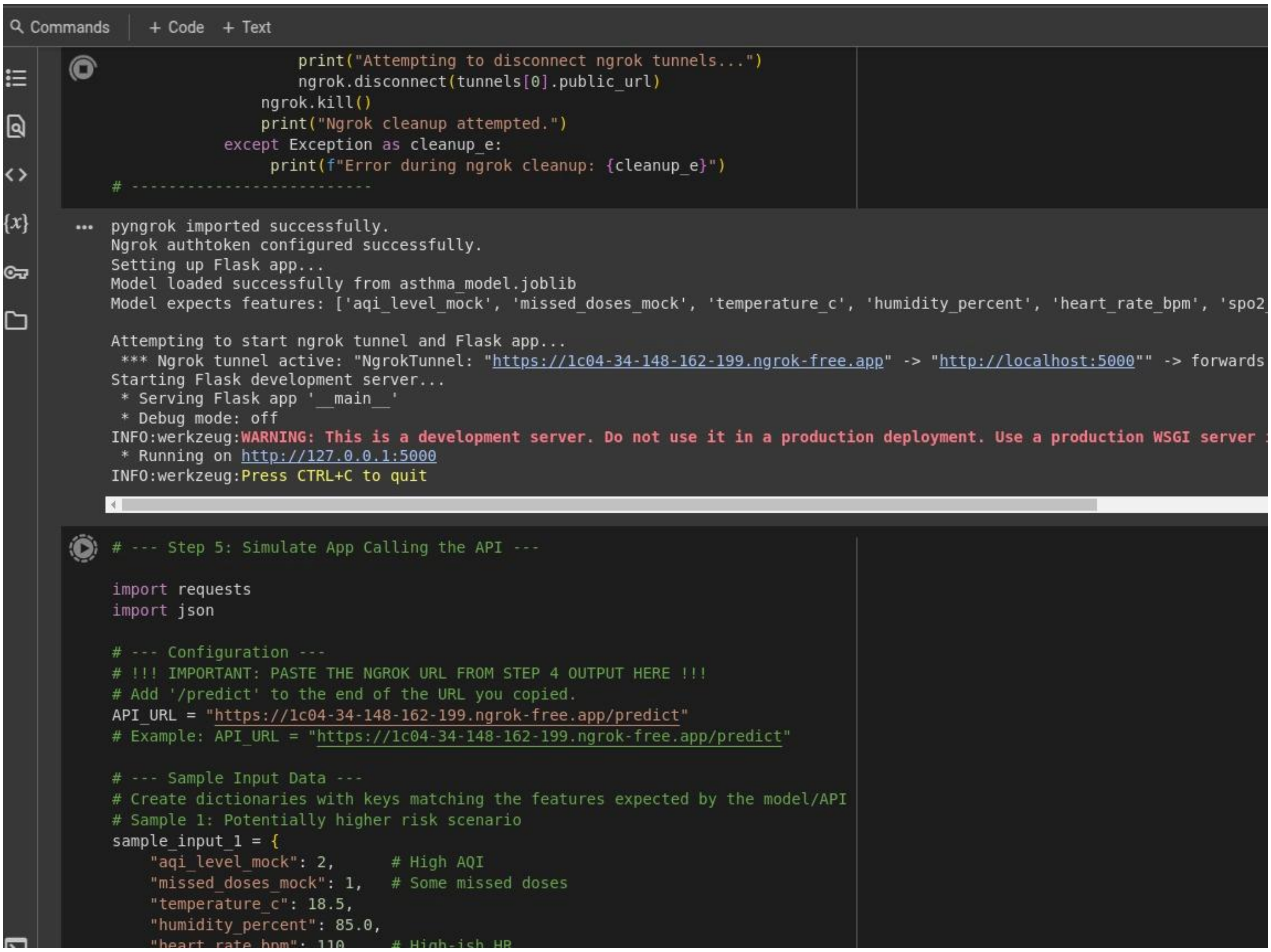
- Refine mock AQI calculation and missed dose detection.

- Experiment with advanced AI models (e.g., Random Forest, Neural Networks).
- Develop a basic UI mock-up for real-time data visualization.

**RESULTS:**

```
Simulating detailed device data. Writing 30 packets to cloud_data_log.jsonl...
Device simulation finished. Data saved to cloud_data_log.jsonl

Sample of generated detailed data:
      timestamp        deviceId  co_ppm  no2_ppb  temperature_c  \
0  1.743354e+09  Inhaler_Mock_01    86.2    389.2           17.2
1  1.743354e+09  Inhaler_Mock_01    33.4    118.3           28.9
2  1.743354e+09  Inhaler_Mock_01    43.6    296.9           34.9
3  1.743354e+09  Inhaler_Mock_01    17.9    290.6           15.4
4  1.743354e+09  Inhaler_Mock_01    70.5    261.7           32.8

   humidity_percent  pressure_diff_pa  heart_rate_bpm  spo2_percent  \
0              77.8              4.35             NaN           NaN
1              57.2              8.72             NaN           NaN
2              74.7             22.29            95.0          94.1
3              89.4              5.44             NaN           NaN
4              61.3              3.94             NaN           NaN

   puff_detected  aqi_level_mock  missed_doses_mock
0          False               2                  0
1          False               1                  0
2           True               2                  2
3          False               2                  1
4          False               2                  0
```

```
Commands  + Code  + Text
3 2025-03-30 16:52:27.669477940  Inhaler_Mock_01    17.9    290.6
4 2025-03-30 16:52:28.169739962  Inhaler_Mock_01    70.5    261.7

   temperature_c  humidity_percent  pressure_diff_pa  heart_rate_bpm  \
0           17.2              77.8              4.35             NaN
1           28.9              57.2              8.72             NaN
2           34.9              74.7             22.29            95.0
3           15.4              89.4              5.44             NaN
4           32.8              61.3              3.94             NaN

   spo2_percent  puff_detected  aqi_level_mock  missed_doses_mock
0           NaN          False               2                  0
1           NaN          False               1                  0
2          94.1           True               2                  2
3           NaN          False               2                  1
4           NaN          False               2                  0
Handling missing values (NaNs) in HR and SpO2...
Missing values handled.
Creating mock 'Risk' target variable based on rules...
Target variable 'Risk' created.
Risk
1    27
0     3
Name: count, dtype: int64

Preparing data for training using features: ['aqi_level_mock', 'missed_doses_mock', 'temperature_c', 'humidity_percent', 'h
Sample of prepared features (X_train):
   aqi_level_mock  missed_doses_mock  temperature_c  humidity_percent  \
0               2                  0           17.2              77.8
1               1                  0           28.9              57.2
2               2                  2           34.9              74.7
3               2                  1           15.4              89.4
4               2                  0           32.8              61.3

   heart_rate_bpm  spo2_percent
0            80.0          98.0
1            80.0          98.0
2            95.0          94.1
3            80.0          98.0
4            80.0          98.0

Training Decision Tree model...
Model trained successfully!
Trained model saved to 'asthma_model.joblib'
--- Finished Step 3 ---
<ipython-input-5-3472801a17d8>:49: FutureWarning: A value is trying to be set on a copy of a DataFrame or Series through ch
The behavior will change in pandas 3.0. This inplace method will never work because the intermediate object on which we are
```



Commands + Code + Text

```
                print("Attempting to disconnect ngrok tunnels...")
                ngrok.disconnect(tunnels[0].public_url)
            ngrok.kill()
            print("Ngrok cleanup attempted.")
        except Exception as cleanup_e:
             print(f"Error during ngrok cleanup: {cleanup_e}")
# ------------------------
```

```
pyngrok imported successfully.
Ngrok authtoken configured successfully.
Setting up Flask app...
Model loaded successfully from asthma_model.joblib
Model expects features: ['aqi_level_mock', 'missed_doses_mock', 'temperature_c', 'humidity_percent', 'heart_rate_bpm', 'spo2

Attempting to start ngrok tunnel and Flask app...
 *** Ngrok tunnel active: "NgrokTunnel: "https://1c04-34-148-162-199.ngrok-free.app" -> "http://localhost:5000"" -> forwards
Starting Flask development server...
 * Serving Flask app '__main__'
 * Debug mode: off
INFO:werkzeug:WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server
 * Running on http://127.0.0.1:5000
INFO:werkzeug:Press CTRL+C to quit
```

```
# --- Step 5: Simulate App Calling the API ---

import requests
import json

# --- Configuration ---
# !!! IMPORTANT: PASTE THE NGROK URL FROM STEP 4 OUTPUT HERE !!!
# Add '/predict' to the end of the URL you copied.
API_URL = "https://1c04-34-148-162-199.ngrok-free.app/predict"
# Example: API_URL = "https://1c04-34-148-162-199.ngrok-free.app/predict"

# --- Sample Input Data ---
# Create dictionaries with keys matching the features expected by the model/API
# Sample 1: Potentially higher risk scenario
sample_input_1 = {
    "aqi_level_mock": 2,      # High AQI
    "missed_doses_mock": 1,   # Some missed doses
    "temperature_c": 18.5,
    "humidity_percent": 85.0,
```

**CONCLUSION:** The AI-based smart inhaler simulation successfully generated and logged sensor data for various parameters, including CO levels, $NO_2$ levels, temperature, humidity, pressure, heart rate, and $SpO_2$. A decision tree model was trained to predict asthma risk, and a Flask-based API was implemented to serve real-time predictions. The simulation produced structured time-series data, confirming the correctness of sensor integration logic.

Sample results show:

- Realistic sensor variations with missing values handled.
- Puff detection and AQI mock levels successfully assigned.
- API readiness for real-time data processing.

## 6.2 Hardware Prototyping & Dry Run (Pending):

- The required hardware components were ordered, and all parts **arrived on 30 March 2025**.
- Since the materials have just arrived, hardware prototyping could not be conducted yet.
- However, with all necessary components in place, we will begin the hardware assembly and testing at the earliest.

**Next Steps for Hardware Dry Run:**

- **Component Integration:** Assemble the sensors, microcontrollers, and control circuitry.

- **Power System Testing:** Ensure the new 1250mAh battery efficiently powers the system.
- **Final Dry Run:** Conduct a full-scale hardware test to verify mobility, sensor accuracy, and response time.

Despite the delay in hardware prototyping, we have made significant progress in software validation. The software dry run confirms system functionality, and hardware testing will follow as soon as assembly is complete.

# 7. Component Procurement:

## 7.1 Procurement Planning:

- Identified **essential components** for hardware prototyping.
- Compared multiple suppliers to ensure **cost-effectiveness, quality, and availability**.
- Prioritized components based on:
    - **Availability** (avoiding long restocking times).
    - **Cost-effectiveness** (choosing reasonably priced alternatives).
    - **Integration feasibility** (ensuring compatibility with other components).

## 7.2 Component Procured:

- **Total Budget Approved by DFP:** ₹23,002
- **Amount Spent on Component Procurement So Far:** ₹5,560
- **Remaining Budget:** ₹17,442

Below Is the Cost Breakdown of Amount Spend on Component Procurement that is Rs. 5560

| Component | Original Choice | Final Choice | Quantity | Expected Price (in Rs.) | Actual Price (in Rs.) | Supplier |
|---|---|---|---|---|---|---|
| Microcontroller | nRF51840 Sense | ESP32 | 2 | 4797 | 998.89 | Amazon.com |
| Gas Sensor | MiCS - 4514 | Same | 1 | 3449 | 3512.28 | Robu.in |
| Heart Rate & Oximeter Sensor | MAX-30102 | Same | 1 | 182 | 190.69 | Robu.in |
| Battery | 120 mAh & 900 mAh | 120 mAh & 1250 mAh | 1 & 1 | 112 & 350 | 178.71 & 418.32 | Robu.in |
| Wires | Male to Female & Female to Female Jumper Wires | Same | 40 & 40 (10 cm each) | 35 & 35 | 38.94 & 33.94 | Robu.in |
| Buzzer | 3.3 V Electromagnetic | Same | 1 | 69 | 68.89 | Robu.in |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Buzzer | | | | | |
| Charging Module | TP-4056 3.7 V Lithium battery charging module | Same | 1 | 150 | 155.75 | Robu.in |
| **TOTAL** | | | | **Rs.9179** | **Rs.5596.41** | |

## 7.3 Components Yet to be Ordered:

**Pressure Sensor (SDP31)**:

- It is an expensive component, so we first checked its availability on the Government e-Marketplace (GeM).
- Since it was not available on GeM, we obtained a Non-Availability Certificate before proceeding.
- Before ordering, we are evaluating how to integrate it efficiently into the device to avoid any installation or compatibility issues after purchase.
- Expected Price: **Rs. 5500**

**AHT10 Temperature & Humidity Sensor**:

- This sensor is currently out of stock on Robu.
- Other platforms are selling it at a higher price compared to Robu.
- Robu is expected to restock by April 13, so we decided to wait as it is not urgently required.
- Since AHT10 can be easily integrated later, we are postponing the order to avoid extra costs.
- Expected Price: **Rs. 70**

## 7.4 Procurement Status:

- **Ordered Components:** All necessary components except the **SDP31 Pressure Sensor and AHT10 Sensor** have been procured.
- **Delivery Status:**
    - **All ordered components arrived on 30 March 2025**.
    - The **pending components will be ordered strategically** to minimize costs.

## 7.5 Challenges & Mitigation Strategies:

**Battery Availability Issue:**

- **Challenge:** 900mAh battery was unavailable and restocking took time.
- **Solution:** Switched to a **1250mAh variant**, which was available at a better price.

**Pressure Sensor Procurement Delay:**

- **Challenge:** Expensive component, needed confirmation on integration.
- **Solution:** Evaluating placement in the device before ordering.

**AHT10 Unavailability Issue:**

- **Challenge:** Out of stock on Robu, high cost on other platforms.
- **Solution:** Waiting for Robu to restock (April 13) since integration can be done later.

# 8. FUTURE SCOPE & CHALLENGES:

## 8.1 Future Scope:

**Enhanced Disease Management**

- Real-time reminders and alerts to improve medication adherence.
- Development of personalized treatment plans based on patient-specific data and usage patterns.

**Integration with Digital Health**

- Seamless integration with mobile apps and telemedicine platforms to enable remote monitoring by healthcare providers.
- Implementation of AI and ML-driven predictive analytics to foresee potential asthma or COPD exacerbations.

**Research and Development**

- Incorporation of advanced sensors for precise dose tracking and inhalation monitoring.
- Real-time detection and monitoring of environmental triggers such as pollen, humidity, and pollution levels.

**Healthcare System Benefits**

- Reduction in hospital admissions due to better management of asthma and COPD.
- Potential cost savings in healthcare expenditure by minimizing severe attacks and emergency interventions.

**Global Accessibility**

- Expansion to low-income regions with cost-effective and affordable models.
- Support for multiple languages and regional customizations to ensure wider accessibility and adoption.

## 8.2 Challenges:

**High Development Costs**

- Significant initial investment required for research, development, and mass production of smart inhalers.

**Data Privacy and Security**

- Risks associated with sensitive health data breaches and unauthorized access.
- Compliance with stringent data protection laws such as GDPR and HIPAA.

**Technological Barriers**

- Limited battery life and sensor reliability, impacting long-term usability.
- Connectivity challenges in rural or underdeveloped areas, limiting accessibility.

**Adoption Barriers**

- Resistance from older populations or individuals unfamiliar with digital technology.
- Lack of awareness or distrust in digital health solutions, leading to slow adoption rates.

**Regulatory Hurdles**

- Complex and time-consuming approval processes from regulatory bodies such as the FDA and EMA.
- Ensuring adherence to rigorous safety and quality standards before commercialization.

# 9. References:

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[3] Jay Grossman, "The Evolution of Inhaler Technology: Journal of Asthma ", Volume 31,1994.

[4] "Smart Inhaler That Could Change Asthma Treatment for Millions | Australia by Design: Innovations" by ByDesign TV, youtube.com

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[9] https://propellerhealth.com/, "Propeller Health".

[10] For making flowchart we use, "Whimsical", https://whimsical.com/FL6wt8EXY643D6dsU6NkSw

[11] chatgpt.com

[12] Google. (n.d.). Google Forms https://www.google.com/forms., for creating user survey form.

[13] Figma. (n.d.). "*Figma: The collaborative interface design tool*", https://www.figma.com, to maintain our workflow.

# 10. Annexure:

## 1. Bill Of Materials

**Bill of materials that is submitted to DFP committee during design phase:**

| S. No. | Component Name | Quantity | Specification | Cost (₹) | Source of Procurement |
|---|---|---|---|---|---|
| 1. | nRF52840 sense microcontroller | 3 | nRF52840 sense | 4797 | Robu.in |
| 2. | Gas Sensor | 1 | DFRobot Gravity (MiCS-4514) | 3449 | Robu.in |
| 3. | Temperature and Humidity Sensor | 1 | AHT 10 | 70 | Robu.in |
| 4. | Electromagnetic Buzzer | 1 | 3V Active Electromagnetic Buzzer | 69 | Robu.in |
| 5. | Wires and Cables | 1 | Seeed Studio Grove 4 pin Female Jumper to Grove 4 pin Conversion Cable | 299 | Robu.in |
| 6. | LiPo Battery | 1 | 950 mAh 3.7V single cell Rechargeable LiPo Battery | 350 | Robu.in |
| 7. | Male To Female Jumper Wires | 1 | 10cm Male to Female Jumper Wires | 35 | Robu.in |
| 8. | I2C Multiplexer | 1 | SmartElex PCA9546 4-Channel I2C Multiplexer | 139 | Robu.in |
| 9. | Heart rate and Pulse oximeter Sensor | 1 | MAX30102 Heart Rate and Pulse Oximeter Sensor Module | 182 | Robu.in |
| 10. | Pressure Sensor | 1 | Sensirion SDP31 | 5500 | Sensirion |
| 11. | Rechargeable LiPo Battery | 1 | WLY450838 120 mAh 3.7V single cell Rechargeable LiPo Battery | 112 | Robu.in |
| 12. | 3D Printing, PCB Design | - | College / City | 3000 | |
| 13. | Cloud, API, Deployment | - | Azure | 2000 | |
| 14. | Miscellaneous | - | - | 3000 | |

Total: **₹ 23002**